

# **TPS65930/TPS65920**

## **Integrated Power Management**

### **Audio Codec (TPS65930 Only)**

**Silicon Revision 1.2**

# **Data Manual**



PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of the Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

Literature Number: SWCS037G  
May 2008–Revised April 2011

## Contents

|          |  |           |
|----------|--|-----------|
| <b>1</b> | <b>Introduction</b> .....                            | <b>9</b>  |
| 1.1      | Features .....                                       | 10        |
| 1.2      | TPS65920 and TPS65930 Device Block Diagrams .....    | 11        |
| <b>2</b> | <b>Terminal Description</b> .....                    | <b>13</b> |
| 2.1      | Ball Characteristics .....                           | 13        |
| 2.2      | Signal Description .....                             | 17        |
| <b>3</b> | <b>Electrical Characteristics</b> .....              | <b>23</b> |
| 3.1      | Absolute Maximum Ratings .....                       | 23        |
| 3.2      | Minimum Voltages and Associated Currents .....       | 23        |
| 3.3      | Recommended Operating Conditions .....               | 24        |
| 3.4      | Digital I/O Electrical Characteristics .....         | 24        |
| <b>4</b> | <b>Power Module</b> .....                            | <b>27</b> |
| 4.1      | Power Providers .....                                | 28        |
| 4.1.1    | VDD1 dc-dc Regulator .....                           | 29        |
| 4.1.1.1  | VDD1 dc-dc Regulator Characteristics .....           | 29        |
| 4.1.1.2  | External Components and Application Schematics ..... | 30        |
| 4.1.2    | VDD2 dc-dc Regulator .....                           | 32        |
| 4.1.2.1  | VDD2 dc-dc Regulator Characteristics .....           | 32        |
| 4.1.2.2  | External Components and Application Schematics ..... | 33        |
| 4.1.3    | VIO dc-dc Regulator .....                            | 35        |
| 4.1.3.1  | VIO dc-dc Regulator Characteristics .....            | 35        |
| 4.1.3.2  | External Components and Application Schematics ..... | 36        |
| 4.1.4    | VDAC LDO Regulator .....                             | 38        |
| 4.1.5    | VPLL1 LDO Regulator .....                            | 39        |
| 4.1.6    | VMMC1 LDO Regulator .....                            | 40        |
| 4.1.7    | VAUX2 LDO Regulator .....                            | 41        |
| 4.1.8    | Output Load Conditions .....                         | 42        |
| 4.1.9    | Charge Pump .....                                    | 43        |
| 4.1.10   | USB LDO Short-Circuit Protection Scheme .....        | 44        |
| 4.2      | Power References .....                               | 45        |
| 4.3      | Power Control .....                                  | 45        |
| 4.3.1    | Backup Battery Charger .....                         | 45        |
| 4.3.2    | Battery Monitoring and Threshold Detection .....     | 46        |
| 4.3.2.1  | Power On/Power Off and Backup Conditions .....       | 46        |
| 4.3.3    | VRRTC LDO Regulator .....                            | 46        |
| 4.4      | Power Consumption .....                              | 47        |
| 4.5      | Power Management .....                               | 49        |
| 4.5.1    | Boot Modes .....                                     | 49        |
| 4.5.2    | Process Modes .....                                  | 49        |
| 4.5.2.1  | MC021 Mode .....                                     | 49        |
| 4.5.3    | Power-On Sequence .....                              | 49        |
| 4.5.3.1  | Timing Before Sequence_Start .....                   | 49        |
| 4.5.3.2  | Power-On Sequence .....                              | 51        |
| 4.5.3.3  | Power On in Slave_C021 Mode .....                    | 51        |
| 4.5.4    | Power-Off Sequence .....                             | 53        |
| 4.5.4.1  | Power-Off Sequence .....                             | 53        |

|           |   |           |
|-----------|---|-----------|
| <b>5</b>  | <b>Real-Time Clock and Embedded Power Controller</b> .....            | <b>54</b> |
| 5.1       | RTC .....   | 54        |
| 5.1.1     | Backup Battery .....  | 54        |
| 5.2       | EPC .....   | 54        |
| <b>6</b>  | <b>Audio/Voice Module (TPS65930 Device Only)</b> .....                | <b>55</b> |
| 6.1       | Audio/Voice Downlink (RX) Module .....                                | 55        |
| 6.1.1     | Predriver for External Class-D Amplifier .....                        | 55        |
| 6.1.1.1   | Predriver Output Characteristics .....                                | 56        |
| 6.1.1.2   | External Components and Application Schematics .....                  | 56        |
| 6.1.2     | Vibrator H-Bridge .....   | 57        |
| 6.1.2.1   | Vibrator H-Bridge Output Characteristics .....                        | 57        |
| 6.1.2.2   | External Components and Application Schematics .....                  | 57        |
| 6.1.3     | Carkit Output .....   | 58        |
| 6.1.4     | Digital Audio Filter Module .....                                     | 59        |
| 6.1.5     | Boost Stage .....   | 59        |
| 6.2       | Audio Uplink (TX) Module .....  | 61        |
| 6.2.1     | Microphone Bias Module .....  | 61        |
| 6.2.1.1   | Analog Microphone Bias Module Characteristics .....                   | 61        |
| 6.2.1.2   | Silicon Microphone Module Characteristics .....                       | 63        |
| 6.2.2     | FM Radio/Auxiliary Input .....  | 65        |
| 6.2.2.1   | External Components .....   | 65        |
| 6.2.3     | Uplink Characteristics .....  | 65        |
| 6.2.4     | Microphone Amplification Stage .....                                  | 66        |
| 6.2.5     | Carkit Input .....  | 67        |
| 6.2.6     | Digital Audio Filter Module .....                                     | 68        |
| <b>7</b>  | <b>USB Transceiver</b> .....  | <b>69</b> |
| 7.1       | USB Transceiver .....   | 69        |
| 7.1.1     | Features .....  | 69        |
| 7.1.2     | HS USB Port Timing .....  | 70        |
| 7.1.3     | USB-CEA Carkit Port Timing .....                                      | 71        |
| 7.1.4     | PHY Electrical Characteristics .....                                  | 73        |
| 7.1.4.1   | HS Differential Receiver .....  | 73        |
| 7.1.4.2   | HS Differential Transmitter .....                                     | 74        |
| 7.1.4.3   | CEA/UART Driver .....   | 75        |
| 7.1.4.4   | Pullup/Pulldown Resistors .....                                       | 75        |
| 7.1.5     | OTG Electrical Characteristics .....                                  | 75        |
| 7.1.5.1   | OTG VBUS Electrical Characteristics .....                             | 76        |
| 7.1.5.2   | OTG ID Electrical Characteristics .....                               | 76        |
| <b>8</b>  | <b>MADC</b> .....   | <b>78</b> |
| 8.1       | General Description .....   | 78        |
| 8.2       | MADC Electrical Characteristics .....                                 | 78        |
| 8.3       | Channel Voltage Input Range .....                                     | 79        |
| 8.3.1     | Sequence Conversion Time (Real-Time or Nonaborted Asynchronous) ..... | 79        |
| <b>9</b>  | <b>LED Drivers</b> .....  | <b>81</b> |
| 9.1       | General Description .....   | 81        |
| <b>10</b> | <b>Keyboard</b> .....   | <b>82</b> |
| 10.1      | Keyboard Connection .....   | 82        |
| <b>11</b> | <b>Clock Specifications</b> .....                                     | <b>83</b> |

- 11.1 Clock Features ..... [83](#)
- 11.2 Input Clock Specifications ..... [84](#)
  - 11.2.1 Clock Source Requirements ..... [84](#)
  - 11.2.2 HFCLKIN ..... [84](#)
  - 11.2.3 32-kHz Input Clock ..... [86](#)
    - 11.2.3.1 External Crystal Description ..... [87](#)
    - 11.2.3.2 External Clock Description ..... [88](#)
- 11.3 Output Clock Specifications ..... [91](#)
  - 11.3.1 32KCLKOUT Output Clock ..... [91](#)
  - 11.3.2 HFCLKOUT Output Clock ..... [92](#)
  - 11.3.3 Output Clock Stabilization Time ..... [93](#)
- 12 Timing Requirements and Switching Characteristics ..... [94](#)**
  - 12.1 Timing Parameters ..... [94](#)
  - 12.2 Target Frequencies ..... [95](#)
  - 12.3 I<sup>2</sup>C Timing ..... [96](#)
  - 12.4 Audio Interface: TDM/I2S Protocol ..... [97](#)
    - 12.4.1 I2S Right- and Left-Justified Data Format ..... [98](#)
    - 12.4.2 TDM Data Format ..... [100](#)
  - 12.5 JTAG Interfaces ..... [101](#)
- 13 Debouncing Time ..... [103](#)**
- 14 External Components ..... [104](#)**
- 15 TPS65920/TPS65930 Package ..... [107](#)**
  - 15.1 TPS65920/TPS65930 Standard Package Symbols ..... [107](#)
  - 15.2 Package Thermal Resistance Characteristics ..... [107](#)
  - 15.3 Mechanical Data ..... [108](#)
  - 15.4 ESD Specifications ..... [109](#)
- 16 Glossary ..... [110](#)**

## List of Figures

|       |   |                    |
|-------|---|--------------------|
| 1-1   | TPS65920 Block Diagram.....   | <a href="#">12</a> |
| 1-2   | TPS65930 Block Diagram.....   | <a href="#">12</a> |
| 2-1   | PBGA Bottom View .....  | <a href="#">13</a> |
| 4-1   | Power Provider Block Diagram .....  | <a href="#">27</a> |
| 4-2   | VDD1 dc-dc Regulator Efficiency .....   | <a href="#">30</a> |
| 4-3   | VDD1 dc-dc Application Schematic.....   | <a href="#">31</a> |
| 4-4   | VDD2 dc-dc Regulator Efficiency .....   | <a href="#">33</a> |
| 4-5   | VDD2 dc-dc Application Schematic.....   | <a href="#">34</a> |
| 4-6   | VIO dc-dc Regulator Efficiency .....  | <a href="#">36</a> |
| 4-7   | VIO dc-dc Application Schematic .....   | <a href="#">37</a> |
| 4-8   | Timing Before Sequence Start .....  | <a href="#">50</a> |
| 4-9   | Timings—Power On in OMAP3 Mode .....  | <a href="#">51</a> |
| 4-10  | Timings—Power On in Slave_C021 Mode.....                                      | <a href="#">52</a> |
| 4-11  | Power-Off Sequence in Master Modes .....                                      | <a href="#">53</a> |
| 6-1   | Audio/Voice Module Block Diagram .....  | <a href="#">55</a> |
| 6-2   | Predriver for External Class D .....  | <a href="#">57</a> |
| 6-3   | Vibrator H-Bridge .....   | <a href="#">58</a> |
| 6-4   | Carkit Output Downlink Path Characteristics .....                             | <a href="#">58</a> |
| 6-5   | Digital Audio Filter Downlink Path Characteristics .....                      | <a href="#">59</a> |
| 6-6   | Analog Microphone Pseudodifferential .....                                    | <a href="#">62</a> |
| 6-7   | Analog Microphone Differential .....  | <a href="#">63</a> |
| 6-8   | Silicon Microphone .....  | <a href="#">64</a> |
| 6-9   | Audio Auxiliary Input .....   | <a href="#">65</a> |
| 6-10  | Uplink Amplifier .....  | <a href="#">65</a> |
| 6-11  | Carkit Input Uplink Path Characteristics .....                                | <a href="#">67</a> |
| 6-12  | Digital Audio Filter Uplink Path Characteristics .....                        | <a href="#">68</a> |
| 7-1   | USB 2.0 PHY Block Diagram .....   | <a href="#">69</a> |
| 7-2   | USB System Application Schematic .....  | <a href="#">70</a> |
| 7-3   | HS-USB Interface—Transmit and Receive Modes (ULPI 8-bit).....                 | <a href="#">71</a> |
| 7-4   | USB-CEA Carkit UART Data Flow.....  | <a href="#">72</a> |
| 7-5   | USB-CEA Carkit UART Timings.....  | <a href="#">73</a> |
| 8-1   | Conversion Sequence General Timing Diagram .....                              | <a href="#">80</a> |
| 9-1   | LED Driver Block Diagram .....  | <a href="#">81</a> |
| 10-1  | Keyboard Connection.....  | <a href="#">82</a> |
| 11-1  | Clock Overview .....  | <a href="#">83</a> |
| 11-2  | HFCLKIN Clock Distribution .....  | <a href="#">84</a> |
| 11-3  | Example of Wired-OR Clock Request .....                                       | <a href="#">85</a> |
| 11-4  | HFCLKIN Squared Input Clock.....  | <a href="#">86</a> |
| 11-5  | 32-kHz Oscillator Block Diagram In Master Mode With Crystal.....              | <a href="#">87</a> |
| 11-6  | 32-kHz Crystal Input .....  | <a href="#">88</a> |
| 11-7  | 32-kHz Oscillator Block Diagram Without Crystal Option 1.....                 | <a href="#">89</a> |
| 11-8  | 32-kHz Oscillator Block Diagram Without Crystal Option 2.....                 | <a href="#">90</a> |
| 11-9  | 32-kHz Oscillator in Bypass Mode Block Diagram Without Crystal Option 3 ..... | <a href="#">90</a> |
| 11-10 | 32-kHz Square- or Sine-Wave Input Clock .....                                 | <a href="#">91</a> |
| 11-11 | 32.768-kHz Clock Output Block Diagram .....                                   | <a href="#">91</a> |
| 11-12 | 32KCLKOUT Output Clock.....   | <a href="#">92</a> |
| 11-13 | HFCLKOUT Output Clock.....  | <a href="#">93</a> |

|       |  |                     |
|-------|--|---------------------|
| 11-14 | 32KCLKOUT and HFCLKOUT Clock Stabilization Time.....               | <a href="#">93</a>  |
| 11-15 | HFCLKOUT Behavior .....  | <a href="#">93</a>  |
| 12-1  | I <sup>2</sup> C Interface—Transmit and Receive in Slave Mode..... | <a href="#">96</a>  |
| 12-2  | I2S Interface—I2S Master Model .....                               | <a href="#">98</a>  |
| 12-3  | I2S Interface—I2S Slave Mode.....                                  | <a href="#">98</a>  |
| 12-4  | TDM Interface—TDM Master Mode .....                                | <a href="#">100</a> |
| 12-5  | JTAG Interface Timing .....  | <a href="#">102</a> |
| 13-1  | Debouncing Sequence Chronogram Example.....                        | <a href="#">103</a> |
| 15-1  | Printed Device Reference .....                                     | <a href="#">107</a> |
| 15-2  | TPS65920/TPS65930 Mechanical Package Bottom View .....             | <a href="#">108</a> |
| 15-3  | Ball Size.....   | <a href="#">108</a> |

## List of Tables

|      |   |                    |
|------|---|--------------------|
| 2-1  | Ball Characteristics .....  | <a href="#">13</a> |
| 2-2  | Signal Description .....  | <a href="#">17</a> |
| 3-1  | Absolute Maximum Ratings .....  | <a href="#">23</a> |
| 3-2  | VBAT Minimum Required Per VBAT Ball and Associated Maximum Current .....              | <a href="#">23</a> |
| 3-3  | Recommended Operating Maximum Ratings .....   | <a href="#">24</a> |
| 3-4  | Digital I/O Electrical Characteristics .....  | <a href="#">24</a> |
| 4-1  | Summary of the Power Providers .....  | <a href="#">28</a> |
| 4-2  | Part Names With Corresponding VDD1 Current Support.....                               | <a href="#">29</a> |
| 4-3  | VDD1 dc-dc Regulator Characteristics .....  | <a href="#">29</a> |
| 4-4  | VDD2 dc-dc Regulator Characteristics .....  | <a href="#">32</a> |
| 4-5  | VIO dc-dc Regulator Characteristics.....  | <a href="#">35</a> |
| 4-6  | VDAC LDO Regulator Characteristics .....  | <a href="#">38</a> |
| 4-7  | VPLL1 LDO Regulator Characteristics .....   | <a href="#">39</a> |
| 4-8  | VMMC1 LDO Regulator Characteristics.....  | <a href="#">40</a> |
| 4-9  | VAUX2 LDO Regulator Characteristics .....   | <a href="#">41</a> |
| 4-10 | Output Load Conditions .....  | <a href="#">42</a> |
| 4-11 | Charge Pump Output Load Conditions .....  | <a href="#">43</a> |
| 4-12 | Voltage Reference Characteristics .....   | <a href="#">45</a> |
| 4-13 | Backup Battery Charger Characteristics .....  | <a href="#">45</a> |
| 4-14 | Battery Threshold Levels .....  | <a href="#">46</a> |
| 4-15 | VRRTC LDO Regulator Characteristics .....   | <a href="#">46</a> |
| 4-16 | Power Consumption .....   | <a href="#">47</a> |
| 4-17 | Regulator State Depending on Use Case.....  | <a href="#">48</a> |
| 4-18 | BOOT Mode Description .....   | <a href="#">49</a> |
| 4-19 | MC021 Mode.....   | <a href="#">49</a> |
| 5-1  | System States .....   | <a href="#">54</a> |
| 6-1  | Predriver Output Characteristics .....  | <a href="#">56</a> |
| 6-2  | Vibrator H-Bridge Output Characteristics .....  | <a href="#">57</a> |
| 6-3  | USB-CEA CarKit Audio Downlink Electrical Characteristics .....                        | <a href="#">58</a> |
| 6-4  | Digital Audio Filter RX Electrical Characteristics .....                              | <a href="#">59</a> |
| 6-5  | Boost Electrical Characteristics Versus $F_S$ Frequency ( $F_S \leq 22.05$ kHz) ..... | <a href="#">60</a> |
| 6-6  | Boost Electrical Characteristics Versus $F_S$ Frequency ( $F_S \geq 24$ kHz) .....    | <a href="#">60</a> |
| 6-7  | Analog Microphone Bias Module Characteristics With Bias Resistor .....                | <a href="#">61</a> |
| 6-8  | Analog Microphone Bias Module Characteristics With Bias Resistor .....                | <a href="#">61</a> |
| 6-9  | Silicon Microphone Module Characteristics.....  | <a href="#">64</a> |
| 6-10 | Uplink Characteristics.....   | <a href="#">65</a> |
| 6-11 | USB-CEA CarKit Audio Uplink Electrical Characteristics.....                           | <a href="#">67</a> |
| 6-12 | Digital Audio Filter TX Electrical Characteristics .....                              | <a href="#">68</a> |
| 7-1  | HS-USB Interface Timing Requirements .....  | <a href="#">71</a> |
| 7-2  | HS-USB Interface Switching Requirements .....   | <a href="#">71</a> |
| 7-3  | USB-CEA CarKit Interface Timing Parameters .....                                      | <a href="#">72</a> |
| 7-4  | USB-CEA CarKit UART Timings.....  | <a href="#">73</a> |
| 7-5  | HS Differential Receiver .....  | <a href="#">74</a> |
| 7-6  | HS Differential Transmitter .....   | <a href="#">74</a> |
| 7-7  | CEA/UART Driver .....   | <a href="#">75</a> |
| 7-8  | Pullup/Pulldown Resistors.....  | <a href="#">75</a> |
| 7-9  | OTG VBUS Electrical Characteristics .....   | <a href="#">76</a> |

|       |  |                     |
|-------|--|---------------------|
| 7-10  | OTG ID Electrical Characteristics .....  | <a href="#">76</a>  |
| 8-1   | MADC Electrical Characteristics .....  | <a href="#">78</a>  |
| 8-2   | Analog Input Voltage Range .....   | <a href="#">79</a>  |
| 8-3   | Sequence Conversion Timing Characteristics .....                               | <a href="#">79</a>  |
| 9-1   | LED Driver Electrical Characteristics .....                                    | <a href="#">81</a>  |
| 11-1  | TPS65920/TPS65930 Input Clock Source Requirements .....                        | <a href="#">84</a>  |
| 11-2  | HFCLKIN Input Clock Electrical Characteristics .....                           | <a href="#">86</a>  |
| 11-3  | HFCLKIN Square Input Clock Timing Requirements with Slicer in Bypass .....     | <a href="#">86</a>  |
| 11-4  | Crystal Electrical Characteristics .....                                       | <a href="#">87</a>  |
| 11-5  | Base Oscillator Switching Characteristics.....                                 | <a href="#">88</a>  |
| 11-6  | 32-kHz Crystal Input Clock Timing Requirements .....                           | <a href="#">88</a>  |
| 11-7  | 32-kHz Input Square- or Sine-Wave Clock Source Electrical Characteristics..... | <a href="#">90</a>  |
| 11-8  | 32-kHz Square-Wave Input Clock Source Timing Requirements.....                 | <a href="#">90</a>  |
| 11-9  | 32KCLKOUT Output Clock Electrical Characteristics .....                        | <a href="#">92</a>  |
| 11-10 | 32KCLKOUT Output Clock Switching Characteristics.....                          | <a href="#">92</a>  |
| 11-11 | HFCLKOUT Output Clock Electrical Characteristics .....                         | <a href="#">92</a>  |
| 11-12 | HFCLKOUT Output Clock Switching Characteristics .....                          | <a href="#">92</a>  |
| 12-1  | Timing Parameters .....  | <a href="#">94</a>  |
| 12-2  | TPS65920/TPS65930 Interface Target Frequencies .....                           | <a href="#">95</a>  |
| 12-3  | I <sup>2</sup> C Interface—Timing Requirements .....                           | <a href="#">96</a>  |
| 12-4  | I <sup>2</sup> C Interface—Switching Requirements .....                        | <a href="#">97</a>  |
| 12-5  | I <sup>2</sup> S Interface—Timing Requirements .....                           | <a href="#">99</a>  |
| 12-6  | I <sup>2</sup> S Interface—Switching Characteristics.....                      | <a href="#">99</a>  |
| 12-7  | TDM Interface Master Mode—Timing Requirements .....                            | <a href="#">101</a> |
| 12-8  | TDM Interface Master Mode—Switching Characteristics .....                      | <a href="#">101</a> |
| 12-9  | JTAG Interface—Timing Requirements.....  | <a href="#">102</a> |
| 12-10 | JTAG Interface—Switching Characteristics .....                                 | <a href="#">102</a> |
| 13-1  | Debouncing .....   | <a href="#">103</a> |
| 14-1  | TPS65920/TPS65930 External Components .....                                    | <a href="#">104</a> |
| 15-1  | TPS65920/TPS65930 Nomenclature Description .....                               | <a href="#">107</a> |
| 15-2  | TPS65920 Thermal Resistance Characteristics .....                              | <a href="#">107</a> |
| 15-3  | TPS65930 Thermal Resistance Characteristics .....                              | <a href="#">107</a> |



# Integrated Power Management Audio Codec (TPS65930 Only)

Check for Samples: [TPS65930/TPS65920](#)

## 1 Introduction

The TPS65920/TPS65930 devices are power-management ICs for OMAP™ and other mobile applications. The devices include power-management, a universal serial bus (USB) high-speed (HS) transceiver, light-emitting diode (LED) drivers, an analog-to-digital converter (ADC), a real-time clock (RTC), and embedded power control (EPC). In addition, the TPS65930 includes a full audio codec with two digital-to-analog converters (DACs) and two ADCs to implement dual voice channels, and a stereo downlink channel that can play all standard audio sample rates through a multiple format inter-integrated sound (I2S™)/time division multiplexing (TDM) interface.

These optimized devices support the power and peripheral requirements of the OMAP application processors. The power portion of the devices contains three buck converters, two controllable by a dedicated SmartReflex™ class-3 interface, multiple low dropout (LDO) regulators, an EPC to manage the power sequencing requirements of OMAP, and an RTC and backup module. The RTC can be powered by a backup battery when the main supply is not present, and the devices include a coin-cell charger to recharge the backup battery as needed.

The USB module provides a HS 2.0 OTG transceiver suitable for direct connection to the OMAP UTMI+ low pin interface (ULPI), with an integrated charge pump and full support for the carkit CEA-936A specification. An ADC is provided for monitoring signals, such as supply voltage, entering the device, and two additional external ADC inputs are provided for system use.

The devices provide driver circuitry to power two LED circuits that can illuminate a panel or provide user indicators. The drivers also provide pulse width modulation (PWM) circuits to control the illumination levels of the LEDs. A keypad interface implements a built-in scanning algorithm to decode hardware-based key presses and reduce software use, with multiple additional general-purpose input/output devices (GPIOs) that can be used as interrupts when configured as inputs.

This TPS65920/TPS65930 data manual presents the electrical and mechanical specifications for the TPS65920 and TPS65930 devices . It covers the following topics:

- TPS65920/TPS65930 terminals: Assignment, multiplexing, electrical characteristics, and functional description (see [Section 2, Terminal Description](#))
- Electrical characteristic requirements: Maximum and recommended operating conditions, digital input/output (I/O) characteristics (see [Section 3, Electrical Characteristics](#))
- Power module: Power provider, power references, power control, power consumption, and power management, with the on and off sequence (see [Section 4, Power Module](#))
- RTC and EPC (see [Section 5, Real-Time Clock and Embedded Power Controller](#))
- Audio/voice module (TPS65930 device only): Electrical characteristics and application schematics for the downlink and uplink paths (see [Section 6, Audio/Voice Module \(TPS65930 Device Only\)](#))
- Various modules: USB transceiver, monitoring analog-to-digital converter (MADC), LED drivers, and keyboard (see [Section 8, MADC](#), [Section 9, LED Driver](#), and [Section 10, Keyboard](#))
- Clock specifications: Clock slicer; input and output clocks (see [Section 11, Clock Specifications](#))
- Timing requirements and switching characteristics (ac timings) of the interfaces (see [Section 12, Timing Requirements and Switching Characteristics](#))
- Debouncing time (see [Section 13, Debouncing Time](#))
- External components for the application schematics (see [Section 14, External Components](#))
- Thermal resistance characteristics, device nomenclature, and mechanical data about the available packaging (see [Section 15, TPS65920/TPS65930 Package](#) )

- Glossary of acronyms and abbreviations used in this data manual (see [Section 16, Glossary](#))

## 1.1 Features

The TPS65930 and TPS65920 devices offer the following features:

- Power:
  - Three efficient stepdown converters
  - Four external linear LDOs for clocks and peripherals
  - SmartReflex dynamic voltage management
- Audio (TPS65930 device only):
  - Differential input main microphones
  - Mono auxiliary/FM input
  - External predrivers for class D (stereo)
  - TDM interface
  - Automatic level control (ALC)
  - Digital and analog mixing
  - 16-bit linear audio stereo DAC (96, 48, 44.1, and 32 kHz and derivatives)
  - 16-bit linear audio stereo ADC (48, 44.1, and 32 kHz and derivatives)
  - Carkit
- USB:
  - USB 2.0 on-the-go (OTG)-compliant HS transceivers
  - 12-bit universal transceiver macro interface ULPI
  - USB power supply (5-V charge pump for VBUS)
  - Consumer Electronics Association (CEA)-2011: OTG transceiver interface specification
  - CEA-936A: Mini-USB analog carkit specification
- Additional Features:
  - LED driver circuit for two external LEDs
  - Two external 10-bit MADC inputs
  - Real-time clock (RTC) and retention modules
  - HS I<sup>2</sup>C serial control
  - Thermal shutdown and hot-die detection
  - Keypad Interface (up to 6 × 6)
  - External vibrator control
  - 15 GPIOs
  - 0.65 mm pitch, 139 pin, 10 × 10 mm package
- Charger:
  - Backup battery charger



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

## 1.2 TPS65920 and TPS65930 Device Block Diagrams

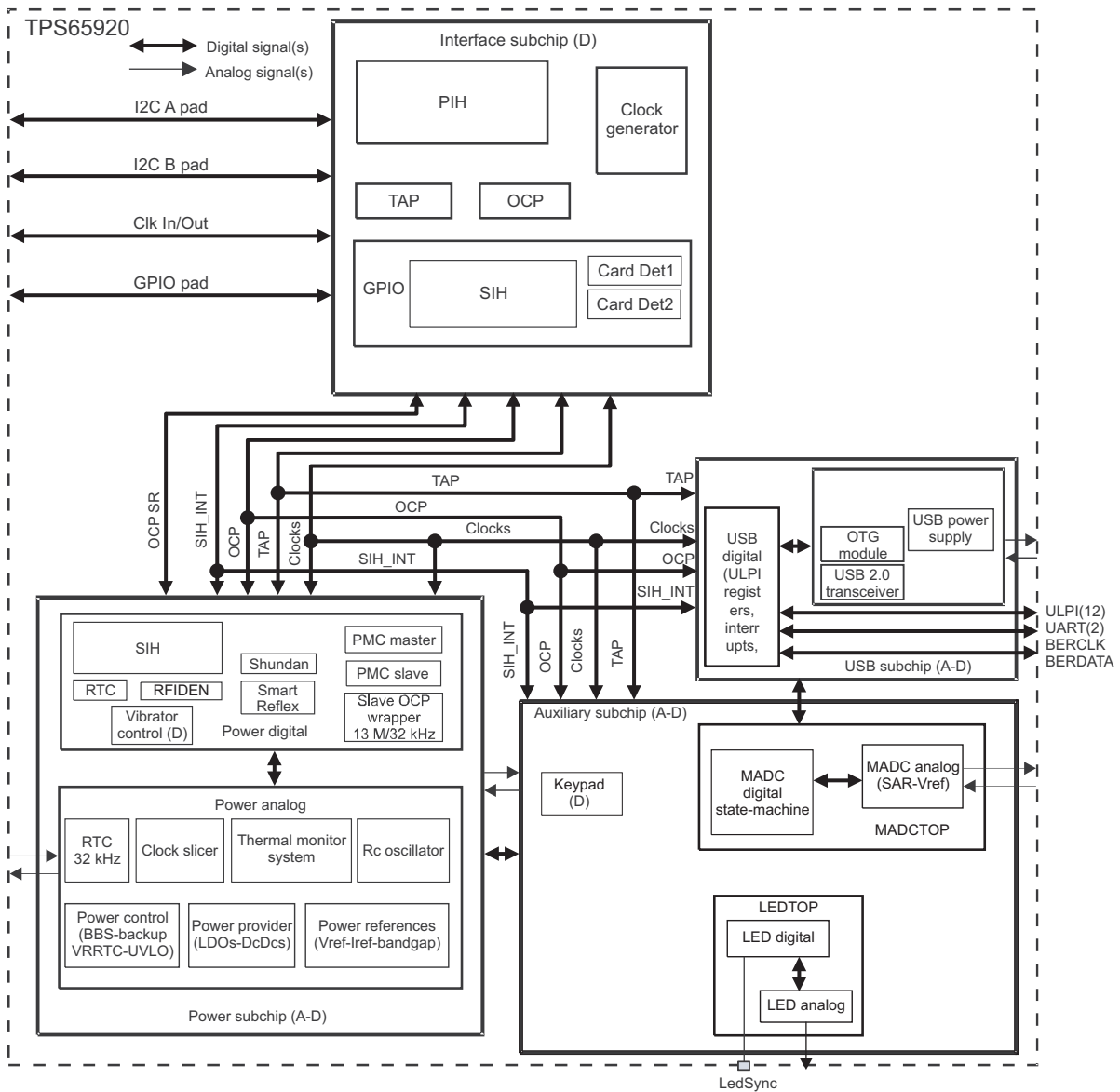


Figure 1-1. TPS65920 Block Diagram

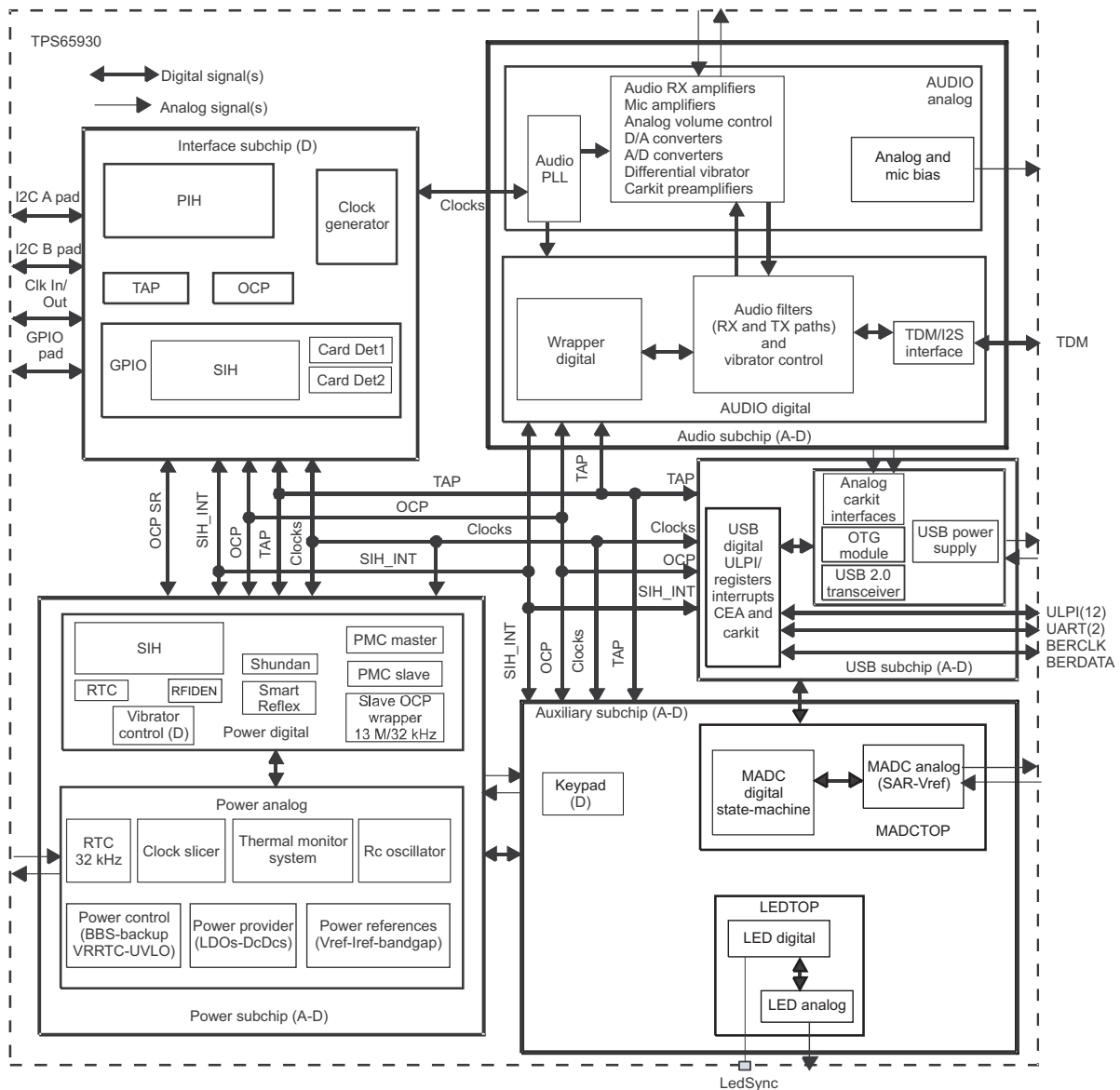


Figure 1-2. TPS65930 Block Diagram

037-002

## 2 Terminal Description

Figure 2-1 shows the ball locations for the 139-ball plastic ball grid array (PBGA) package. Use this array with Table 2-1 to locate signal names and ball grid numbers.

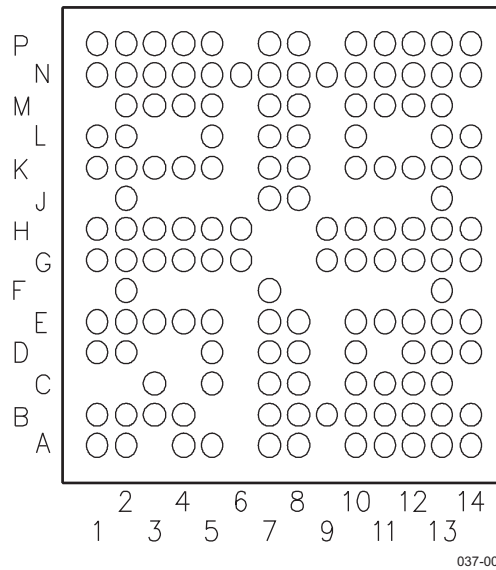


Figure 2-1. PBGA Bottom View

### 2.1 Ball Characteristics

Table 2-1 describes the terminal characteristics and the signals multiplexed on each pin. The following list describes the table column headers:

1. Ball: Ball number(s) associated with each signal(s)
2. Pin Name: The names of all the signals that are multiplexed on each ball
3. A/D: Analog or digital signal
4. Type: The terminal type when a particular signal is multiplexed on the terminal:
  - I = Input
  - O = Output
5. Reference Level: See the power module chapter for values.
6. PU/PD: Denotes the presence of an internal pullup or pulldown. Pullups and pulldowns can be enabled or disabled by software.
7. Buffer Strength: Drive strength of the associated output buffer

Table 2-1. Ball Characteristics

| TPS65920 Ball[1] | TPS65930 Ball[1] | Pin Name[2] | A/D [3] | Type[4] | Reference Level RL[5] | PU[6] (kΩ) |     |     | PD[6] (kΩ) |     |     | Buffer Strength (mA)[7] |
|------------------|------------------|-------------|---------|---------|-----------------------|------------|-----|-----|------------|-----|-----|-------------------------|
|                  |                  |             |         |         |                       | Min        | Typ | Max | Min        | Typ | Max |                         |
| H2               | H2               | ADCIN0      | A       | I/O     | VINTANA1.OUT          |            |     |     |            |     |     |                         |
| F2               | F2               | ADCIN2      | A       | I       | VINTANA2.OUT          |            |     |     |            |     |     |                         |
| M5               | M5               | PCHGAC      | A       | I       | VACCHARGER            |            |     |     |            |     |     |                         |
| N1               | N1               | VPRECH      | A       | O       | VPRECH                |            |     |     |            |     |     |                         |
| N5               | N5               | VBAT        | A       | Power   | VBAT                  |            |     |     |            |     |     |                         |
| F7               | F7               | GPIO0/CD1   | D       | I/O     | IO_1P8                | 75         | 100 | 202 | 59         | 100 | 144 | 8                       |
|                  |                  | JTAG.TDO    | D       | I/O     | IO_1P8                |            |     |     |            |     |     | 8                       |

**Table 2-1. Ball Characteristics (continued)**

| TPS65920 Ball[1]   | TPS65930 Ball[1] | Pin Name[2]             | A/D [3] | Type[4]            | Reference Level RL[5] | PU[6] (kΩ) |      |     | PD[6] (kΩ) |     |     | Buffer Strength (mA)[7] |
|--------------------|------------------|-------------------------|---------|--------------------|-----------------------|------------|------|-----|------------|-----|-----|-------------------------|
|                    |                  |                         |         |                    |                       | Min        | Typ  | Max | Min        | Typ | Max |                         |
| E7                 | E7               | GPIO1                   | D       | I/O                | IO_1P8                | 75         | 100  | 202 | 59         | 100 | 144 | 2                       |
|                    |                  | JTAG.TMS                | D       | I                  | IO_1P8                |            |      |     |            |     |     | 2                       |
| P2                 | P2               | GPIO2                   | D       | I/O                | IO_1P8                | 156        | 220  | 450 | 59         | 100 | 144 | 2                       |
|                    |                  | TEST1                   | D       | I/O                | IO_1P8                |            |      |     |            |     |     | 2                       |
| P13                | P13              | GPIO15                  | D       | I/O                | IO_1P8                | 156        | 220  | 450 | 59         | 100 | 144 | 2                       |
|                    |                  | TEST2                   | D       | I/O                | IO_1P8                |            |      |     |            |     |     | 2                       |
| L5                 | L5               | GPIO6                   | D       | I/O                | IO_1P8                | 75         | 100  | 202 | 59         | 100 | 144 | 2                       |
|                    |                  | PWM0                    | D       | O                  | IO_1P8                |            |      |     |            |     |     | 4                       |
|                    |                  | TEST3                   | D       | I/O                | IO_1P8                |            |      |     |            |     |     | 2                       |
| J7                 | J7               | GPIO7                   | D       | I/O                | IO_1P8                | 75         | 100  | 202 | 59         | 100 | 144 | 2                       |
|                    |                  | VIBRA.SYNC              | D       | I                  | IO_1P8                |            |      |     |            |     |     | 4                       |
|                    |                  | PWM1                    | D       | O                  | IO_1P8                |            |      |     |            |     |     | 2                       |
|                    |                  | TEST4                   | D       | I/O                | IO_1P8                |            |      |     |            |     |     | 2                       |
| D8                 | D8               | SYSEN                   | D       | Open drain/I       | IO_1P8                | 4.7        | 7.35 | 10  |            |     |     | 2                       |
| A4                 | A4               | CLKEN                   | D       | O                  | IO_1P8                |            |      |     |            |     |     | 2                       |
| B13                | B13              | CLKREQ                  | D       | I                  | IO_1P8                |            |      |     | 60         | 100 | 146 |                         |
| C10                | C10              | INT1                    | D       | O                  | IO_1P8                |            |      |     |            |     |     | 2                       |
| C8                 | C8               | NRESPWRON               | D       | O                  | IO_1P8                |            |      |     |            |     |     | 2                       |
| B9                 | B9               | NRESWARM                | D       | I                  | IO_1P8                |            |      |     |            |     |     | 2                       |
| D10                | D10              | PWRON                   | D       | I                  | VBAT                  |            |      |     |            |     |     |                         |
| G5                 | G5               | NSLEEP1                 | D       | I                  | IO_1P8                |            |      |     |            |     |     |                         |
| E10                | E10              | CLK256FS <sup>(1)</sup> | D       | O                  | IO_1P8                |            |      |     |            |     |     | 2                       |
| E4                 | E4               | VMODE1                  | D       | I                  | IO_1P8                |            |      |     |            |     |     |                         |
| E8                 | E8               | BOOT0                   | A/D     | I/O                | VBAT                  |            |      |     |            |     |     |                         |
| D7                 | D7               | BOOT1                   | A/D     | I/O                | VBAT                  |            |      |     |            |     |     |                         |
| B8                 | B8               | REGEN                   | D       | Open drain         | VBAT                  | 5.5        | 8    | 12  |            |     |     | 2                       |
| H4                 | H4               | MSECURE                 | D       | I                  | IO_1P8                |            |      |     |            |     |     |                         |
| L13                | L13              | VREF                    | A       | Power              | VREF                  |            |      |     |            |     |     |                         |
| K13                | K13              | AGND                    | A       | Power ground (GND) | GND                   |            |      |     |            |     |     |                         |
| B3                 | B3               | N.C.                    |         |                    |                       |            |      |     |            |     |     |                         |
|                    |                  | I2C.SR.SDA              | D       | I/O                | IO_1P8                | 2.5        |      | 3.4 |            |     |     | 12                      |
| C5                 | C5               | VMODE2                  | D       | I                  | IO_1P8                |            |      |     |            |     |     | 2                       |
|                    |                  | I2C.SR.SCL              | D       | I/O                | IO_1P8                | 2.5        |      | 3.4 |            |     |     | 12                      |
| C3                 | C3               | I2C.CNTL.SDA            | D       | I/O                | IO_1P8                | 2.5        |      | 3.4 |            |     |     | 12                      |
| B4                 | B4               | I2C.CNTL.SCL            | D       | I                  | IO_1P8                | 2.5        |      | 3.4 |            |     |     | 12                      |
| See <sup>(2)</sup> | H3               | I2S.CLK                 | D       | I/O                | IO_1P8                |            |      |     |            |     |     | 2                       |
| See <sup>(2)</sup> | K2               | I2S.SYNC                | D       | I/O                | IO_1P8                |            |      |     |            |     |     | 2                       |
| See <sup>(2)</sup> | K4               | I2S.DIN                 | D       | I                  | IO_1P8                |            |      |     |            |     |     | 2                       |
| See <sup>(2)</sup> | K3               | I2S.DOUT                | D       | O                  | IO_1P8                |            |      |     |            |     |     | 2                       |
| See <sup>(2)</sup> | D1               | MIC.MAIN.P              | A       | I                  | MICBIAS1.OUT          |            |      |     |            |     |     |                         |
| See <sup>(2)</sup> | E1               | MIC.MAIN.M              | A       | I                  | MICBIAS1.OUT          |            |      |     |            |     |     |                         |
| A10                | A10              | VBAT.RIGHT              | A       | Power              | VBAT                  |            |      |     |            |     |     |                         |
| See <sup>(2)</sup> | A7               | PreDrv.LEFT             | A       | O                  | VINTANA2.OUT          |            |      |     |            |     |     |                         |
|                    |                  | VMID                    | A       | Power              | VINTANA2.OUT          |            |      |     |            |     |     |                         |
| See <sup>(2)</sup> | A8               | PreDrv.RIGHT            | A       | O                  | VINTANA2.OUT          |            |      |     |            |     |     |                         |
|                    |                  | ADCIN7                  | A       | I                  | VINTANA2.OUT          |            |      |     |            |     |     |                         |
| See <sup>(2)</sup> | G1               | AUXR                    | A       | I                  | VINTANA2.OUT          |            |      |     |            |     |     |                         |
| See <sup>(2)</sup> | E2               | MICBIAS1.OUT            | A       | Power              | VINTANA2.OUT          |            |      |     |            |     |     |                         |
|                    |                  | VMIC1.OUT               | A       | Power              | VINTANA2.OUT          |            |      |     |            |     |     |                         |
| See <sup>(2)</sup> | D2               | MICBIAS.GND             |         | Power GND          | GND                   |            |      |     |            |     |     |                         |

- (1) To avoid reflection on this pin as a result of impedance mismatch, a serial resistance of 33 Ω must be added. This clock output is available in TPS65920 also. Can be used as a clock source, if required.
- (2) Balls A7, A8, D1, D2, E1, E2, G1, H3, K2, K3, and K4 are present on TPS65920 package. However, there is no function associated with these pins. These can be left floating.

**Table 2-1. Ball Characteristics (continued)**

| TPS65920<br>Ball[1] | TPS65930<br>Ball[1] | Pin<br>Name[2]       | A/D<br>[3] | Type[4]   | Reference Level<br>RL[5] | PU[6] (kΩ) |     |     | PD[6] (kΩ) |     |     | Buffer<br>Strength<br>(mA)[7] |
|---------------------|---------------------|----------------------|------------|-----------|--------------------------|------------|-----|-----|------------|-----|-----|-------------------------------|
|                     |                     |                      |            |           |                          | Min        | Typ | Max | Min        | Typ | Max |                               |
| G2                  | G2                  | AVSS1                | A          | Power GND | GND                      |            |     |     |            |     |     |                               |
| L7                  | L7                  | AVSS2                | A          | Power GND | GND                      |            |     |     |            |     |     |                               |
| N14                 | N14                 | AVSS3                | A          | Power GND | GND                      |            |     |     |            |     |     |                               |
| C7                  | C7                  | AVSS4                | A          | Power GND | GND                      |            |     |     |            |     |     |                               |
| M10                 | M10                 | 32KCLKOUT            | D          | O         | IO_1P8                   |            |     |     |            |     |     |                               |
| L14                 | L14                 | 32KXIN               | A          | I         | IO_1P8                   |            |     |     |            |     |     |                               |
| K14                 | K14                 | 32KXOUT              | A          | O         | IO_1P8                   |            |     |     |            |     |     |                               |
| A11                 | A11                 | HFCLKIN              | A          | I         | IO_1P8                   |            |     |     |            |     |     |                               |
| M11                 | M11                 | HFCLKOUT             | D          | O         | IO_1P8                   |            |     |     |            |     |     |                               |
| P8                  | P8                  | VBUS                 | A          | Power     | VBUS                     |            |     |     |            |     |     |                               |
| N10                 | N10                 | DP/UART3.RXD         | A          | I/O       | VBUS                     |            |     |     |            |     |     | 2                             |
| P10                 | P10                 | DN/UART3.TXD         | A          | I/O       | VBUS                     |            |     |     |            |     |     | 2                             |
| G6                  | G6                  | ID                   | A          | I/O       | VBUS                     |            |     |     |            |     |     | 2                             |
| K11                 | K11                 | UCLK                 | D          | I         | IO_1P8                   |            |     |     |            |     |     | 16                            |
| H12                 | H12                 | STP                  | D          | I         | IO_1P8                   | 75         | 100 | 202 | 59         | 100 | 144 | 16                            |
|                     |                     | GPIO9                | D          | I/O       | IO_1P8                   |            |     |     |            |     |     | 2                             |
| H11                 | H11                 | DIR                  | D          | O         | IO_1P8                   | 75         | 100 | 202 | 59         | 100 | 144 | 16                            |
|                     |                     | GPIO10               | D          | I/O       | IO_1P8                   |            |     |     |            |     |     | 2                             |
| J8                  | J8                  | NXT                  | D          | O         | IO_1P8                   | 75         | 100 | 202 | 59         | 100 | 144 | 16                            |
|                     |                     | GPIO11               | D          | I/O       | IO_1P8                   |            |     |     |            |     |     | 2                             |
| L10                 | L10                 | DATA0                | D          | I/O       | IO_1P8                   |            |     |     |            |     |     | 16                            |
|                     |                     | UART4.TXD            | D          | I         | IO_1P8                   |            |     |     |            |     |     |                               |
| K10                 | K10                 | DATA1                | D          | I/O       | IO_1P8                   |            |     |     |            |     |     | 16                            |
|                     |                     | UART4.RXD            | D          | O         | IO_1P8                   |            |     |     |            |     |     |                               |
| G11                 | G11                 | DATA2                | D          | I/O       | IO_1P8                   |            |     |     |            |     |     | 16                            |
|                     |                     | UART4.RTSI           | D          | I         | IO_1P8                   |            |     |     |            |     |     |                               |
| G10                 | G10                 | DATA3                | D          | I/O       | IO_1P8                   | 60         | 100 | 140 | 60         | 100 | 140 | 16                            |
|                     |                     | UART4.CTSO           | D          | O         | IO_1P8                   |            |     |     |            |     |     | 16                            |
|                     |                     | GPIO12               | D          | I/O       | IO_1P8                   |            |     |     |            |     |     | 75                            |
| E12                 | E12                 | DATA4                | D          | I/O       | IO_1P8                   | 75         | 100 | 202 | 59         | 100 | 144 | 16                            |
|                     |                     | GPIO14               | D          | I/O       | IO_1P8                   |            |     |     |            |     |     | 2                             |
| G9                  | G9                  | DATA5                | D          | I/O       | IO_1P8                   | 75         | 100 | 202 | 59         | 100 | 144 | 16                            |
|                     |                     | GPIO3                | D          | I/O       | IO_1P8                   |            |     |     |            |     |     | 2                             |
| G12                 | G12                 | DATA6                | D          | I/O       | IO_1P8                   | 75         | 100 | 202 | 59         | 100 | 144 | 16                            |
|                     |                     | GPIO4                | D          | I/O       | IO_1P8                   |            |     |     |            |     |     | 2                             |
| E11                 | E11                 | DATA7                | D          | I/O       | IO_1P8                   | 75         | 100 | 202 | 59         | 100 | 144 | 16                            |
|                     |                     | GPIO5                | D          | I/O       | IO_1P8                   |            |     |     |            |     |     | 2                             |
| P14                 | P14                 | TEST.RESET           | A/D        | I         | VBAT                     |            |     |     | 30         | 50  | 70  |                               |
| P1                  | P1                  | TESTV1               | A          | I/O       | VBAT                     |            |     |     |            |     |     |                               |
| A14                 | A14                 | TESTV2               | A          | I/O       | VINTANA2.OUT             |            |     |     |            |     |     |                               |
| A1                  | A1                  | TEST                 | D          | I         | IO_1P8                   |            |     |     | 60         | 100 | 146 |                               |
| A13                 | A13                 | JTAG.TDI/<br>BERDATA | D          | I         | IO_1P8                   |            |     |     |            |     |     |                               |
| B14                 | B14                 | JTAG.TCK/<br>BERCLK  | D          | I         | IO_1P8                   |            |     |     |            |     |     |                               |
| P7                  | P7                  | CP.IN                | A          | Power     | VBAT/VBUS                |            |     |     |            |     |     |                               |
| N7                  | N7                  | CP.CAPP              | A          | O         | CP.CAPP                  |            |     |     |            |     |     |                               |
| N6                  | N6                  | CP.CAPM              | A          | O         | CP.CAPM                  |            |     |     |            |     |     |                               |
| P5                  | P5                  | CP.GND               | A          | Power GND | GND                      |            |     |     |            |     |     |                               |
| N9                  | N9                  | VBAT.USB             | A          | Power     | VBAT                     |            |     |     |            |     |     |                               |
| M8                  | M8                  | VUSB.3P1             | A          | Power     | VUSB.3P1                 |            |     |     |            |     |     |                               |
| L1                  | L1                  | VAUX12S.IN           | A          | Power     | VBAT                     |            |     |     |            |     |     |                               |
| N2                  | N2                  | VAUX2.OUT            | A          | Power     | VAUX2.OUT                |            |     |     |            |     |     |                               |
| H14                 | H14                 | VPLLA3R.IN           | A          | Power     | VBAT                     |            |     |     |            |     |     |                               |
| K12                 | K12                 | VRTC.OUT             | A          | Power     | VRTC.OUT                 |            |     |     |            |     |     |                               |

Table 2-1. Ball Characteristics (continued)

| TPS65920<br>Ball[1] | TPS65930<br>Ball[1] | Pin<br>Name[2]     | A/D<br>[3] | Type[4]    | Reference Level<br>RL[5] | PU[6] (k $\Omega$ ) |     |     | PD[6] (k $\Omega$ ) |     |     | Buffer<br>Strength<br>(mA)[7] |
|---------------------|---------------------|--------------------|------------|------------|--------------------------|---------------------|-----|-----|---------------------|-----|-----|-------------------------------|
|                     |                     |                    |            |            |                          | Min                 | Typ | Max | Min                 | Typ | Max |                               |
| G14                 | G14                 | VPLL1.OUT          | A          | Power      | VPLL1.OUT                |                     |     |     |                     |     |     |                               |
| A2                  | A2                  | VMMC1.IN           | A          | Power      | VBAT                     |                     |     |     |                     |     |     |                               |
| B1                  | B1                  | VMMC1.OUT          | A          | Power      | VMMC1.OUT                |                     |     |     |                     |     |     |                               |
| M7                  | M7                  | VINTUSB1P5.<br>OUT | A          | Power      | VINTUSB1P5.OUT           |                     |     |     |                     |     |     |                               |
| N8                  | N8                  | VINTUSB1P8.<br>OUT | A          | Power      | VINTUSB1P8.OUT           |                     |     |     |                     |     |     |                               |
| K1                  | K1                  | VDAC.IN            | A          | Power      | VBAT                     |                     |     |     |                     |     |     |                               |
| L2                  | L2                  | VDAC.OUT           | A          | Power      | VDAC.OUT                 |                     |     |     |                     |     |     |                               |
| H13                 | H13                 | VINT.IN            | A          | Power      | VBAT                     |                     |     |     |                     |     |     |                               |
| H1                  | H1                  | VINTANA1.OUT       | A          | Power      | VINTANA1.OUT             |                     |     |     |                     |     |     |                               |
| J2                  | J2                  | VINTANA2.OUT       | A          | Power      | VINTANA2.OUT             |                     |     |     |                     |     |     |                               |
| A5                  | A5                  | VINTANA2.OUT       | A          | Power      | VINTANA2.OUT             |                     |     |     |                     |     |     |                               |
| J13                 | J13                 | VINTDIG.OUT        | A          | Power      | VINTDIG.OUT              |                     |     |     |                     |     |     |                               |
| D13                 | D13                 | VDD1.IN            | A          | Power      | VBAT                     |                     |     |     |                     |     |     |                               |
| D12                 | D12                 | VDD1.IN            | A          | Power      | VBAT                     |                     |     |     |                     |     |     |                               |
| D14                 | D14                 | VDD1.IN            | A          | Power      | VBAT                     |                     |     |     |                     |     |     |                               |
| C11                 | C11                 | VDD1.SW            | A          | O          | VBAT                     |                     |     |     |                     |     |     |                               |
| C12                 | C12                 | VDD1.SW            | A          | O          | VBAT                     |                     |     |     |                     |     |     |                               |
| C13                 | C13                 | VDD1.SW            | A          | O          | VBAT                     |                     |     |     |                     |     |     |                               |
| E14                 | E14                 | VDD1.FB            | A          | I          |                          |                     |     |     |                     |     |     |                               |
| A12                 | A12                 | VDD1.GND           | A          | Power GND  | GND                      |                     |     |     |                     |     |     |                               |
| B11                 | B11                 | VDD1.GND           | A          | Power GND  | GND                      |                     |     |     |                     |     |     |                               |
| B12                 | B12                 | VDD1.GND           | A          | Power GND  | GND                      |                     |     |     |                     |     |     |                               |
| M13                 | M13                 | VDD2.IN            | A          | Power      | VBAT                     |                     |     |     |                     |     |     |                               |
| M12                 | M12                 | VDD2.IN            | A          | Power      | VBAT                     |                     |     |     |                     |     |     |                               |
| N13                 | N13                 | VDD2.FB            | A          | I          |                          |                     |     |     |                     |     |     |                               |
| N11                 | N11                 | VDD2.SW            | A          | O          | VBAT                     |                     |     |     |                     |     |     |                               |
| P11                 | P11                 | VDD2.SW            | A          | O          | VBAT                     |                     |     |     |                     |     |     |                               |
| N12                 | N12                 | VDD2.GND           | A          | Power GND  | GND                      |                     |     |     |                     |     |     |                               |
| P12                 | P12                 | VDD2.GND           | A          | Power GND  | GND                      |                     |     |     |                     |     |     |                               |
| M2                  | M2                  | VIO.IN             | A          | Power      | VBAT                     |                     |     |     |                     |     |     |                               |
| M3                  | M3                  | VIO.IN             | A          | Power      | VBAT                     |                     |     |     |                     |     |     |                               |
| M4                  | M4                  | VIO.FB             | A          | I          |                          |                     |     |     |                     |     |     |                               |
| N4                  | N4                  | VIO.SW             | A          | O          | VBAT                     |                     |     |     |                     |     |     |                               |
| P4                  | P4                  | VIO.SW             | A          | O          | VBAT                     |                     |     |     |                     |     |     |                               |
| N3                  | N3                  | VIO.GND            | A          | Power GND  | GND                      |                     |     |     |                     |     |     |                               |
| P3                  | P3                  | VIO.GND            | A          | Power GND  | GND                      |                     |     |     |                     |     |     |                               |
| H9                  | H9                  | BKBAT              | A          | Power      | VBACK                    |                     |     |     |                     |     |     |                               |
| B7                  | B7                  | IO_1P8             | A          | Power      | IO_1P8                   |                     |     |     |                     |     |     |                               |
| H10                 | H10                 | DGND               | A          | Power GND  | GND                      |                     |     |     |                     |     |     |                               |
| F13                 | F13                 | LEDGND             | A          | Power GND  | GND                      |                     |     |     |                     |     |     |                               |
| B10                 | B10                 | GPIO13             | D          | I/O        | IO_1P8                   | 75                  | 100 | 202 | 59                  | 100 | 144 |                               |
|                     |                     | LEDSYNC            | D          | I          | IO_1P8                   |                     |     |     |                     |     |     |                               |
| E13                 | E13                 | LEDA               | A          | Open drain | VBAT                     |                     |     |     |                     |     |     |                               |
|                     |                     | VIBRA.P            | A          | Open drain | VBAT                     |                     |     |     |                     |     |     |                               |
| G13                 | G13                 | LEDB               | A          | Open drain | VBAT                     |                     |     |     |                     |     |     |                               |
|                     |                     | VIBRA.M            | A          | Open drain | VBAT                     |                     |     |     |                     |     |     |                               |
| G4                  | G4                  | KPD.C0             | D          | Open drain | IO_1P8                   |                     |     |     |                     |     |     |                               |
| G3                  | G3                  | KPD.C1             | D          | Open drain | IO_1P8                   |                     |     |     |                     |     |     |                               |
| E5                  | E5                  | KPD.C2             | D          | Open drain | IO_1P8                   |                     |     |     |                     |     |     |                               |
| B2                  | B2                  | KPD.C3             | D          | Open drain | IO_1P8                   |                     |     |     |                     |     |     |                               |
| E3                  | E3                  | KPD.C4             | D          | Open drain | IO_1P8                   |                     |     |     |                     |     |     |                               |
| D5                  | D5                  | KPD.C5             | D          | Open drain | IO_1P8                   |                     |     |     |                     |     |     |                               |
| K7                  | K7                  | KPD.R0             | D          | I          | IO_1P8                   | 8                   | 10  | 12  |                     |     |     |                               |



**Table 2-1. Ball Characteristics (continued)**

| TPS65920 Ball <sup>[1]</sup> | TPS65930 Ball <sup>[1]</sup> | Pin Name <sup>[2]</sup> | A/D <sup>[3]</sup> | Type <sup>[4]</sup> | Reference Level RL <sup>[5]</sup> | PU <sup>[6]</sup> (kΩ) |     |     | PD <sup>[6]</sup> (kΩ) |     |     | Buffer Strength (mA) <sup>[7]</sup> |
|------------------------------|------------------------------|-------------------------|--------------------|---------------------|-----------------------------------|------------------------|-----|-----|------------------------|-----|-----|-------------------------------------|
|                              |                              |                         |                    |                     |                                   | Min                    | Typ | Max | Min                    | Typ | Max |                                     |
| H5                           | H5                           | KPD.R1                  | D                  | I                   | IO_1P8                            | 8                      | 10  | 12  |                        |     |     |                                     |
| K5                           | K5                           | KPD.R2                  | D                  | I                   | IO_1P8                            | 8                      | 10  | 12  |                        |     |     |                                     |
| H6                           | H6                           | KPD.R3                  | D                  | I                   | IO_1P8                            | 8                      | 10  | 12  |                        |     |     |                                     |
| K8                           | K8                           | KPD.R4                  | D                  | I                   | IO_1P8                            | 8                      | 10  | 12  |                        |     |     |                                     |
| L8                           | L8                           | KPD.R5                  | D                  | I                   | IO_1P8                            | 8                      | 10  | 12  |                        |     |     |                                     |

## 2.2 Signal Description

Table 2-2 describes the signals on the TPS65920 and TPS65930 devices; some signals are available on multiple pins.

**Table 2-2. Signal Description**

| Module         | Signal Name   | Description   | Type  | TPS65920 Ball | TPS65930 Ball | Default Configuration After Reset Released |       |                      | Features Not Used <sup>(1)</sup> |
|----------------|---|---|-------|---------------|---------------|--|-------|----------------------|----------------------------------|
|                |   |   |       |               |               | Signal                                     | Type  | Internal Pull or Not |                                  |
| ADC            | ADCIN0  | Battery type  | I/O   | H2            | H2            | ADCIN0                                     |       |                      | GND                              |
|                | ADCIN2  | General-purpose ADC input                             | I     | F2            | F2            | ADCIN2                                     | I     |                      | GND                              |
| Charger        | PCHGAC  | AC precharge sense signal. Also used for EEPROM.      | I     | M5            | M5            | PCHGAC                                     | I     |                      | GND                              |
|                | VPRECH  | Precharge regulator output                            | O     | N1            | N1            | VPRECH                                     | O     |                      | Cap to GND <sup>(2)</sup>        |
|                | VBAT  | Battery voltage sensing                               | Power | N5            | N5            | VBAT                                       | Power |                      | VBAT                             |
| GPIOs/<br>JTAG | GPIO0/CD1   | GPIO0/card detection 1                                | I/O   | F7            | F7            | GPIO0                                      | I     | PD                   | Floating                         |
|                | JTAG.TDO  | JTAG test data output                                 | I/O   |               |               |  |       |                      |                                  |
|                | GPIO1   | GPIO1   | I/O   | E7            | E7            | GPIO1                                      | I     | PD                   | Floating                         |
|                | JTAG.TMS  | JTAG test mode state                                  | I     |               |               |  |       |                      |                                  |
|                | GPIO2   | GPIO2   | I/O   | P2            | P2            | GPIO2                                      | I     | PD                   | Floating                         |
|                | TEST1   | TEST1 pin used in test mode only                      | I/O   |               |               |  |       |                      |                                  |
|                | GPIO15  | GPIO15  | I/O   | P13           | P13           | GPIO15                                     | I     | PD                   | Floating                         |
|                | TEST2   | TEST2 pin used in test mode only                      | I/O   |               |               |  |       |                      |                                  |
|                | GPIO6   | GPIO6   | I/O   | L5            | L5            | GPIO6                                      | I     | PD                   | Floating                         |
|                | PWM0  | Pulse width driver 0                                  | O     |               |               |  |       |                      |                                  |
|                | TEST3   | TEST3 pin used in test mode only (controlled by JTAG) | I/O   | J7            | J7            | GPIO7                                      | I     | PD                   | Floating                         |
|                | GPIO7   | GPIO7   | I/O   |               |               |  |       |                      |                                  |
|                | VIBRA.SYNC  | Vibrator on-off synchronization                       | I     |               |               |  |       |                      |                                  |
| PWM1           | Pulse width driver                                    | O   |       |               |               |  |       |                      |                                  |
| TEST4          | TEST4 pin used in test mode only (controlled by JTAG) | I/O   |       |               |               |  |       |                      |                                  |

**Table 2-2. Signal Description (continued)**

| Module                        | Signal Name                            | Description   | Type         | TPS65920 Ball | TPS65930 Ball | Default Configuration After Reset Released |           |                      | Features Not Used <sup>(1)</sup> |
|-------------------------------|--|---|--------------|---------------|---------------|--|-----------|----------------------|----------------------------------|
|                               |  |   |              |               |               | Signal                                     | Type      | Internal Pull or Not |                                  |
| CONTROL                       | SYSEN                                  | System enable output  | Open drain/I | D8            | D8            | SYSEN                                      | OD        | PU                   | Floating                         |
|                               | CLKEN                                  | Clock enable  | O            | A4            | A4            | CLKEN                                      | O         |                      | Floating                         |
|                               | CLKREQ                                 | Clock request   | I            | B13           | B13           | CLKREQ                                     | I         | PD                   | GND                              |
|                               | INT1                                   | Output interrupt line 1                                     | O            | C10           | C10           | INT1                                       | O         |                      | Floating                         |
|                               | NRESPWRON                              | Output control the NRESPWRON of the application processor   | O            | C8            | C8            | NRESPWRON                                  | O         |                      | Floating                         |
|                               | NRESWARM                               | Input; detect user action on the reset button               | I            | B9            | B9            | NRESWARM                                   | I         |                      | GND                              |
|                               | PWRON                                  | Input; detect a control command to start or stop the system | I            | D10           | D10           | PWRON                                      | I         |                      | VBAT                             |
|                               | NSLEEP1                                | Sleep request from device 1                                 | I            | G5            | G5            | NSLEEP1                                    | I         |                      | GND                              |
|                               | CLK256FS                               |   | O            | E10           | E10           | CLK256FS                                   | O         |                      | Floating                         |
|                               | VMODE1                                 | Digital voltage scaling linked with VDD1                    | I            | E4            | E4            | VMODE1                                     | I         |                      | GND                              |
|                               | BOOT0                                  | Boot pin 0  | I            | E8            | E8            | BOOT0                                      | I         | PD                   | N/A                              |
|                               | BOOT1                                  | Boot pin 1  | I            | D7            | D7            | BOOT1                                      | I         | PD                   | N/A                              |
|                               | REGEN                                  | Enable signal for external LDO                              | Open drain   | B8            | B8            | REGEN                                      | OD        | PU                   | Floating                         |
| MSECURE                       | Security and digital rights management | I   | H4           | H4            | MSECURE       | I  |           | N/A                  |                                  |
| VREF                          | VREF                                   | Reference voltage   | Power        | L13           | L13           | VREF                                       | Power     |                      | N/A                              |
|                               | AGND                                   | Analog ground for reference voltage                         | Power GND    | K13           | K13           | AGND                                       | Power GND |                      | GND                              |
| I <sup>2</sup> C Smart Reflex | N.C.                                   | Not connected   |              | B3            | B3            | Signal not functional <sup>(3)</sup>       |           |                      | Floating                         |
|                               | I2C.SR.SDA                             | SmartReflex I <sup>2</sup> C data                           | I/O          |               |               |  |           |                      |                                  |
|                               | VMODE2                                 | Digital voltage scaling linked with VDD2                    | I            | C5            | C5            |  |           |                      |                                  |
| I <sup>2</sup> C              | I2C.SR.SCL                             | SmartReflex I <sup>2</sup> C data                           | I/O          |               |               |  |           |                      |                                  |
|                               | I2C.CNTL.SDA                           | General-purpose I <sup>2</sup> C data                       | I/O          | C3            | C3            | I2C.CNTL.SDA                               | I/O       | PU                   | N/A                              |
| TDM                           | I2C.CNTL.SCL                           | General-purpose I <sup>2</sup> C clock                      | I/O          | B4            | B4            | I2C.CNTL.SCL                               | I/O       | PU                   | N/A                              |
|                               | I2S.CLK                                | Clock signal (audio port)                                   | I/O          |               | H3            | I2S.CLK                                    | I/O       |                      | Floating                         |
|                               | I2S.SYNC                               | Synchronization signal (audio port)                         | I/O          |               | K2            | I2S.SYNC                                   | I/O       |                      | Floating                         |
|                               | I2S.DIN                                | Data receive (audio port)                                   | I            |               | K4            | I2S.DIN                                    | I         |                      | GND                              |
| ANA.MIC                       | I2S.DOUT                               | Data transmit (audio port)                                  | O            |               | K3            | I2S.DOUT                                   | O         |                      | Floating                         |
|                               | MIC.MAIN.P                             | Main microphone left input (P)                              | I            |               | D1            | MIC.MAIN.P                                 | I         |                      | Cap to GND                       |
| Hands-Free                    | MIC.MAIN.M                             | Main microphone left input (M)                              | I            |               | E1            | MIC.MAIN.M                                 | I         |                      | Cap to GND                       |
|                               | VBAT.RIGHT                             | Battery voltage input                                       | Power        | A10           | A10           | VBAT.RIGHT                                 | Power     |                      | VBAT                             |
| Headset                       | PreDrv.LEFT                            | Predriver output left P for external class-D amplifier      | O            |               | A7            | VMID                                       | Power     |                      | Floating                         |
|                               | VMID                                   |   | Power        |               |               |  |           |                      |                                  |
|                               | PreDrv.RIGHT                           | Predriver output right P for external class-D amplifier     | O            |               | A8            | ADCIN7                                     | I         |                      | GND                              |
|                               | ADCIN7                                 | General-purpose ADC input 7                                 | I            |               |               |  |           |                      |                                  |
| AUX Input                     | AUXR                                   | Auxiliary audio input right                                 | I            |               | G1            | AUXR                                       | I         |                      | Cap to GND                       |

**Table 2-2. Signal Description (continued)**

| Module    | Signal Name  | Description   | Type      | TPS65920 Ball | TPS65930 Ball | Default Configuration After Reset Released |           |                      | Features Not Used <sup>(1)</sup> |     |
|-----------|--------------|---|-----------|---------------|---------------|--|-----------|----------------------|----------------------------------|-----|
|           |              |   |           |               |               | Signal                                     | Type      | Internal Pull or Not |                                  |     |
| VMIC BIAS | MICBIAS1.OUT | Analog microphone bias 1  | Power     |               | E2            | MICBIAS1.OUT                               | Power     |                      | Floating                         |     |
|           | VMIC1.OUT    | Digital microphone power supply 1   | Power     |               |               |  |           |                      |                                  |     |
|           | MICBIAS.GND  | Dedicated ground for microphones  | Power GND |               | D2            | MICBIAS.GND                                | Power GND |                      | GND                              |     |
|           | AVSS1        | Analog ground   | Power GND |               | G2            | G2   | AVSS1     | Power GND            |                                  | GND |
|           | AVSS2        |   |           | L7            | L7            | AVSS2                                      |           |                      |                                  |     |
|           | AVSS3        |   |           | N14           | N14           | AVSS3                                      |           |                      |                                  |     |
| AVSS4     | C7           |   |           | C7            | AVSS4         |  |           |                      |                                  |     |
| CLOCK     | 32KCLKOUT    | Buffered output of the 32-kHz digital clock   | O         | M10           | M10           | 32KCLKOUT                                  | O         |                      | Floating                         |     |
|           | 32KXIN       | Input of the 32-kHz oscillator  | I         | L14           | L14           | 32KXIN                                     | I         |                      | N/A                              |     |
|           | 32KXOUT      | Output of the 32-kHz oscillator   | O         | K14           | K14           | 32KXOUT                                    | O         |                      | Floating                         |     |
|           | HFCLKIN      | Input of the digital (or sine) HS clock   | I         | A11           | A11           | HFCLKIN                                    | I         |                      | N/A                              |     |
|           | HFCLKOUT     | HS clock output   | O         | M11           | M11           | HFCLKOUT                                   | O         |                      | Floating                         |     |
| USB PHY   | VBUS         | VBUS power rail   | Power     | P8            | P8            | VBUS                                       | Power     |                      | N/A                              |     |
|           | DP/UART3.RXD | USB data P/USB carkit receive data/universal asynchronous receiver/transmitter (UART)3 receive data | I/O       | N10           | N10           | DP/UART3.RXD                               | I/O       |                      | N/A                              |     |
|           | DN/UART3.TXD | USB data N/USB carkit transmit data/UART3 transmit data   | I/O       | P10           | P10           | DN/UART3.TXD                               | I/O       |                      | N/A                              |     |
|           | ID           | USB ID  | I/O       | G6            | G6            | ID   | I/O       |                      | Connected to VRUSB3V1            |     |
| ULPI      | UCLK         | HS USB clock  | I         | K11           | K11           | UCLK                                       | O         |                      | Floating                         |     |
|           | STP          | HS USB stop   | I         | H12           | H12           | STP  | I         | PU                   | Floating                         |     |
|           | GPIO9        | GPIO9   | I/O       |               |               |  |           |                      |                                  |     |
|           | DIR          | HS USB direction  | O         | H11           | H11           | DIR  | O         |                      | Floating                         |     |
|           | GPIO10       | GPIO10  | I/O       |               |               |  |           |                      |                                  |     |
|           | NXT          | HS USB next   | O         | J8            | J8            | NXT  | O         |                      | Floating                         |     |
|           | GPIO11       | GPIO11  | I/O       |               |               |  |           |                      |                                  |     |
|           | DATA0        | HS USB Data0  | I/O       | L10           | L10           | DATA0                                      | O         |                      | Floating                         |     |
|           | UART4.TXD    | UART4.TXD   | I         |               |               |  |           |                      |                                  |     |
|           | DATA1        | HS USB Data1  | I/O       | K10           | K10           | DATA1                                      | O         |                      | Floating                         |     |
|           | UART4.RXD    | UART4.RXD   | O         |               |               |  |           |                      |                                  |     |
|           | DATA2        | HS USB Data2  | I/O       | G11           | G11           | DATA2                                      | O         |                      | Floating                         |     |
|           | UART4.RTSI   | UART4.RTSI  | I         |               |               |  |           |                      |                                  |     |
|           | DATA3        | HS USB Data3  | I/O       | G10           | G10           | DATA3                                      | O         |                      | Floating                         |     |
|           | UART4.CTSO   | UART4.CTSO  | O         |               |               |  |           |                      |                                  |     |
|           | GPIO12       | GPIO12  | I/O       | E12           | E12           | DATA4                                      | O         |                      | Floating                         |     |
|           | DATA4        | HS USB Data4  | I/O       |               |               |  |           |                      |                                  |     |
|           | GPIO14       | GPIO14  | I/O       | G9            | G9            | DATA5                                      | O         |                      | Floating                         |     |
|           | DATA5        | HS USB Data5  | I/O       |               |               |  |           |                      |                                  |     |
|           | GPIO3        | GPIO3   | I/O       | G12           | G12           | DATA6                                      | O         |                      | Floating                         |     |
| DATA6     | HS USB Data6 | I/O   |           |               |               |  |           |                      |                                  |     |
| GPIO4     | GPIO4        | I/O   | E11       | E11           | DATA7         | O  |           | Floating             |                                  |     |
| DATA7     | HS USB Data7 | I/O   |           |               |               |  |           |                      |                                  |     |
| GPIO5     | GPIO5        | I/O   |           |               |               |  |           |                      |                                  |     |

**Table 2-2. Signal Description (continued)**

| Module      | Signal Name      | Description   | Type      | TPS65920 Ball | TPS65930 Ball | Default Configuration After Reset Released |           |                      | Features Not Used <sup>(1)</sup> |
|-------------|------------------|---|-----------|---------------|---------------|--|-----------|----------------------|----------------------------------|
|             |                  |   |           |               |               | Signal                                     | Type      | Internal Pull or Not |                                  |
| TEST        | TEST.RESET       | Reset T2 device (except power state-machine)                                    | I         | P14           | P14           | TEST.RESET                                 | I         | PD                   | GND                              |
|             | TESTV1           | Analog test   | I/O       | P1            | P1            | TESTV1                                     | I/O       |                      | Floating                         |
|             | TESTV2           | Analog test   | I/O       | A14           | A14           | TESTV2                                     | I/O       |                      | Floating                         |
|             | TEST             | Selection between JTAG mode and application mode for JTAG/GPIOs (with PU or PD) | I         | A1            | A1            | TEST                                       | I         | PD                   | Floating                         |
|             | JTAG.TDI/BERDATA | JTAG.TDI/BERDATA  | I         | A13           | A13           | JTAG.TDI/BERDATA                           | I         |                      | GND                              |
|             | JTAG.TCK/BERCLK  | JTAG.TCK/BERCLK   | I         | B14           | B14           | JTAG.TCK/BERCLK                            | I         |                      | GND                              |
| USB CP      | CP.IN            | Charge pump input voltage   | Power     | P7            | P7            | CP.IN                                      | Power     |                      | VBAT                             |
|             | CP.CAPP          | Charge pump flying capacitor P  | O         | N7            | N7            | CP.CAPP                                    | O         |                      | Floating                         |
|             | CP.CAPM          | Charge pump flying capacitor M  | O         | N6            | N6            | CP.CAPM                                    | O         |                      | Floating                         |
|             | CP.GND           | Charge pump ground  | Power GND | P5            | P5            | CP.GND                                     | Power GND |                      | GND                              |
| VBAT.USB B  | VBAT.USB         | USB LDOs (VINTUSB1P5, VINTUSB1P8, VUSB.3P1) VBAT                                | Power     | N9            | N9            | VBAT.USB                                   | Power     |                      | VBAT                             |
| USB.LDO     | VUSB.3P1         | USB LDO output  | Power     | M8            | M8            | VUSB.3P1                                   | Power     |                      | N/A                              |
| VAUX1       | VAUX12S.IN       | VAUX1/VAUX2/VSIM LDO input voltage  | Power     | L1            | L1            | VAUX12S.IN                                 | Power     |                      | VBAT                             |
| VAUX2       | VAUX2.OUT        | VAUX2 LDO output voltage  | Power     | N2            | N2            | VAUX2.OUT                                  | Power     |                      | Floating                         |
| VPLLA3R     | VPLLA3R.IN       | Input for VPLL1, VPLL2, VAUX3, and VRTC LDOs                                    | Power     | H14           | H14           | VPLLA3R.IN                                 | Power     |                      | VBAT                             |
| VRTC        | VRTC.OUT         | VRTC internal LDO output (internal use only)                                    | Power     | K12           | K12           | VRTC.OUT                                   | Power     |                      | N/A                              |
| VPLL1       | VPLL1.OUT        | LDO output voltage  | Power     | G14           | G14           | VPLL1.OUT                                  | Power     |                      | Floating                         |
| VMMC1       | VMMC1.IN         | VMMC1 LDO input voltage   | Power     | A2            | A2            | VMMC1.IN                                   | Power     |                      | VBAT                             |
|             | VMMC1.OUT        | VMMC1 LDO output voltage  | Power     | B1            | B1            | VMMC1.OUT                                  | Power     |                      | Floating                         |
| VINTUSB1 P5 | VINTUSB1P5. OUT  | VINTUSB1P5 internal LDO output (internal use only)                              | Power     | M7            | M7            | VINTUSB1P5. OUT                            | Power     |                      | Floating                         |
| VINTUSB1 P8 | VINTUSB1P8. OUT  | VINTUSB1P8 internal LDO output (internal use only)                              | Power     | N8            | N8            | VINTUSB1P8. OUT                            | Power     |                      | Floating                         |
| Video DAC   | VDAC.IN          | Input for VDAC, VINTANA1, and VINTANA2 LDOs                                     | Power     | K1            | K1            | VDAC.IN                                    | Power     |                      | VBAT                             |
|             | VDAC.OUT         | Output voltage of the regulator   | Power     | L2            | L2            | VDAC.OUT                                   | Power     |                      | Floating                         |
| VINT        | VINT.IN          | Input for VINTDIG LDO   | Power     | H13           | H13           | VINT.IN                                    | Power     |                      | VBAT                             |
| VINTANA1    | VINTANA1. OUT    | VINTANA1 internal LDO output (internal use only)                                | Power     | H1            | H1            | VINTANA1. OUT                              | Power     |                      | N/A                              |
| VINTANA2    | VINTANA2. OUT    | VINTANA2 internal LDO output (internal use only)                                | Power     | J2            | J2            | VINTANA2. OUT                              | Power     |                      | N/A                              |
|             | VINTANA2. OUT    | VINTANA2 internal LDO output (internal use only)                                | Power     | A5            | A5            | VINTANA2. OUT                              | Power     |                      | N/A                              |
| VINTDIG     | VINTDIG. OUT     | VINTDIG internal LDO output (internal use only)                                 | Power     | J13           | J13           | VINTDIG. OUT                               | Power     |                      | N/A                              |

**Table 2-2. Signal Description (continued)**

| Module         | Signal Name         | Description                          | Type       | TPS65920 Ball | TPS65930 Ball | Default Configuration After Reset Released |           |                      | Features Not Used <sup>(1)</sup> |
|----------------|---------------------|--------------------------------------|------------|---------------|---------------|--|-----------|----------------------|----------------------------------|
|                |                     |                                      |            |               |               | Signal                                     | Type      | Internal Pull or Not |                                  |
| VDD1           | VDD1.IN             | VDD1 dc-dc input voltage             | Power      | D13           | D13           | VDD1.IN                                    | Power     |                      | VBAT                             |
|                | VDD1.IN             | VDD1 dc-dc input voltage             | Power      | D12           | D12           | VDD1.IN                                    | Power     |                      | VBAT                             |
|                | VDD1.IN             | VDD1 dc-dc input voltage             | Power      | D14           | D14           | VDD1.IN                                    | Power     |                      | VBAT                             |
|                | VDD1.SW             | VDD1 dc-dc switch                    | O          | C11           | C11           | VDD1.SW                                    | O         |                      | Floating                         |
|                | VDD1.SW             | VDD1 dc-dc switch                    | O          | C12           | C12           | VDD1.SW                                    | O         |                      | Floating                         |
|                | VDD1.SW             | VDD1 dc-dc switch                    | O          | C13           | C13           | VDD1.SW                                    | O         |                      | Floating                         |
|                | VDD1.FB             | VDD1 dc-dc output voltage (feedback) | I          | E14           | E14           | VDD1.FB                                    | I         |                      | GND                              |
|                | VDD1.GND            | VDD1 dc-dc ground                    | Power GND  | A12           | A12           | VDD1.GND                                   | Power GND |                      | GND                              |
|                | VDD1.GND            | VDD1 dc-dc ground                    | Power GND  | B11           | B11           | VDD1.GND                                   | Power GND |                      | GND                              |
| VDD1.GND       | VDD1 dc-dc ground   | Power GND                            | B12        | B12           | VDD1.GND      | Power GND                                  |           | GND                  |                                  |
| VDD2           | VDD2.IN             | VDD2 dc-dc input voltage             | Power      | M13           | M13           | VDD2.IN                                    | Power     |                      | VBAT                             |
|                | VDD2.IN             | VDD2 dc-dc input voltage             | Power      | M12           | M12           | VDD2.IN                                    | Power     |                      | VBAT                             |
|                | VDD2.FB             | VDD2 dc-dc output voltage (feedback) | I          | N13           | N13           | VDD2.FB                                    | I         |                      | GND                              |
|                | VDD2.SW             | VDD2 dc-dc switch                    | O          | N11           | N11           | VDD2.SW                                    | O         |                      | Floating                         |
|                | VDD2.SW             | VDD2 dc-dc switch                    | O          | P11           | P11           | VDD2.SW                                    | O         |                      | Floating                         |
|                | VDD2.GND            | VDD2 dc-dc ground                    | Power GND  | N12           | N12           | VDD2.GND                                   | Power GND |                      | GND                              |
|                | VDD2.GND            | VDD2 dc-dc ground                    | Power GND  | P12           | P12           | VDD2.GND                                   | Power GND |                      | GND                              |
| VIO            | VIO.IN              | VIO dc-dc input voltage              | Power      | M2            | M2            | VIO.IN                                     | Power     |                      | VBAT                             |
|                | VIO.IN              | VIO dc-dc input voltage              | Power      | M3            | M3            | VIO.IN                                     | Power     |                      | VBAT                             |
|                | VIO.FB              | VIO dc-dc output voltage (feedback)  | I          | M4            | M4            | VIO.FB                                     | I         |                      | GND                              |
|                | VIO.SW              | VIO dc-dc switch                     | O          | N4            | N4            | VIO.SW                                     | O         |                      | Floating                         |
|                | VIO.SW              | VIO dc-dc switch                     | O          | P4            | P4            | VIO.SW                                     | O         |                      | Floating                         |
|                | VIO.GND             | VIO dc-dc ground                     | Power GND  | N3            | N3            | VIO.GND                                    | Power GND |                      | GND                              |
|                | VIO.GND             | VIO dc-dc ground                     | Power GND  | P3            | P3            | VIO.GND                                    | Power GND |                      | GND                              |
| Backup battery | BKBAT               | Backup battery                       | Power      | H9            | H9            | BKBAT                                      | Power     |                      | GND                              |
| Digital VDD    | IO.1P8              | TPS65920/TPS65930 device I/O input   | Power      | B7            | B7            | IO.1P8                                     | Power     |                      | N/A                              |
| Digital ground | DGND                | Digital ground                       | Power GND  | H10           | H10           | DGND                                       | Power GND |                      | GND                              |
| LED driver     | LEDGND              | LED driver ground                    | Power GND  | F13           | F13           | LEDGND                                     | Power GND |                      | GND                              |
|                | GPIO13              | GPIO13                               | I/O        | B10           | B10           | GPIO13                                     | I         | PD                   | Floating                         |
|                | LEDSYNC             | LED synchronization input            | I          |               |               |  |           |                      |                                  |
|                | LEDA                | LED leg A                            | Open drain | E13           | E13           | Signal not functional <sup>(3)</sup>       |           |                      | Floating                         |
|                | VIBRA.P             | H-bridge vibrator P                  | Open drain |               |               |  |           |                      |                                  |
|                | LEDB                | LED leg B                            | Open drain | G13           | G13           | Signal not functional <sup>(3)</sup>       |           |                      | Floating                         |
| VIBRA.M        | H-bridge vibrator M | Open drain                           |            |               |               |  |           |                      |                                  |

**Table 2-2. Signal Description (continued)**

| Module | Signal Name | Description     | Type       | TPS65920 Ball | TPS65930 Ball | Default Configuration After Reset Released |      |                      | Features Not Used <sup>(1)</sup> |
|--------|-------------|-----------------|------------|---------------|---------------|--|------|----------------------|----------------------------------|
|        |             |                 |            |               |               | Signal                                     | Type | Internal Pull or Not |                                  |
| Keypad | KPD.C0      | Keypad column 0 | Open drain | G4            | G4            | KPD.C0                                     | OD   |                      | Floating                         |
|        | KPD.C1      | Keypad column 1 | Open drain | G3            | G3            | KPD.C1                                     | OD   |                      | Floating                         |
|        | KPD.C2      | Keypad column 2 | Open drain | E5            | E5            | KPD.C2                                     | OD   |                      | Floating                         |
|        | KPD.C3      | Keypad column 3 | Open drain | B2            | B2            | KPD.C3                                     | OD   |                      | Floating                         |
|        | KPD.C4      | Keypad column 4 | Open drain | E3            | E3            | KPD.C4                                     | OD   |                      | Floating                         |
|        | KPD.C5      | Keypad column 5 | Open drain | D5            | D5            | KPD.C5                                     | OD   |                      | Floating                         |
|        | KPD.R0      | Keypad row 0    | I          | K7            | K7            | KPD.R0                                     | I    | PU                   | Floating                         |
|        | KPD.R1      | Keypad row 1    | I          | H5            | H5            | KPD.R1                                     | I    | PU                   | Floating                         |
|        | KPD.R2      | Keypad row 2    | I          | K5            | K5            | KPD.R2                                     | I    | PU                   | Floating                         |
|        | KPD.R3      | Keypad row 3    | I          | H6            | H6            | KPD.R3                                     | I    | PU                   | Floating                         |
|        | KPD.R4      | Keypad row 4    | I          | K8            | K8            | KPD.R4                                     | I    | PU                   | Floating                         |
|        | KPD.R5      | Keypad row 5    | I          | L8            | L8            | KPD.R5                                     | I    | PU                   | Floating                         |

(1) This column provides the connection when the associated feature is not used or not connected. When there is a pin muxing, not all functions on the muxed pin are used. But even if a function is not used, the Default Configuration After Reset Released column still applies.

Connection criteria:

- Analog pins:
  - For input: GND
  - For output: Floating (except VPRECH is connected to GND)
  - For I/O if input by default: GND (except for audio features input: capacitor to ground with a 100-nF typical value capacitor)
- Digital pins:
  - For input: GND (except keypad and STP are left floating)
  - For input and pullup: Floating
  - For output: Floating
  - For I/O and pullup: Floating

N/A (not applicable): When the associated feature is mandatory for correct functioning of the TPS65920/TPS65930 device

(2) The signal VPRECH must be connected to the CPRECH capacitor to GND.

(3) Signal not functional indicates that no signal is presented on the pad after a release reset.

### 3 Electrical Characteristics

#### 3.1 Absolute Maximum Ratings

Table 3-1 lists the absolute maximum ratings.

**Table 3-1. Absolute Maximum Ratings**

| Parameter  | Test Conditions   | Min | Typ | Max        | Unit |
|--|---|-----|-----|------------|------|
| Main battery supply voltage <sup>(1)</sup>                       |   | 2.1 |     | 4.5        | V    |
| Voltage on any input   | Supply represents the voltage applied to the power supply pin associated with the input | 0.0 |     | 1.0*Supply | V    |
| Storage temperature range  |   | –55 |     | 125        | °C   |
| Ambient temperature range  |   | –40 |     | 85         | °C   |
| Junction temperature (T <sub>J</sub> )                           | At 1.4 W (Theta JB 11°C/W 2S2P board)   |     |     | 105        | °C   |
| Junction temperature (T <sub>J</sub> ) for parametric compliance |   | –40 |     | 105        | °C   |

(1) The product has negligible reliability impact if voltage spikes of 5.2 V occur for a total duration of 10 milliseconds.

#### 3.2 Minimum Voltages and Associated Currents

Table 3-2 lists the VBAT minimum and maximum currents per VBAT ball.

**Table 3-2. VBAT Minimum Required Per VBAT Ball and Associated Maximum Current**

| Category                 | Pin and Module      | Maximum Current Specified (mA) | Output Voltage (V)  | VBAT Minimum (V)                                   |
|--------------------------|---------------------|--------------------------------|---|--|
| VBAT pin name            | VDD_VPLLA3R_IN_6POV | 340                            |   |  |
| Internal module supplied | VPLL1 (LDO)         | 40                             | 1.0 / 1.2 / 1.3 / 1.8 / 2.8 / 3.0   | Maximum<br>(2.7, output voltage selected + 250 mV) |
|                          | VDD1 core (DCDC)    | < 1                            |   | 2.7  |
|                          | VDD2 core (DCDC)    | < 1                            |   | 2.7  |
|                          | SYSPOR (power ref)  | < 1                            |   | 2.7  |
|                          | PBIAS (power ref)   | < 1                            |   | 2.7  |
| VBAT pin name            | VDD_VDAC_IN_6POV    | 370                            |   |  |
| Internal module supplied | VDAC (LDO)          | 70                             | 1.2 / 1.3 / 1.8   | Maximum<br>(2.7, output voltage selected + 250 mV) |
|                          | VINTANA1 (LDO)      | 50                             | 1.5   | Maximum<br>(2.7, output voltage selected + 250 mV) |
|                          | VINTANA2 (LDO)      | 250                            | 2.5 / 2.75  | Maximum<br>(2.7, output voltage selected +250 mV)  |
|                          | VIO core (DCDC)     | < 1                            |   | 2.7  |
| VBAT pin name            | VDD_VAUXI2S_IN_6POV | 350                            |   |  |
| Internal module supplied | VAUX2 (LDO)         | 100                            | 1.3 / 1.5 / 1.6 / 1.7 / 1.8 / 1.9 / 2.0 / 2.1 / 2.2 / 2.3 / 2.4 / 2.5 / 2.8 | Maximum<br>(2.7, output voltage selected + 250 mV) |
| VBAT pin name            | VDD_VMMC1_IN_6POV   | 220                            |   |  |
| Internal module supplied | VMMC1 (LDO)         | 220                            | 1.85 / 2.85 / 3.0 / 3.15  | Maximum<br>(2.7, output voltage selected + 250 mV) |
|                          | Power_REGBATT       | 0.001                          |   | 2.7  |
| VBAT pin name            | VDD_VINT_IN_6POV    | 131                            |   |  |

**Table 3-2. VBAT Minimum Required Per VBAT Ball and Associated Maximum Current (continued)**

| Category                 | Pin and Module | Maximum Current Specified (mA) | Output Voltage (V)    | VBAT Minimum (V)                                   |
|--------------------------|----------------|--------------------------------|-----------------------|--|
| Internal module supplied | VINTDIG (LDO)  | 80                             | 1.0 / 1.2 / 1.3 / 1.5 | Maximum<br>(2.7, output voltage selected + 250 mV) |
|                          | VRRTC (LDO)    | 30                             | 1.5                   | Maximum<br>(2.7, output voltage selected + 250 mV) |
|                          | VBACKUP (LDO)  | 1                              | 2.5 / 3.0 / 3.1 / 3.2 | Maximum<br>(2.7, output voltage selected + 250 mV) |

### 3.3 Recommended Operating Conditions

Table 3-3 lists the recommended operating maximum ratings.

**Table 3-3. Recommended Operating Maximum Ratings**

| Parameter                     | Test Conditions | Min                | Typ | Max | Unit |
|-------------------------------|-----------------|--------------------|-----|-----|------|
| Main battery supply voltage   |                 | 2.7 <sup>(1)</sup> | 3.6 | 4.5 | V    |
| Backup battery supply voltage |                 | 1.8                | 3.2 | 3.3 | V    |
| Ambient temperature range     |                 | –40                |     | 85  | °C   |

(1) 2.7 V is the minimum threshold for the battery at which the device will turn OFF. However, the minimum voltage at which the device will power ON is 3.2 V ±100 mV (if PWRON does not have a switch and is connected to VBAT) considering battery plug as the device switch on event. If PWRON has a switch then 3.2 V is the minimum for the device to turn ON.

### 3.4 Digital I/O Electrical Characteristics

Table 3-4 describes the digital I/O electrical characteristics. The following list defines abbreviations used in the table:

- RL: Reference level voltage applied to the I/O cell
- VOL: Low-level output voltage
- VOH: High-level output voltage
- VIL: Low-level input voltage
- VIH: High-level input voltage
- Min: Minimum value
- Max: Maximum value

**Table 3-4. Digital I/O Electrical Characteristics**

| Pin Name   | VOL (V) |      | VOH (V) |     | VIL (V) |         | VIH (V) |     | Max Freq (MHz) | Load (pF) Output Mode | Rise Time (ns) | Fall Time (ns) |
|------------|---------|------|---------|-----|---------|---------|---------|-----|----------------|-----------------------|----------------|----------------|
|            | Min     | Max  | Min     | Max | Min     | Max     | Min     | Max |                |                       |                |                |
| GPIO0/CD1  | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35xRL | 0.65xRL | RL  | 33             | 30                    | 5.2            | 5.2            |
| JTAG.TDO   |         |      |         |     |         |         |         |     |                |                       |                |                |
| GPIO0      | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35xRL | 0.65xRL | RL  | 33             | 30                    | 5.2            | 5.2            |
| JTAG.TMS   |         |      |         |     |         |         |         |     |                |                       |                |                |
| GPIO2      | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35xRL | 0.65xRL | RL  | 3              | 30                    | 5.2            | 5.2            |
| TEST1      |         |      |         |     |         |         |         |     |                |                       |                |                |
| GPIO15     | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35xRL | 0.65xRL | RL  | 3              | 30                    | 5.2            | 5.2            |
| TEST2      |         |      |         |     |         |         |         |     |                |                       |                |                |
| GPIO6      | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35xRL | 0.65xRL | RL  | 3              | 30                    | 5.2            | 5.2            |
| PWM0       |         |      |         |     |         |         |         |     |                |                       |                |                |
| GPIO7      | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35xRL | 0.65xRL | RL  | 3              | 30                    | 5.2            | 5.2            |
| VIBRA.SYNC |         |      |         |     |         |         |         |     |                |                       |                |                |
| PWM1       |         |      |         |     |         |         |         |     |                |                       |                |                |
| TEST4      |         |      |         |     |         |         |         |     |                |                       |                |                |



**Table 3-4. Digital I/O Electrical Characteristics (continued)**

| Pin Name             | VOL (V) |      | VOH (V) |     | VIL (V) |           | VIL (V)   |        | Max Freq (MHz) | Load (pF)<br>Output Mode | Rise Time (ns) | Fall Time (ns) |
|----------------------|---------|------|---------|-----|---------|-----------|-----------|--------|----------------|--------------------------|----------------|----------------|
|                      | Min     | Max  | Min     | Max | Min     | Max       | Min       | Max    |                |                          |                |                |
| SYSEN                | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     |                |                          | 5.2            | 5.2            |
| CLKEN                | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 3              | 30                       | 33.3           | 33.3           |
| CLKREQ               | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 3              |                          | 33.3           | 33.3           |
| INT1                 | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 3              | 30                       | 33.3           | 33.3           |
| NRESPWRON            | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 3              | 30                       | 33.3           | 33.3           |
| NRESWARM             | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 3              | 30                       | 33.3           | 33.3           |
| PWRON                |         |      |         |     | 0       | 0.35×1.8V | 0.65×1.8V | VBAT   | 3              |                          | 33.3           | 33.3           |
| NSLEEP1              | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 3              |                          | 33.3           | 33.3           |
| CLK256FS             | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 12.288         | 30                       | 16.3           | 16.3           |
| VMODE1               | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 3              |                          | 33.3           | 33.3           |
| BOOT0                | 0       |      |         |     |         |           |           | RL     | 3              |                          | 33.3           | 33.3           |
| BOOT1                | 0       |      |         |     |         |           |           | RL     | 3              |                          | 33.3           | 33.3           |
| REGEN                | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 3              | 30                       | 33.3           | 33.3           |
| MSECURE              | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 3              |                          | 33.3           | 33.3           |
| I2C.SR.SDA           | 0       | 0.4  |         |     | –0.5    | 0.3×RL    | 0.7×RL    | RL+0.5 | 3.4            | Up to 400                |                |                |
| VMODE2               | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 3.4            |                          | 29.4           | 29.4           |
| I2C.SR.SCL           | 0       | 0.4  |         |     | –0.5    | 0.3×RL    | 0.7×RL    | RL+0.5 | 3.4            |                          | 10.0           | 10.0           |
| I2C.CNTL.SDA         | 0       | 0.4  |         |     | –0.5    | 0.3×RL    | 0.7×RL    | RL+0.5 | 3.4            | Up to 400                |                |                |
| I2C.CNTL.SCL         | 0       | 0.4  |         |     | –0.5    | 0.3×RL    | 0.7×RL    | RL+0.5 | 3.4            |                          | 10.0           | 10.0           |
| I2S.CLK              | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 6.5            | 30                       | 33.0           | 33.0           |
| I2S.SYNC             | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 6.5            | 30                       | 33.0           | 33.0           |
| I2S.DIN              | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 3.25           | 30                       | 33.0           | 33.0           |
| I2S.DOUT             | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 3.25           | 30                       | 29.0           | 29.0           |
| 32KCLKOUT            | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 0.032          | 30                       | 16             | 16             |
| HFCLKOUT             | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 38.4           | 30                       | 2.6            | 2.6            |
| UCLK                 | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 60             | 10                       | 1.0            | 1.0            |
| STP                  |         |      |         |     |         |           |           |        |                |                          |                |                |
| GPIO9                | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 30             | 10                       | 1.0            | 1.0            |
| DIR                  |         |      |         |     |         |           |           |        |                |                          |                |                |
| GPIO10               | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 30             | 10                       | 1.0            | 1.0            |
| NXT                  |         |      |         |     |         |           |           |        |                |                          |                |                |
| GPIO11               | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 30             | 10                       | 1.0            | 1.0            |
| DATA0                |         |      |         |     |         |           |           |        |                |                          |                |                |
| UART4.TXD            | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 30             | 10                       | 1.0            | 1.0            |
| DATA1                |         |      |         |     |         |           |           |        |                |                          |                |                |
| UART4.RXD            | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 30             | 10                       | 1.0            | 1.0            |
| DATA2                |         |      |         |     |         |           |           |        |                |                          |                |                |
| UART4.RTSI           | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 30             | 10                       | 1.0            | 1.0            |
| DATA3                |         |      |         |     |         |           |           |        |                |                          |                |                |
| UART4.CTSO           | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 30             | 10                       | 1.0            | 1.0            |
| GPIO12               | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 30             | 10                       | 1.0            | 1.0            |
| DATA4                |         |      |         |     |         |           |           |        |                |                          |                |                |
| GPIO14               | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 30             | 10                       | 1.0            | 1.0            |
| DATA5                |         |      |         |     |         |           |           |        |                |                          |                |                |
| GPIO3                | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 30             | 10                       | 1.0            | 1.0            |
| DATA6                |         |      |         |     |         |           |           |        |                |                          |                |                |
| GPIO4                | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 30             | 10                       | 1.0            | 1.0            |
| DATA7                |         |      |         |     |         |           |           |        |                |                          |                |                |
| GPIO5                | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 30             | 10                       | 1.0            | 1.0            |
| TEST.RESET           | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 3              |                          | 33.0           | 33.0           |
| TEST                 | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 3              | 30                       | 29.0           | 29.0           |
| JTAG.TDI/<br>BERDATA | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 3              |                          | 33.0           | 33.0           |
| JTAG.TCK/<br>BERDATA | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL   | 0.65×RL   | RL     | 3              |                          | 33.0           | 33.0           |

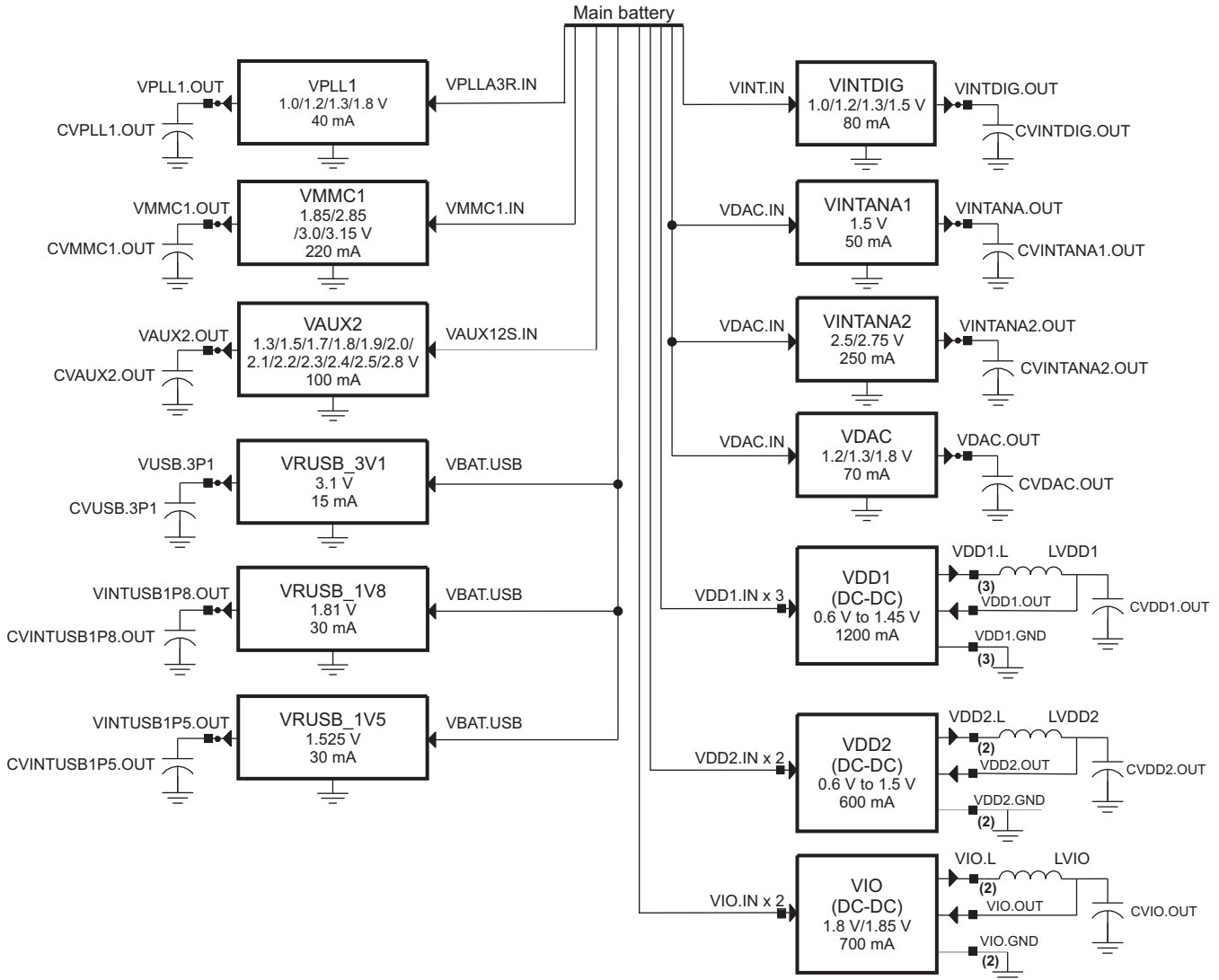
**Table 3-4. Digital I/O Electrical Characteristics (continued)**

| Pin Name | VOL (V) |      | VOH (V) |     | VIL (V) |         | VIL (V) |     | Max Freq (MHz) | Load (pF)<br>Output Mode | Rise Time (ns) | Fall Time (ns) |
|----------|---------|------|---------|-----|---------|---------|---------|-----|----------------|--------------------------|----------------|----------------|
|          | Min     | Max  | Min     | Max | Min     | Max     | Min     | Max |                |                          |                |                |
| GPIO13   | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL | 0.35×RL |     | 3              | 30                       | 33.3           | 33.3           |
| LEDSYNC  |         |      |         |     |         |         |         |     |                |                          |                |                |
| KPD.C0   | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL | 0.65×RL | RL  | 0.033          | 30                       | 29.0           | 29.0           |
| KPD.C1   | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL | 0.65×RL | RL  | 0.033          | 30                       | 29.0           | 29.0           |
| KPD.C2   | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL | 0.65×RL | RL  | 0.033          | 30                       | 29.0           | 29.0           |
| KPD.C3   | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL | 0.65×RL | RL  | 0.033          | 30                       | 29.0           | 29.0           |
| KPD.C4   | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL | 0.65×RL | RL  | 0.033          | 30                       | 29.0           | 29.0           |
| KPD.C5   | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL | 0.65×RL | RL  | 0.033          | 30                       | 29.0           | 29.0           |
| KPD.C6   | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL | 0.65×RL | RL  | 0.033          | 30                       | 29.0           | 29.0           |
| KPD.C7   | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL | 0.65×RL | RL  | 0.033          | 30                       | 29.0           | 29.0           |
| KPD.R0   | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL | 0.65×RL | RL  | 0.033          |                          | 3051.8         | 3051.8         |
| KPD.R1   | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL | 0.65×RL | RL  | 0.033          |                          | 3051.8         | 3051.8         |
| KPD.R2   | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL | 0.65×RL | RL  | 0.033          |                          | 3051.8         | 3051.8         |
| KPD.R3   | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL | 0.65×RL | RL  | 0.033          |                          | 3051.8         | 3051.8         |
| KPD.R4   | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL | 0.65×RL | RL  | 0.033          |                          | 3051.8         | 3051.8         |
| KPD.R5   | 0       | 0.45 | RL–0.45 | RL  | 0       | 0.35×RL | 0.65×RL | RL  | 0.033          |                          | 3051.8         | 3051.8         |
| KPD.R6   | 0       | 0.45 | 0.45    | RL  | 0       | 0.35×RL | 0.65×RL | RL  | 0.033          |                          | 3051.8         | 3051.8         |
| KPD.R7   | 0       | 0.45 | 0.45    | RL  | 0       | 0.35×RL | 0.65×RL | RL  | 0.033          |                          | 3051.8         | 3051.8         |

## 4 Power Module

This section describes the electrical characteristics of the voltage regulators and timing characteristics of the supplies digitally controlled in the TPS65920 and TPS65930 devices.

Figure 4-1 is the power provider block diagram.



037-010

Two internal regulators, VRRRTC and VBRTC, are not shown. VRRRTC provides power to the RTC, and VBRTC is not used in this configuration.

**Figure 4-1. Power Provider Block Diagram**

### NOTE

For the component values, see [Table 14-1](#).

## 4.1 Power Providers

Table 4-1 summarizes the power providers.

**Table 4-1. Summary of the Power Providers**

| Name     | Usage    | Type        | Voltage Range (V)  | Default Voltage | Maximum Current |
|----------|----------|-------------|--|-----------------|-----------------|
| VAUX2    | External | LDO         | 1.3, 1.5, 1.7, 1.8, 1.9, 2.0, 2.1, 2.2, 2.3, 2.4, 2.5, 2.8 | 1.8 V           | 100 mA          |
| VMMC1    | External | LDO         | 1.85, 2.85, 3.0, 3.15                                      | 3.0 V           | 220 mA          |
| VPLL1    | External | LDO         | 1.0, 1.2, 1.3, 1.8, 2.8, 3.0                               | 1.8 V           | 40 mA           |
| VDAC     | External | LDO         | 1.2, 1.3, 1.8  | 1.8 V           | 70 mA           |
| VIO      | External | SMPS        | 1.8, 1.85  | 1.8 V           | 700 mA          |
| VDD1     | External | SMPS        | 0.6 ... 1.45   | 1.2 V           | 1200 mA         |
| VDD2     | External | SMPS        | 0.6 ... 1.5  | 1.2 V           | 600 mA          |
| VINTANA1 | Internal | LDO         | 1.5  | 1.5 V           | 50 mA           |
| VINTANA2 | Internal | LDO         | 2.5, 2.75  | 2.75 V          | 250 mA          |
| VINTDIG  | Internal | LDO         | 1.0, 1.2, 1.3, 1.5   | 1.5 V           | 80 mA           |
| USBCP    | Internal | Charge pump | 5  | 5 V             | 100 mA          |
| VUSB1V5  | Internal | LDO         | 1.5  | 1.5 V           | 30 mA           |
| VUSB1V8  | Internal | LDO         | 1.8  | 1.8 V           | 30 mA           |
| VUSB3V1  | Internal | LDO         | 3.1  | 3.1 V           | 15 mA           |
| VRRTC    | Internal | LDO         | 1.5  | 1.5 V           | 30 mA           |
| VBRTC    | Internal | LDO         | 1.3  | 1.3 V           | 100 $\mu$ A     |

## 4.1.1 VDD1 dc-dc Regulator

### 4.1.1.1 VDD1 dc-dc Regulator Characteristics

The VDD1 dc-dc regulator is a stepdown dc-dc converter with a configurable output voltage. The programming of the output voltage and the characteristics of the dc-dc converter are SmartReflex-compatible. The regulator can be put in sleep mode to reduce its leakage (PFM) or in power-down mode when it is not in use. [Table 4-3](#) describes the regulator characteristics.

**Table 4-2. Part Names With Corresponding VDD1 Current Support**

| Device Name                                 | VDD1 Current Support |
|---|----------------------|
| TPS65920A2ZCH (some bug fixes, see errata)  | 1.2 A                |
| TPS65920A2ZCHR (some bug fixes, see errata) | 1.2 A                |
| TPS65930A2ZCH (some bug fixes, see errata)  | 1.2 A                |
| TPS65930A2ZCHR (some bug fixes, see errata) | 1.2 A                |

**Table 4-3. VDD1 dc-dc Regulator Characteristics**

| Parameter  | Comments   | Min | Typ  | Max  | Unit  |
|--|--|-----|------|------|-------|
| Input voltage range  |  | 2.7 | 3.6  | 4.5  | V     |
| Output voltage   |  | 0.6 |      | 1.45 | V     |
| Output voltage step  | Covering the 0.6-V to 1.45-V range   |     | 12.5 |      | mV    |
| Output accuracy <sup>(1)</sup>   | 0.6 V to < 0.8 V   | –6% |      | 6%   |       |
|  | 0.8 V to 1.45 V  | –4% |      | 4%   |       |
| Switching frequency  |  |     | 3.2  |      | MHz   |
| Conversion efficiency <sup>(2)</sup> , <a href="#">Figure 4-2</a> in active mode | I <sub>O</sub> = 10 mA, sleep  |     | 82%  |      |       |
|  | 100 mA < I <sub>O</sub> < 400 mA   |     | 85%  |      |       |
|  | 400 mA < I <sub>O</sub> < 600 mA   |     | 80%  |      |       |
|  | 600 mA < I <sub>O</sub> < 800 mA   |     | 75%  |      |       |
| Output current   | Active mode  |     |      | 1.2  | A     |
|  | Sleep mode   |     |      | 10   | mA    |
| Ground current (I <sub>O</sub> )   | Off at 30°C  |     |      | 3    | μA    |
|  | Sleep, unloaded  |     | 30   | 50   |       |
|  | Active, unloaded, not switching  |     |      | 300  |       |
| Short-circuit current  | V <sub>IN</sub> = V <sub>Max</sub>   |     | 2.2  |      | A     |
| Load regulation  | 0 < I <sub>O</sub> < I <sub>Max</sub>  |     |      | 20   | mV    |
| Transient load regulation <sup>(3)</sup>   | I <sub>O</sub> = 10 mA to (I <sub>Max</sub> /2) + 10 mA, Maximum slew rate is I <sub>Max</sub> /2/100 ns | –65 |      | 50   | mV    |
| Line regulation  |  |     |      | 10   | mV    |
| Transient line regulation  | 300 mV <sub>PP</sub> ac input, 10-μs rise and fall time  |     |      | 10   | mV    |
| Start-up time  |  |     | 0.25 | 1    | ms    |
| Recovery time  | From sleep mode to on mode with constant load  |     | <10  | 100  | μs    |
| Slew rate (rising or falling) <sup>(4)</sup>                                     |  | 4   | 8    | 16   | mV/μs |
| Output shunt resistor (pulldown)   |  |     | 500  | 700  | Ω     |
| External coil  | Value  | 0.7 | 1    | 1.3  | μH    |
|  | Data capture record (DCR)  |     |      | 0.1  | Ω     |
|  | Saturation current   | 1.8 |      |      | A     |

(1) Accuracy includes all variations (line and load regulations, line and load transients, temperature, and process)

(2) VBAT = 3.8 V, VDD1 = 1.3 V, Fs = 3.2 MHz, L = 1 μH, L<sub>DCR</sub> = 100 mΩ, C = 10 μF, ESR = 10 mΩ

(3) Output voltage must discharge the load current completely and settle to its final value within 100 μs.

(4) Load current varies proportionally with the output voltage. The slew rate is for increasing and decreasing voltages, and the maximum load current is 1.1 A.

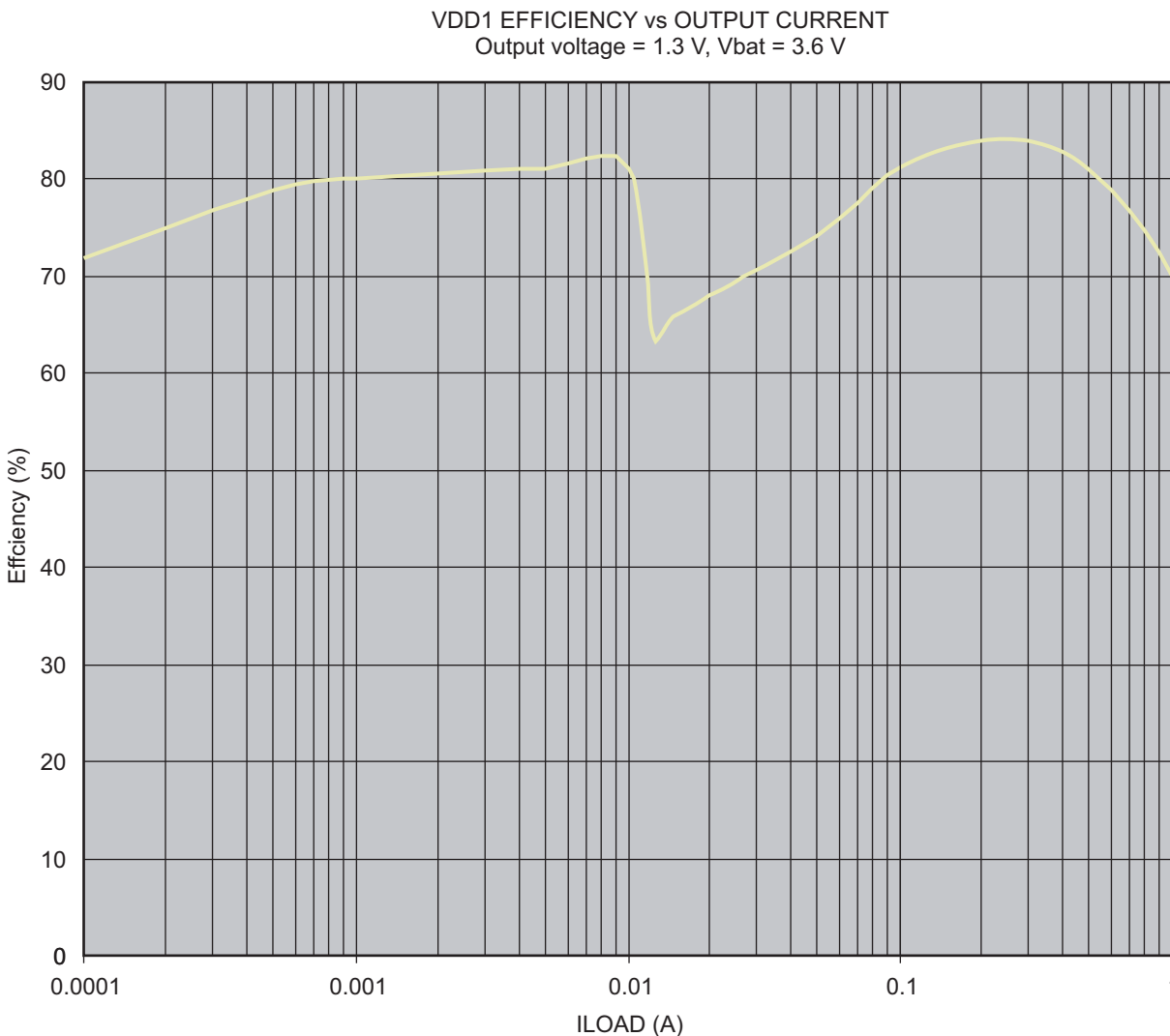
**Table 4-3. VDD1 dc-dc Regulator Characteristics (continued)**

| Parameter                         | Comments  | Min | Typ | Max | Unit |
|-----------------------------------|---|-----|-----|-----|------|
| External capacitor <sup>(5)</sup> | Value   | 8   | 10  | 12  | μF   |
|                                   | Equivalent series resistance (ESR) at switching frequency | 0   |     | 20  | mΩ   |

(5) Under current load condition step:  
 I<sub>max</sub>/2 (550 mA) in 100 ns with a ±20% external capacitor accuracy or  
 I<sub>max</sub>/3 (367 mA) in 100 ns with a ±50% external capacitor accuracy

See [Table 2-2](#) for how to connect the VDD1/2 dc-dc converter when it is not in use.

[Figure 4-2](#) shows the efficiency of the VDD1 dc-dc regulator in active mode and sleep mode.

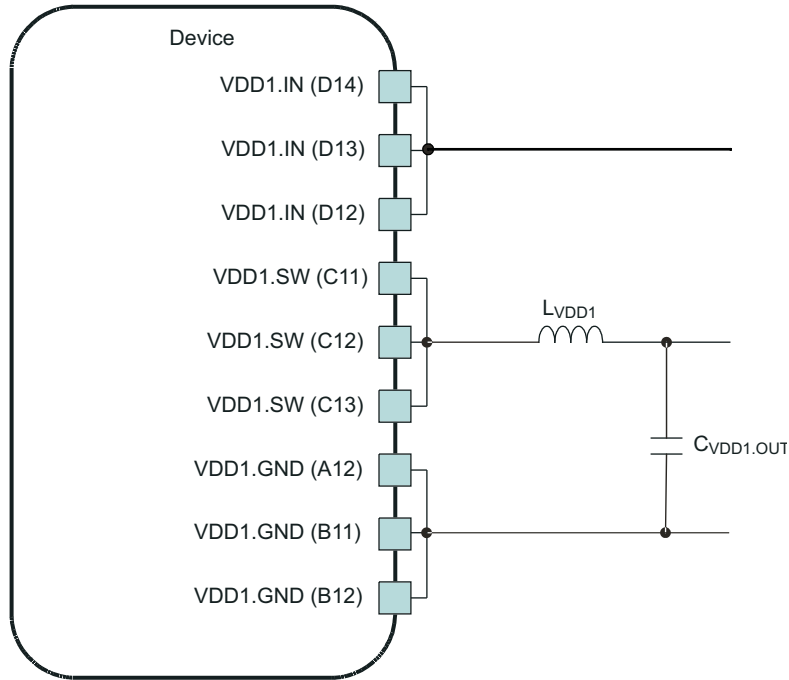


SWCS037-018

**Figure 4-2. VDD1 dc-dc Regulator Efficiency**

**4.1.1.2 External Components and Application Schematics**

[Figure 4-3](#) is an application schematic with the external components on the VDD1 dc-dc regulator.



030-009

**Figure 4-3. VDD1 dc-dc Application Schematic**

**NOTE**

For the component values, see [Table 14-1](#).

## 4.1.2 VDD2 dc-dc Regulator

### 4.1.2.1 VDD2 dc-dc Regulator Characteristics

The VDD2 dc-dc regulator is a programmable output stepdown dc-dc converter with an internal field effect transistor (FET). Like the VDD1 regulator, the VDD2 regulator can be placed in sleep or power-down mode and is SmartReflex-compatible. The VDD2 regulator differs from VDD1 in its current load capability. [Table 4-4](#) describes the regulator characteristics.

**Table 4-4. VDD2 dc-dc Regulator Characteristics**

| Parameter  | Comments  | Min | Typ  | Max | Unit  |
|--|---|-----|------|-----|-------|
| Input voltage range  |   | 2.7 | 3.6  | 4.5 | V     |
| Output voltage   |   | 0.6 | 1    | 1.5 | V     |
| Output voltage step  | Covering the 0.6-V to 1.45-V range, 1.5 V is a single programmable value        |     | 12.5 |     | mV    |
| Output accuracy <sup>(1)</sup>   | 0.6 V to < 0.8 V  | –6% |      | 6%  |       |
|  | 0.8 V to 1.5 V  | –4% |      | 4%  |       |
| Switching frequency  |   |     | 3.2  |     | MHz   |
| Conversion efficiency <sup>(2)</sup> , <a href="#">Figure 4-4</a> in active mode | $I_O = 10$ mA, sleep  |     | 82%  |     |       |
|  | $100$ mA < $I_O$ < $300$ mA   |     | 85%  |     |       |
|  | $300$ mA < $I_O$ < $500$ mA   |     | 80%  |     |       |
| Output current   | Active mode   |     |      | 600 | mA    |
|  | Sleep mode  |     |      | 10  | mA    |
| Ground current ( $I_Q$ )   | Off at 30°C   |     |      | 1   | μA    |
|  | Sleep, unloaded   |     |      | 50  |       |
|  | Active, unloaded, not switching   |     |      | 300 |       |
| Short-circuit current  | $V_{IN} = V_{Max}$  |     | 1.2  |     | A     |
| Load regulation  | $0 < I_O < I_{Max}$   |     |      | 20  | mV    |
| Transient load regulation <sup>(3)</sup>   | $I_O = 10$ mA to $(I_{Max}/2) + 10$ mA, Maximum slew rate is $I_{Max}/2/100$ ns | –65 |      | 50  | mV    |
| Line regulation  |   |     |      | 10  | mV    |
| Transient line regulation  | 300 mV <sub>PP</sub> ac input, 10-μs rise and fall time                         |     |      | 10  | mV    |
| Output shunt resistor (internal pulldown)  |   |     | 500  | 700 | Ω     |
| Start-up time  |   |     | 0.25 | 1   | ms    |
| Recovery time  | From sleep mode to on mode with constant load                                   |     | 25   | 100 | μs    |
| Slew rate (rising or falling) <sup>(4)</sup>                                     |   | 4   | 8    | 16  | mV/μs |
| External coil  | Value   | 0.7 | 1    | 1.3 | μH    |
|  | DCR   |     |      | 0.1 | Ω     |
|  | Saturation current  | 900 |      |     | mA    |
| External capacitor <sup>(5)</sup>  | Value   | 8   | 10   | 12  | μF    |
|  | ESR at switching frequency  | 0   |      | 20  | mΩ    |

(1) Accuracy includes all variations (line and load regulations, line and load transients, temperature, and process)

(2) VBAT = 3.8 V, VDD2 = 1.3 V, Fs = 3.2 MHz, L = 1 μH, L<sub>DCR</sub> = 100 mΩ, C = 10 μF, ESR = 10 mΩ

(3) Output voltage needs to discharge the load current completely and settle to its final value within 100 μs.

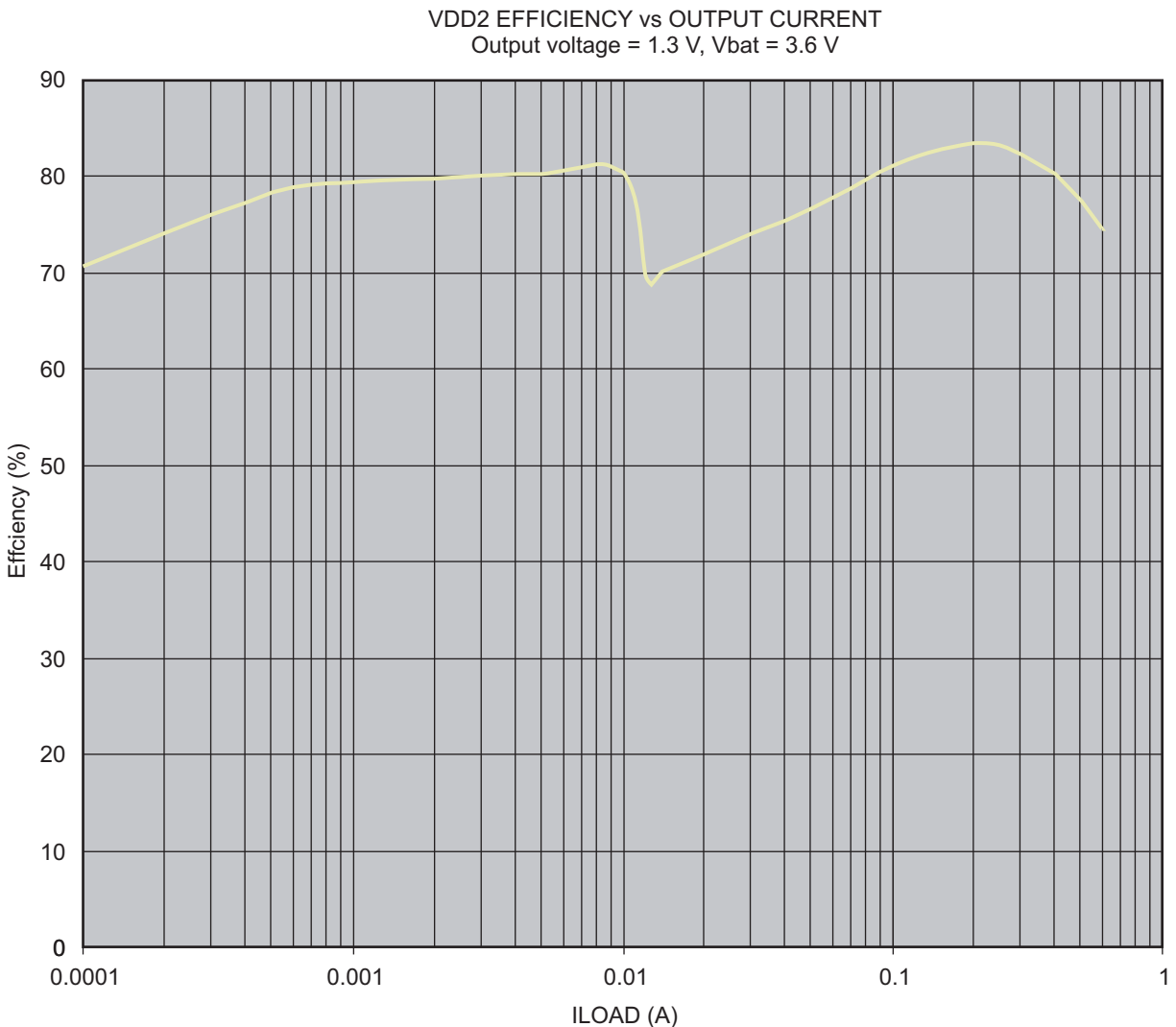
(4) Load current varies proportionally with the output voltage. The slew rate is for both increasing and decreasing voltages and the maximum load current is 600 mA.

(5) Under current load condition step:  
 $I_{max}/2$  (300 mA) in 100 ns with a ±20% external capacitor accuracy or  
 $I_{max}/3$  (200 mA) in 100 ns with a ±50% external capacitor accuracy



See [Table 2-2](#) for how to connect the VDD1/2 dc-dc converter when it is not in use.

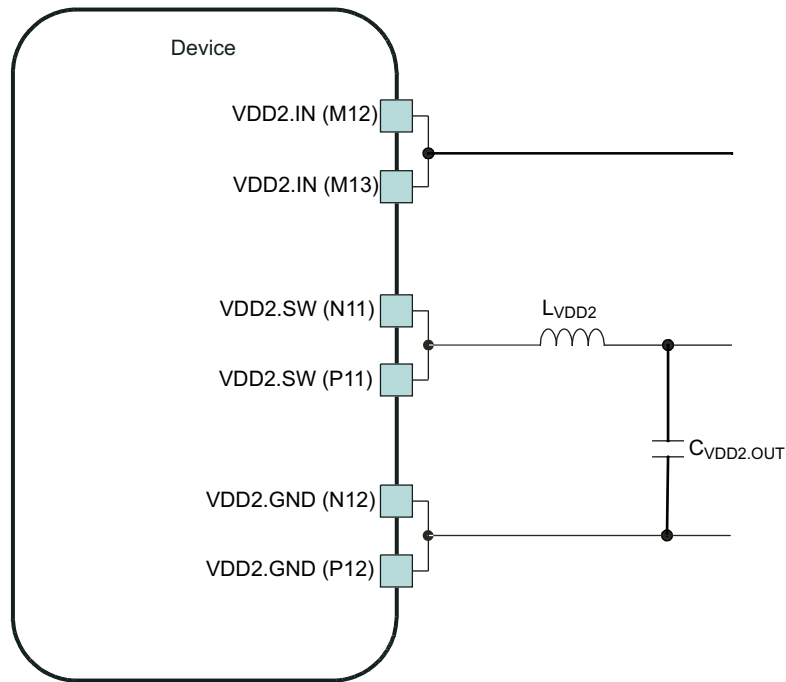
[Figure 4-4](#) shows the efficiency of the VDD2 dc-dc regulator in active mode and sleep mode.



**Figure 4-4. VDD2 dc-dc Regulator Efficiency**

#### 4.1.2.2 External Components and Application Schematics

[Figure 4-5](#) is an application schematic with the external components on the VDD2 dc-dc regulator.



030-010

**Figure 4-5. VDD2 dc-dc Application Schematic**

**NOTE**

For the component values, see [Table 14-1](#).

### 4.1.3 VIO dc-dc Regulator

#### 4.1.3.1 VIO dc-dc Regulator Characteristics

The I/O and memory dc-dc regulator is a 600-mA stepdown dc-dc converter (internal FET) with two output voltage settings. It supplies the memories and all I/O ports in the application and is one of the first power providers to switch on in the power-up sequence. This dc-dc regulator can be placed in sleep or power-down mode; however, care must be taken in the sequencing of this power provider, because numerous ESD blocks are connected to this supply. [Table 4-5](#) describes the regulator characteristics.

**Table 4-5. VIO dc-dc Regulator Characteristics**

| Parameter  | Comments  | Min | Typ         | Max | Unit |
|--|---|-----|-------------|-----|------|
| Input voltage range  |   | 2.7 | 3.6         | 4.5 | V    |
| Output voltage <sup>(1)</sup>  |   |     | 1.8<br>1.85 |     | V    |
| Output accuracy <sup>(2)</sup>   |   | -4% |             | 4%  |      |
|  |   | -3% |             | 3%  |      |
| Switching frequency  |   |     | 3.2         |     | MHz  |
| Conversion efficiency <sup>(3)</sup> <a href="#">Figure 4-6</a> in active mode | $I_O = 10$ mA, sleep                                    |     | 85%         |     |      |
|  | 100 mA < $I_O$ < 400 mA                                 |     | 85%         |     |      |
|  | 400 mA < $I_O$ < 600 mA                                 |     | 80%         |     |      |
| Output current   | On mode   |     |             | 700 | mA   |
|  | Sleep mode  |     |             | 10  |      |
| Ground current ( $I_Q$ )   | Off at 30°C   |     |             | 1   | μA   |
|  | Sleep, unloaded   |     |             | 50  |      |
|  | Active, unloaded, not switching                         |     |             | 300 |      |
| Load transient <sup>(4)</sup>  |   |     |             | 50  | mV   |
| Line transient   | 300 mV <sub>PP</sub> ac, input rise and fall time 10 μs |     |             | 10  | mV   |
| Start-up time  |   |     | 0.25        | 1   | ms   |
| Recovery time  | From sleep mode to on mode with constant load           |     | <10         | 100 | μs   |
| Output shunt resistor (internal pulldown)                                      |   |     | 500         | 700 | Ω    |
| External coil  | Value   | 0.7 | 1           | 1.3 | μH   |
|  | DCR   |     |             | 0.1 | Ω    |
|  | Saturation current                                      | 900 |             |     | mA   |
| External capacitor   | Value   | 8   | 10          | 12  | μF   |
|  | ESR at switching frequency                              | 1   |             | 20  | mΩ   |

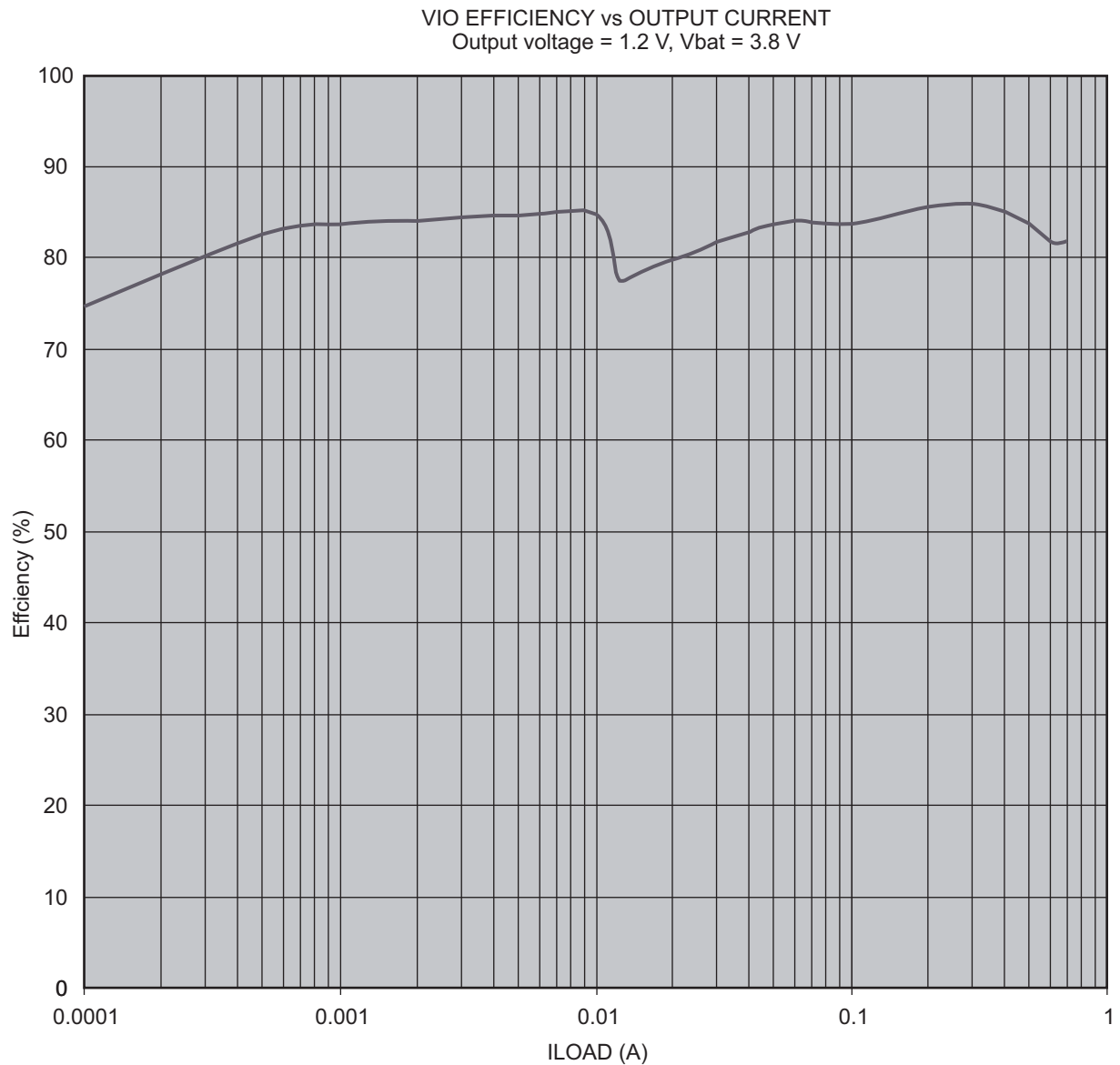
(1) This voltage is tuned according to the platform and transient requirements.

(2) ±4% accuracy includes all the variation (line and load regulation, line and load transient, temperature, process)  
±3% accuracy is dc accuracy only.

(3) VBAT = 3.8 V, VIO = 1.8 V, Fs = 3.2 MHz, L = 1 μH, L<sub>DCR</sub> = 100 mΩ, C = 10 μF, ESR = 10 mΩ

(4) Load transient can also be specified as  $0 < I_O < I_{OUTmax}/2$ , Δt = 1 μs, 100 mV but this is not included in ±4% accuracy.

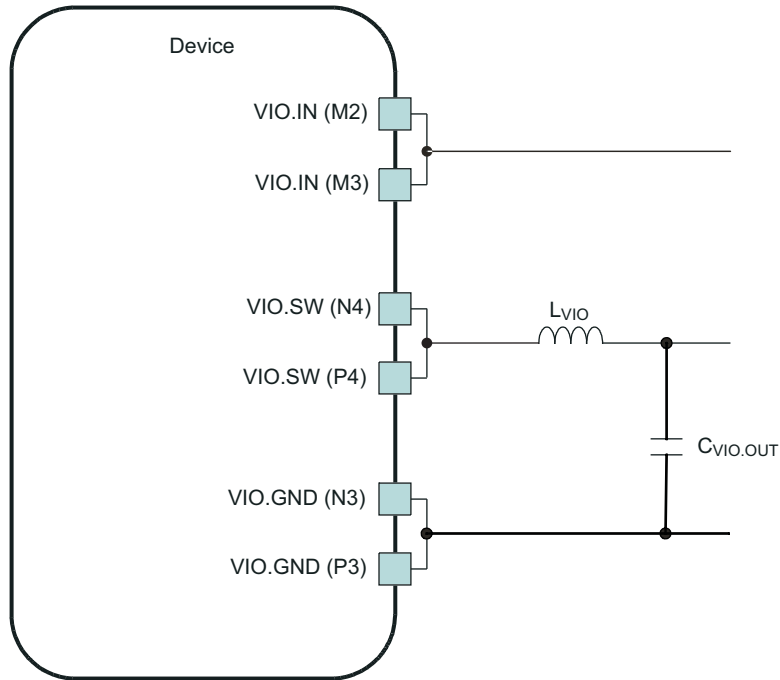
Figure 4-6 shows the efficiency of the VIO dc-dc regulator in active mode and sleep mode.



**Figure 4-6. VIO dc-dc Regulator Efficiency**

#### 4.1.3.2 External Components and Application Schematics

Figure 4-7 is an application schematic with the external components on the VIO dc-dc regulator.



030-011

**Figure 4-7. VIO dc-dc Application Schematic**

**NOTE**

For the component values, see [Table 14-1](#).

#### 4.1.4 VDAC LDO Regulator

The VDAC programmable LDO regulator is a high-PSRR, low-noise linear regulator that powers the host processor dual-video DAC. It is controllable with registers through I<sup>2</sup>C and can be powered down. Table 4-6 describes the regulator characteristics.

**Table 4-6. VDAC LDO Regulator Characteristics**

| Parameter                         | Test Conditions                          | Min   | Typ            | Max | Unit   |    |
|-----------------------------------|--|---|----------------|-----|--------|----|
| <b>Output Load Conditions</b>     |  |   |                |     |        |    |
| Filtering capacitor               | Connected from VDAC.OUT to analog ground | 0.3   | 1              | 2.7 | μF     |    |
| Filtering capacitor ESR           |  | 20  |                | 600 | mΩ     |    |
| <b>Electrical Characteristics</b> |  |   |                |     |        |    |
| V <sub>IN</sub>                   | Input voltage                            | 2.7   | 3.6            | 4.5 | V      |    |
| V <sub>OUT</sub>                  | Output voltage                           | On mode   | 1.164          | 1.2 | 1.236  | V  |
|                                   |  |   | 1.261          | 1.3 | 1.339  |    |
|                                   |  |   | 1.746          | 1.8 | 1.854  |    |
| I <sub>OUT</sub>                  | Rated output current                     | On mode   |                |     | 70     | mA |
|                                   |  |   | Low-power mode |     |        |    |
|                                   | dc load regulation                       | On mode: 0 < I <sub>O</sub> < I <sub>Max</sub>  |                | 20  | mV     |    |
|                                   | dc line regulation                       | On mode, V <sub>IN</sub> = V <sub>INmin</sub> to V <sub>INmax</sub> at I <sub>OUT</sub> = I <sub>OUTmax</sub> |                | 3   | mV     |    |
|                                   | Turn-on time                             | I <sub>OUT</sub> = 0, C <sub>L</sub> = 1 μF (within 10% of V <sub>OUT</sub> )                                 |                | 100 | μs     |    |
|                                   | Wake-up time                             | Full load capability  |                | 10  | μs     |    |
|                                   | Ripple rejection                         | f < 20 kHz  | 65             |     | dB     |    |
|                                   |  | 20 kHz < f < 100 kHz  | 45             |     |        |    |
|                                   |  | f = 1 MHz   | 40             |     |        |    |
|                                   |  | V <sub>IN</sub> = V <sub>OUT</sub> + 1 V, I <sub>O</sub> = I <sub>Max</sub>                                   |                |     |        |    |
|                                   | Output noise                             | 100 Hz < f < 5 kHz  |                | 400 | nV/√Hz |    |
|                                   |  | 5 kHz < f < 400 kHz   |                | 125 |        |    |
|                                   |  | 400 kHz < f < 10 MHz  |                | 50  |        |    |
|                                   | Ground current                           | On mode, I <sub>OUT</sub> = 0   |                | 150 | μA     |    |
|                                   |  | On mode, I <sub>OUT</sub> = I <sub>OUTmax</sub>   |                | 350 |        |    |
|                                   |  | Low-power mode, I <sub>OUT</sub> = 0  |                | 15  |        |    |
|                                   |  | Low-power mode, I <sub>OUT</sub> = 1 mA   |                | 25  |        |    |
|                                   |  | Off mode at 55°C  |                | 1   |        |    |
| V <sub>DO</sub>                   | Dropout voltage                          | On mode, I <sub>OUT</sub> = I <sub>OUTmax</sub>   |                | 250 | mV     |    |
|                                   | Transient load regulation                | I <sub>Load</sub> : I <sub>Min</sub> – I <sub>Max</sub><br>Slew: 60 mA/μs                                     |                | –40 | 40     | mV |
|                                   | Transient line regulation                | V <sub>IN</sub> drops 500 mV<br>Slew: 40 mV/μs  |                |     | 10     | mV |

### 4.1.5 VPLL1 LDO Regulator

The VPLL1 programmable LDO regulator is a high-PSRR, low-noise, linear regulator used for the host processor PLL supply. [Table 4-7](#) describes the regulator characteristics.

**Table 4-7. VPLL1 LDO Regulator Characteristics**

| Parameter                         | Test Conditions                           | Min   | Typ   | Max | Unit  |   |
|-----------------------------------|---|---|-------|-----|-------|---|
| <b>Output Load Conditions</b>     |   |   |       |     |       |   |
| Filtering capacitor               | Connected from VPLL1.OUT to analog ground | 0.3   | 1     | 2.7 | μF    |   |
| Filtering capacitor ESR           |   | 20  |       | 600 | mΩ    |   |
| <b>Electrical Characteristics</b> |   |   |       |     |       |   |
| V <sub>IN</sub>                   | Input voltage                             | 2.7   | 3.6   | 4.5 | V     |   |
| V <sub>OUT</sub>                  | Output voltage                            | On mode and low-power mode  | 0.97  | 1.0 | 1.03  | V |
|                                   |   |   | 1.164 | 1.2 | 1.236 |   |
|                                   |   |   | 1.261 | 1.3 | 1.339 |   |
|                                   |   |   | 1.746 | 1.8 | 1.854 |   |
|                                   |   |   | 2.716 | 2.8 | 2.884 |   |
|                                   |   |   | 2.91  | 3.0 | 3.090 |   |
| I <sub>OUT</sub>                  | Rated output current                      | On mode   |       | 40  | mA    |   |
|                                   |   | Low-power mode  |       | 5   |       |   |
|                                   | dc load regulation                        | On mode: 0 < I <sub>O</sub> < I <sub>Max</sub>  |       | 20  | mV    |   |
|                                   | dc line regulation                        | On mode, V <sub>IN</sub> = V <sub>INmin</sub> to V <sub>INmax</sub> at I <sub>OUT</sub> = I <sub>OUTmax</sub> |       | 3   | mV    |   |
|                                   | Turn-on time                              | I <sub>OUT</sub> = 0, C <sub>L</sub> = 1 μF (within 10% of V <sub>OUT</sub> )                                 |       | 100 | μs    |   |
|                                   | Wake-up time                              | Full load capability  |       | 10  | μs    |   |
|                                   | Ripple rejection                          | f < 10 kHz  | 50    |     | dB    |   |
|                                   |   | 10 kHz < f < 100 kHz  | 40    |     |       |   |
|                                   |   | f = 1 MHz   | 30    |     |       |   |
|                                   |   | V <sub>IN</sub> = V <sub>OUT</sub> + 1 V, I <sub>O</sub> = I <sub>Max</sub>                                   |       |     |       |   |
|                                   | Ground current                            | On mode, I <sub>OUT</sub> = 0   |       | 70  | μA    |   |
|                                   |   | On mode, I <sub>OUT</sub> = I <sub>OUTmax</sub>   |       | 110 |       |   |
|                                   |   | Low-power mode, I <sub>OUT</sub> = 0  |       | 15  |       |   |
|                                   |   | Low-power mode, I <sub>OUT</sub> = 1 mA   |       | 16  |       |   |
|                                   |   | Off mode at 55°C  |       | 1   |       |   |
| V <sub>DO</sub>                   | Dropout voltage                           | On mode, I <sub>OUT</sub> = I <sub>OUTmax</sub>   |       | 250 | mV    |   |
|                                   | Transient load regulation                 | I <sub>Load</sub> : I <sub>Min</sub> – I <sub>Max</sub><br>Slew: 60 mA/μs                                     | –40   | 40  | mV    |   |
|                                   | Transient line regulation                 | V <sub>IN</sub> drops 500 mV<br>Slew: 40 mV/μs  |       | 10  | mV    |   |

#### 4.1.6 VMMC1 LDO Regulator

The VMMC1 LDO regulator is a programmable linear voltage converter that powers the multimedia card (MMC) slot. It includes a discharge resistor and overcurrent protection (short-circuit). This LDO regulator can also be turned off automatically when MMC card extraction is detected. The VMMC1 LDO can be powered through an independent supply other than the battery; for example, a charge pump. In this case, the input from the VMMC1 LDO can be higher than the battery voltage. Table 4-8 describes the regulator characteristics.

**Table 4-8. VMMC1 LDO Regulator Characteristics**

| Parameter                         | Test Conditions                           | Min                                | Typ                         | Max                                | Unit |
|-----------------------------------|---|------------------------------------|-----------------------------|------------------------------------|------|
| <b>Output Load Conditions</b>     |   |                                    |                             |                                    |      |
| Filtering capacitor               | Connected from VMMC1.OUT to analog ground | 0.3                                | 1                           | 2.7                                | μF   |
| Filtering capacitor ESR           |   | 20                                 |                             | 600                                | mΩ   |
| <b>Electrical Characteristics</b> |   |                                    |                             |                                    |      |
| V <sub>IN</sub>                   | Input voltage                             | 2.7                                | 3.6                         | 5.5                                | V    |
| V <sub>OUT</sub>                  | Output voltage                            | 1.7945<br>2.7645<br>2.91<br>3.0555 | 1.85<br>2.85<br>3.0<br>3.15 | 1.9055<br>2.9355<br>3.09<br>3.2445 | V    |
| I <sub>OUT</sub>                  | Rated output current                      |                                    |                             | 220<br>5                           | mA   |
|                                   | dc load regulation                        |                                    |                             | 20                                 | mV   |
|                                   | dc line regulation                        |                                    |                             | 3                                  | mV   |
|                                   | Turn-on time                              |                                    |                             | 100                                | μs   |
|                                   | Wake-up time                              |                                    |                             | 10                                 | μs   |
|                                   | Ripple rejection                          | 50<br>40<br>25                     |                             |                                    | dB   |
|                                   | Ground current                            |                                    |                             | 70<br>290<br>17<br>20<br>1         | μA   |
| V <sub>DO</sub>                   | Dropout voltage                           |                                    |                             | 250                                | mV   |
|                                   | Transient load regulation                 | -40                                |                             | 40                                 | mV   |
|                                   | Transient line regulation                 |                                    |                             | 10                                 | mV   |



### 4.1.7 VAUX2 LDO Regulator

The VAUX2 general-purpose LDO regulator powers the auxiliary devices. [Table 4-9](#) describes the regulator characteristics.

**Table 4-9. VAUX2 LDO Regulator Characteristics**

| Parameter                         | Test Conditions                           | Min   | Typ  | Max                        | Unit |
|-----------------------------------|---|---|--|----------------------------|------|
| <b>Output Load Conditions</b>     |   |   |  |                            |      |
| Filtering capacitor               | Connected from VAUX2.OUT to analog ground | 0.3   | 1  | 2.7                        | μF   |
| Filtering capacitor ESR           |   | 20  |  | 600                        | mΩ   |
| <b>Electrical Characteristics</b> |   |   |  |                            |      |
| V <sub>IN</sub>                   | Input voltage                             | 2.7   | 3.6  | 4.5                        | V    |
| V <sub>OUT</sub>                  | Output voltage                            | –3%   | 1.3<br>1.5<br>1.7<br>1.8<br>1.9<br>2.0<br>2.1<br>2.2<br>2.3<br>2.4<br>2.5<br>2.8 | 3%                         | V    |
| I <sub>OUT</sub>                  | Rated output current                      | On mode<br>Low-power mode   |  | 100<br>5                   | mA   |
|                                   | dc load regulation                        | On mode: I <sub>OUT</sub> = I <sub>OUTmax</sub> to 0  |  | 20                         | mV   |
|                                   | dc line regulation                        | On mode, V <sub>IN</sub> = V <sub>INmin</sub> to V <sub>INmax</sub> at I <sub>OUT</sub> = I <sub>OUTmax</sub>   |  | 3                          | mV   |
|                                   | Turn-on time                              | I <sub>OUT</sub> = 0, C <sub>L</sub> = 1 μF (within 10% of V <sub>OUT</sub> )   |  | 100                        | μs   |
|                                   | Wake-up time                              | Full load capability  |  | 10                         | μs   |
|                                   | Ripple rejection                          | f < 10 kHz<br>10 kHz < f < 100 kHz<br>f = 1 MHz<br>V <sub>IN</sub> = V <sub>OUT</sub> + 1 V, I <sub>O</sub> = I <sub>Max</sub>  | 50<br>40<br>25   |                            | dB   |
|                                   | Ground current                            | On mode, I <sub>OUT</sub> = 0<br>On mode, I <sub>OUT</sub> = I <sub>OUTmax</sub><br>Low-power mode, I <sub>OUT</sub> = 0<br>Low-power mode, I <sub>OUT</sub> = 5 mA<br>Off mode at 55°C |  | 70<br>170<br>17<br>20<br>1 | μA   |
| V <sub>DO</sub>                   | Dropout voltage                           | On mode, I <sub>OUT</sub> = I <sub>OUTmax</sub>   |  | 250                        | mV   |
|                                   | Transient load regulation                 | I <sub>Load</sub> : I <sub>Min</sub> – I <sub>Max</sub><br>Slew: 40 mA/μs   | –40  | 40                         | mV   |
|                                   | Transient line regulation                 | V <sub>IN</sub> drops 500 mV<br>Slew: 40 mV/μs  |  | 10                         | mV   |

### 4.1.8 Output Load Conditions

Table 4-10 lists the regulators that power the device, and the output loads associated with them.

**Table 4-10. Output Load Conditions**

| Regulator     | Parameter               | Test Conditions                              | Min | Typ | Max | Unit             |
|---------------|-------------------------|--|-----|-----|-----|------------------|
| VINTDIG LDO   | Filtering capacitor     | Connected from VINTDIG.OUT to analog ground  | 0.3 | 1   | 2.7 | $\mu\text{F}$    |
|               | Filtering capacitor ESR |  | 20  |     | 600 | $\text{m}\Omega$ |
| VINTANA1 LDO  | Filtering capacitor     | Connected from VINTANA1.OUT to analog ground | 0.3 | 1   | 2.7 | $\mu\text{F}$    |
|               | Filtering capacitor ESR |  | 20  |     | 600 | $\text{m}\Omega$ |
| VINTANA2 LDO  | Filtering capacitor     | Connected from VINTANA2.OUT to analog ground | 0.3 | 1   | 2.7 | $\mu\text{F}$    |
|               | Filtering capacitor ESR |  | 20  |     | 600 | $\text{m}\Omega$ |
| VRUSB_3V1 LDO | Filtering capacitor     | Connected from VUSB.3P1 to GND               | 0.3 | 1   | 2.7 | $\mu\text{F}$    |
|               | Filtering capacitor ESR |  | 0   | 10  | 600 | $\text{m}\Omega$ |
| VRUSB_1V8 LDO | Filtering capacitor     | Connected from VINTUSB1P8.OUT to GND         | 0.3 | 1   | 2.7 | $\mu\text{F}$    |
|               | Filtering capacitor ESR |  | 0   | 10  | 600 | $\text{m}\Omega$ |
| VRUSB_1V5 LDO | Filtering capacitor     | Connected from VINTUSB1P5 to GND             | 0.3 | 1   | 2.7 | $\mu\text{F}$    |
|               | Filtering capacitor ESR |  | 0   | 10  | 600 | $\text{m}\Omega$ |

### 4.1.9 Charge Pump

The charge pump generates a 4.8-V (nominal) power supply voltage from the battery to the VBUS pin. The input voltage range is 2.7 to 4.5 V for the battery voltage. The charge pump operating frequency is 1 MHz.

The charge pump tolerates 7 V on VBUS when it is in power-down mode. The charge pump integrates a short-circuit current limitation at 450 mA. [Table 4-11](#) lists the charge pump output load conditions.

**Table 4-11. Charge Pump Output Load Conditions**

| Parameter                     | Test Conditions             | Min  | Typ | Max  | Unit |
|-------------------------------|-----------------------------|------|-----|------|------|
| <b>Output Load Conditions</b> |                             |      |     |      |      |
| Filtering capacitor           | Connected from VBUS to VSSP | 1.41 | 4.7 | 6.5  | μF   |
| Flying capacitor              | Connected from CP to CN     | 1.32 | 2.2 | 3.08 | μF   |
| Filtering capacitor ESR       |                             |      |     | 20   | mΩ   |

#### 4.1.10 USB LDO Short-Circuit Protection Scheme

The short-circuit current for the LDOs and dc-dcs in the TPS65920 and TPS65930 devices is approximately twice the maximum load current. When the output of the block is shorted to ground, the power dissipation can exceed the 1.2-W requirement if no action is taken. A short-circuit protection scheme is included in the TPS65920 and TPS65930 devices to ensure that if the output of an LDO or dc-dc is short-circuited, the power dissipation does not exceed the 1.2-W level.

The three USB LDOs, VRUSB3V1, VRUSB1V8, and VRUSB1V5, are included in this short-circuit protection scheme, which monitors the LDO output voltage at a frequency of 1 Hz and generates an interrupt (sc\_it) when a short-circuit is detected.

The scheme compares the LDO output voltage to a reference voltage and detects a short-circuit if the LDO voltage drops below this reference value (0.5 or 0.75 V programmable). In the case of the VRUSB3V1 and VRUSB1V8 LDOs, the reference is compared with a divided down voltage (1.5 V typical).

If a short-circuit is detected on VRUSB3V1, the power subchip FSM switches this LDO to sleep mode.

If a short-circuit is detected on VRUSB1V8 or VRUSB1V5, the power subchip FSM switches off the relevant LDO.

## 4.2 Power References

The bandgap voltage reference is filtered (resistance/capacitance [RC] filter) using an external capacitor connected across the VREF output and an analog ground (REFGND). The VREF voltage is scaled, distributed, and buffered in the device. The bandgap is started in fast mode (not filtered), and is set automatically by the power state-machine in slow mode (filtered, less noisy) when required.

Table 4-12 lists the voltage reference characteristics.

**Table 4-12. Voltage Reference Characteristics**

| Parameter                                     | Test Conditions  | Min   | Typ   | Max                        | Unit     |
|---|--|-------|-------|----------------------------|----------|
| <b>Output Load Condition</b>                  |  |       |       |                            |          |
| Filtering capacitor                           | Connected from V <sub>REF</sub> to GNDREF  | 0.3   | 1     | 2.7                        | μF       |
| <b>Electrical Characteristics</b>             |  |       |       |                            |          |
| V <sub>IN</sub> Input voltage                 | On mode  | 2.7   | 3.6   | 4.5                        | V        |
| Internal bandgap reference voltage            | On mode, measured through TESTV terminal   | 1.272 | 1.285 | 1.298                      | V        |
| Reference voltage (V <sub>REF</sub> terminal) | On mode  | 0.749 | 0.75  | 0.77                       | V        |
| Retention mode reference                      | On mode  | 0.492 | 0.5   | 0.508                      | V        |
| I <sub>REF</sub> NMOS sink                    |  | 0.9   | 1     | 1.1                        | μA       |
| Ground current                                | Bandgap<br>I <sub>REF</sub> block<br>Preregulator<br>V <sub>REF</sub> buffer<br>Retention reference buffer |       |       | 25<br>20<br>15<br>10<br>10 | μA       |
| Output spot noise                             | 100 Hz   |       |       | 1                          | μV/√Hz   |
| A-weighted noise (rms)                        |  |       | 200   |                            | nV (rms) |
| P-weighted noise (rms)                        |  |       | 150   |                            | nV (rms) |
| Integrated noise                              | 20 to 100 kHz  |       | 2.2   |                            | μV       |
| I <sub>BIAS</sub> trim bit LSB                |  |       |       | 0.1                        | μA       |
| Ripple rejection                              | <1 MHz from VBAT   | 60    |       |                            | dB       |
| Start-up time                                 |  |       |       | 1                          | ms       |

## 4.3 Power Control

### 4.3.1 Backup Battery Charger

If the backup battery is rechargeable, it can be recharged from the main battery. A programmable voltage regulator powered by the main battery allows recharging of the backup battery. The backup battery charge must be enabled using a control bit register. Recharging starts when two conditions are met:

- Main battery voltage > backup battery voltage
- Main battery > 3.2 V

The comparators of the backup battery system (BBS) give the two thresholds of the backup battery charge startup. The programmed voltage for the charger gives the end-of-charge threshold. The programmed current for the charger gives the charge current.

Overcharging is prevented by measurement of the backup battery voltage through the GP ADC. Table 4-13 lists the characteristics of the backup battery charger.

**Table 4-13. Backup Battery Charger Characteristics**

| Parameter                         | Test Conditions           | Min | Typ  | Max | Unit |
|-----------------------------------|---------------------------|-----|------|-----|------|
| VBACKUP-to-MADC input attenuation | VBACKUP from 1.8 to 3.3 V |     | 0.33 |     | V/V  |

**Table 4-13. Backup Battery Charger Characteristics (continued)**

| Parameter  | Test Conditions                           | Min  | Typ | Max | Unit |
|--|---|------|-----|-----|------|
| Backup battery charging current                  | VBACKUP = 2.8 V, BBCHEN = 1, BBISEL = 00  | 10   | 25  | 45  | μA   |
|  | VBACKUP = 2.8 V, BBCHEN = 1, BBISEL = 01  | 105  | 150 | 270 | μA   |
|  | VBACKUP = 2.8 V, BBCHEN = 1, BBISEL = 10  | 350  | 500 | 900 | μA   |
|  | VBACKUP = 2.8 V, BBCHEN = 1, BBISEL = 11  | 0.7  | 1   | 1.8 | mA   |
|  | VBACKUP = 0 V, BBCHEN = 1, BBISEL = 00    | 17.5 | 25  | 45  | μA   |
|  | VBACKUP = 0 V, BBCHEN = 1, BBISEL = 01    | 105  | 150 | 270 | μA   |
|  | VBACKUP = 0 V, BBCHEN = 1, BBISEL = 10    | 350  | 500 | 900 | μA   |
|  | VBACKUP = 0 V, BBCHEN = 1, BBISEL = 11    | 0.7  | 1   | 1.8 | mA   |
| End backup battery charging voltage:<br>VBBCHGEN | I <sub>VBACKUP</sub> = -10 μA, BBSEL = 00 | 2.4  | 2.5 | 2.6 | V    |
|  | I <sub>VBACKUP</sub> = -10 μA, BBSEL = 01 | 2.9  | 3.0 | 3.1 | V    |
|  | I <sub>VBACKUP</sub> = -10 μA, BBSEL = 10 | 3.0  | 3.1 | 3.2 | V    |
|  | I <sub>VBACKUP</sub> = -10 μA, BBSEL = 11 | 3.1  | 3.2 | 3.3 | V    |

### 4.3.2 Battery Monitoring and Threshold Detection

#### 4.3.2.1 Power On/Power Off and Backup Conditions

Table 4-14 lists the threshold levels of the battery.

**Table 4-14. Battery Threshold Levels**

| Parameter                               | Test Conditions  | Min  | Typ  | Max  | Unit |
|---|--|------|------|------|------|
| Main battery charged threshold<br>VMBCH | Measured on VBAT terminal  | 3.1  | 3.2  | 3.3  | V    |
| Main battery low threshold VMBLO        | VBACKUP = 3.2 V, measured on VBAT terminal (monitored on terminal ONNOFF)  | 2.55 | 2.7  | 2.85 | V    |
| Main battery high threshold VMBHI       | Measured on terminal VBAT, VBACKUP = 0 V                                   | 2.5  | 2.65 | 2.95 | V    |
|   | Measured on terminal VBAT, VBACKUP = 3.2 V                                 | 2.5  | 2.85 | 2.95 |      |
| Batteries not present threshold VBNPR   | Measured on terminal VBACKUP with VBAT < 2.1 V                             | 1.6  | 1.8  | 2.0  | V    |
|   | Measured on terminal VBAT with VBACKUP = 0 V (monitored on terminal VRRTC) | 1.95 | 2.1  | 2.25 |      |

### 4.3.3 VRRTC LDO Regulator

The VRRTC voltage regulator is a programmable, low dropout, linear voltage regulator supplying (1.5 V) the embedded real-time clock (32.768-kHz oscillator) and dedicated I/Os of the digital host counterpart. The VRRTC regulator is also the supply voltage of the power-management digital state-machine. The VRRTC regulator is supplied from the UPR line, switched on by the main or backup battery, depending on the system state. The VRRTC output is present as long as a valid energy source is present. The VRRTC line is supplied by an LDO when VBAT > 2.7, and a clamp circuit when in backup mode. Table 4-15 describes the regulator characteristics.

**Table 4-15. VRRTC LDO Regulator Characteristics**

| Parameter                         | Test Conditions                          | Min     | Typ  | Max  | Unit |
|-----------------------------------|--|---------|------|------|------|
| <b>Output Load Conditions</b>     |  |         |      |      |      |
| Filtering capacitor               | Connected from VRTC.OUT to analog ground | 0.3     | 1    | 2.7  | μF   |
| Filtering capacitor ESR           |  | 20      |      | 600  | mΩ   |
| <b>Electrical Characteristics</b> |  |         |      |      |      |
| V <sub>IN</sub>                   | Input voltage                            | On mode | VBAT | 4.5  | V    |
| V <sub>OUT</sub>                  | Output voltage                           | On mode | 1.5  | 1.55 | V    |

**Table 4-15. VRRTC LDO Regulator Characteristics (continued)**

| Parameter        |                                | Test Conditions   | Min | Typ | Max | Unit |
|------------------|--------------------------------|---|-----|-----|-----|------|
| I <sub>OUT</sub> | Rated output current           | On mode   |     |     | 30  | mA   |
|                  |                                | Sleep mode  |     |     | 1   |      |
|                  | DC load regulation             | On mode: I <sub>OUT</sub> = I <sub>OUTmax</sub> to 0  |     |     | 100 | mV   |
|                  | DC line regulation             | On mode, V <sub>IN</sub> = V <sub>INmin</sub> to V <sub>INmax</sub> at I <sub>OUT</sub> = I <sub>OUTmax</sub> |     |     | 100 | mV   |
|                  | Turn-on time                   | I <sub>OUT</sub> = 0, at V <sub>OUT</sub> = V <sub>OUTfinal</sub> ± 3%  |     | 100 |     | µs   |
|                  | Wake-up time                   | On mode from low power to On mode, I <sub>OUT</sub> = 0, at V <sub>OUT</sub> = V <sub>OUTfinal</sub> ± 3%     |     | 100 |     | µs   |
|                  |                                | From backup to On mode, I <sub>OUT</sub> = 0, at V <sub>OUT</sub> = V <sub>OUTfinal</sub> ± 3%                |     | 100 |     |      |
|                  | Ripple rejection (VRRTC)       | f < 10 kHz  | 50  |     |     | dB   |
|                  |                                | 10 kHz < f < 100 kHz  | 40  |     |     |      |
|                  |                                | f = 1 MHz   | 30  |     |     |      |
|                  |                                | V <sub>IN</sub> = V <sub>OUT</sub> + 1 V, I <sub>O</sub> = I <sub>MAX</sub>                                   |     |     |     |      |
|                  | Ground current                 | On mode, I <sub>OUT</sub> = 0   |     |     | 70  | µA   |
|                  |                                | On mode, I <sub>OUT</sub> = I <sub>OUTmax</sub>   |     |     | 100 |      |
|                  |                                | Sleep mode, I <sub>OUT</sub> = 0  |     |     | 10  |      |
|                  |                                | Sleep mode, I <sub>OUT</sub> = 1 mA   |     |     | 11  |      |
|                  |                                | Off mode  |     |     | 1   |      |
| V <sub>DO</sub>  | Dropout voltage <sup>(1)</sup> | On mode, I <sub>OUT</sub> = I <sub>OUTmax</sub>   |     |     | 250 | mV   |
|                  | Transient load regulation      | I <sub>LOAD</sub> : I <sub>MIN</sub> – I <sub>MAX</sub><br>Slew: 40 mA/µs                                     | –40 |     | 40  | mV   |
|                  | Transient line regulation      | V <sub>IN</sub> drops 500 mV<br>Slew: 40 mV/µs  |     |     | 10  | mV   |
|                  | Overshoot                      | Softstart   |     |     | 3%  |      |
|                  | Pull down resistance           | Default in off mode   | 250 | 320 | 450 | Ω    |

(1) For nominal output voltage

#### 4.4 Power Consumption

Table 4-16 describes the power consumption depending on the use cases.

#### NOTE

Typical power consumption is obtained in the nominal operating conditions and with the TPS65920 and TPS65930 devices in stand-alone configuration.

**Table 4-16. Power Consumption**

| Mode           | Description   |                  | Typical Consumption   |
|----------------|---|------------------|-----------------------|
| Backup         | Only the RTC date is maintained with a couple of registers in the backup domain. No main source is connected. Consumption is on the backup battery.   | VBAT not present | 2.25 * 3.2 = 7.2 µW   |
| Wait on        | The phone is apparently off for the user, a main battery is present and well-charged. The RTC registers and registers in the backup domain are maintained. The wake-up capabilities (such as the PWRON button) are available. | VBAT = 3.8 V     | 64 * 3.8 = 243.2 µW   |
| Active no load | The subsystem is powered by the main battery, all supplies are enabled with full current capability, internal reset is released, and the associated processor is running.   | VBAT = 3.8 V     | 3291 * 3.8 = 12505 µW |
| Sleep no load  | The main battery powers the subsystem, selected supplies are enabled but in low-consumption mode, and the associated processor is in low-power mode.  | VBAT = 3.8 V     | 496 * 3.8 = 1884.4 µW |

Table 4-17 lists the regulator states according to the mode in use.

**Table 4-17. Regulator State Depending on Use Case**

| Regulator | Mode   |         |               |                |
|-----------|--------|---------|---------------|----------------|
|           | Backup | Wait On | Sleep No Load | Active No Load |
| VAUX2     | OFF    | OFF     | SLEEP         | ON             |
| VMMC1     | OFF    | OFF     | OFF           | OFF            |
| VPLL1     | OFF    | OFF     | SLEEP         | ON             |
| VDAC      | OFF    | OFF     | OFF           | OFF            |
| VINTANA1  | OFF    | OFF     | SLEEP         | ON             |
| VINTANA2  | OFF    | OFF     | SLEEP         | ON             |
| VINTDIG   | OFF    | OFF     | SLEEP         | ON             |
| VIO       | OFF    | OFF     | SLEEP         | ON             |
| VDD1      | OFF    | OFF     | SLEEP         | ON             |
| VDD2      | OFF    | OFF     | SLEEP         | ON             |
| VUSB_1V5  | OFF    | OFF     | OFF           | OFF            |
| VUSB_1V8  | OFF    | OFF     | OFF           | OFF            |
| VUSB_3V1  | OFF    | OFF     | SLEEP         | SLEEP          |



## 4.5 Power Management

### 4.5.1 Boot Modes

Table 4-18 lists the modes corresponding to BOOT0–BOOT1.

**Table 4-18. BOOT Mode Description**

| Name  | Description            | BOOT0 | BOOT1 |
|-------|------------------------|-------|-------|
|       | Reserved               | 0     | 0     |
| MC027 | Master_C027_Generic 01 | 0     | 1     |
| MC021 | Master_C021_Generic 10 | 1     | 0     |
| SC021 | Slave_C021_Generic 11  | 1     | 1     |

### 4.5.2 Process Modes

This parameter defines:

- The boot voltage for the host core
- The boot sequence associated with the process
- The dynamic voltage and frequency scaling (DVFS) protocol associated with the process

#### 4.5.2.1 MC021 Mode

Table 4-19 lists the characteristics of MC021 mode.

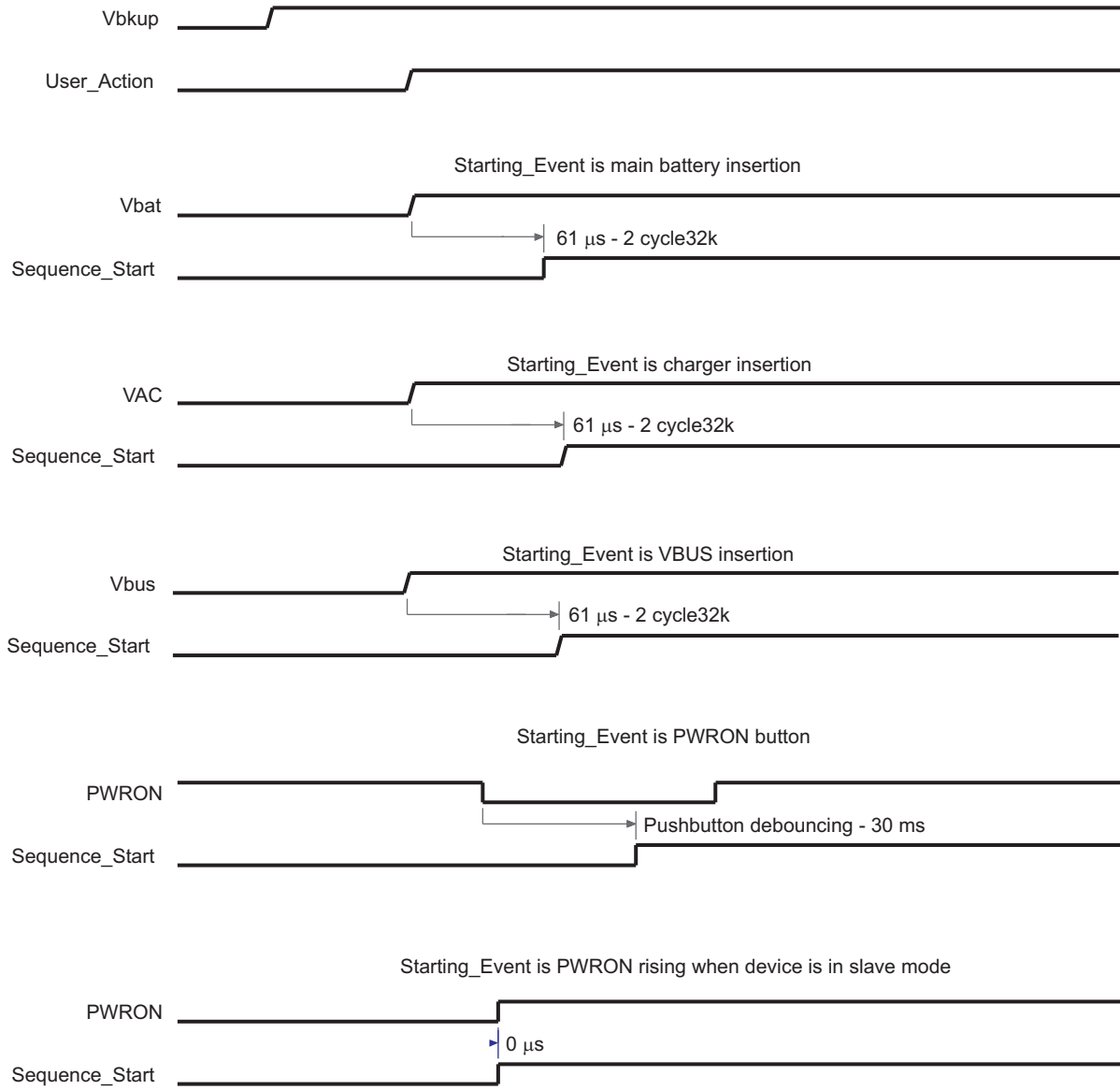
**Table 4-19. MC021 Mode**

|                   |                                      |
|-------------------|--------------------------------------|
| Boot core voltage | 1.2 V                                |
| Power sequence    | VIO followed by VPLL1, VDD2, VDD1    |
| DVFS protocol     | SmartReflex IF (I <sup>2</sup> C HS) |

### 4.5.3 Power-On Sequence

#### 4.5.3.1 Timing Before Sequence\_Start

Sequence\_Start is a symbolic internal signal to ease the description of the power sequences. It occurs according to the events shown in Figure 4-8.



030-012

Figure 4-8. Timing Before Sequence Start

### 4.5.3.2 Power-On Sequence

Figure 4-9 describes the timing and control that must occur in the OMAP3 mode. Sequence\_Start is a symbolic internal signal to ease the description of the power sequences. It occurs according to the events shown in Figure 4-8.

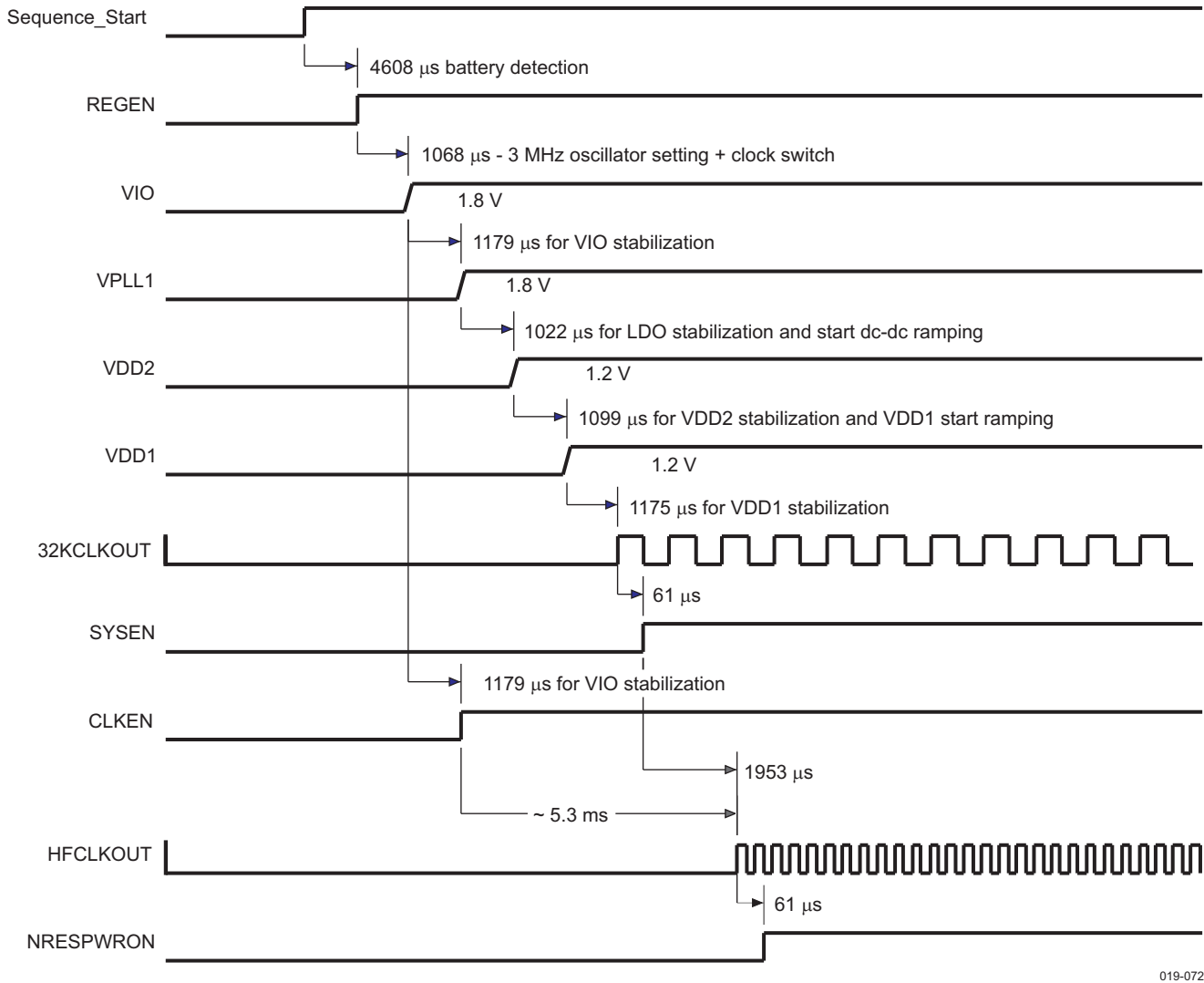
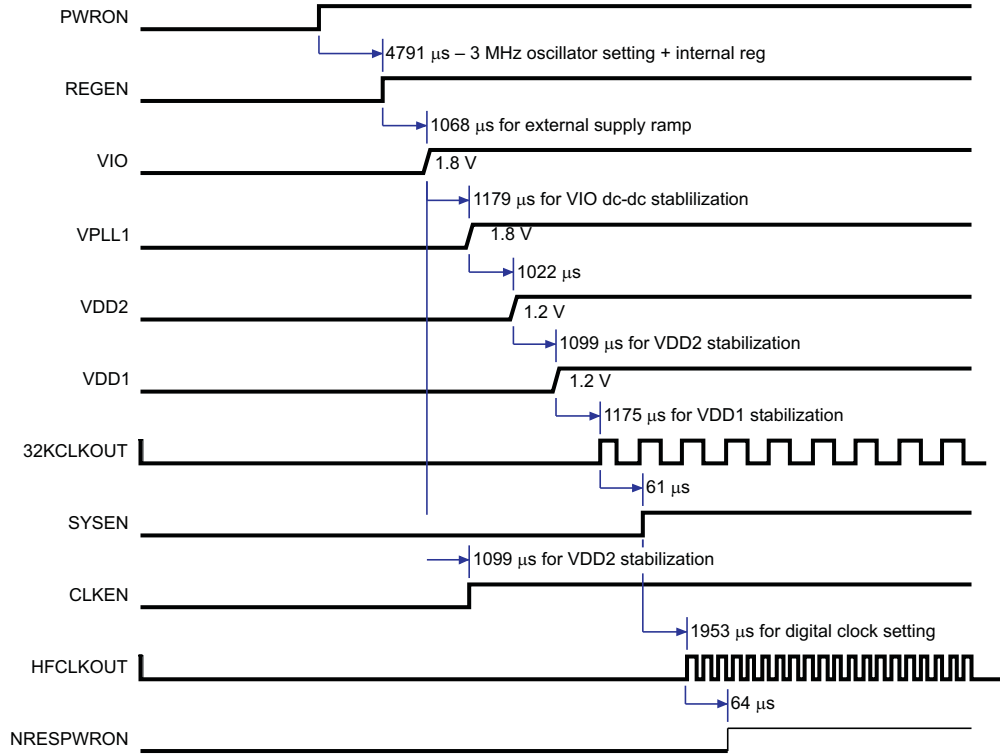


Figure 4-9. Timings—Power On in OMAP3 Mode

### 4.5.3.3 Power On in Slave\_C021 Mode

Figure 4-10 describes the timing and control that must occur in the Slave\_C021 mode. Sequence\_Start is a symbolic internal signal to ease the description of the power sequences and occurs according to the different events detailed in Figure 4-8.



030-022

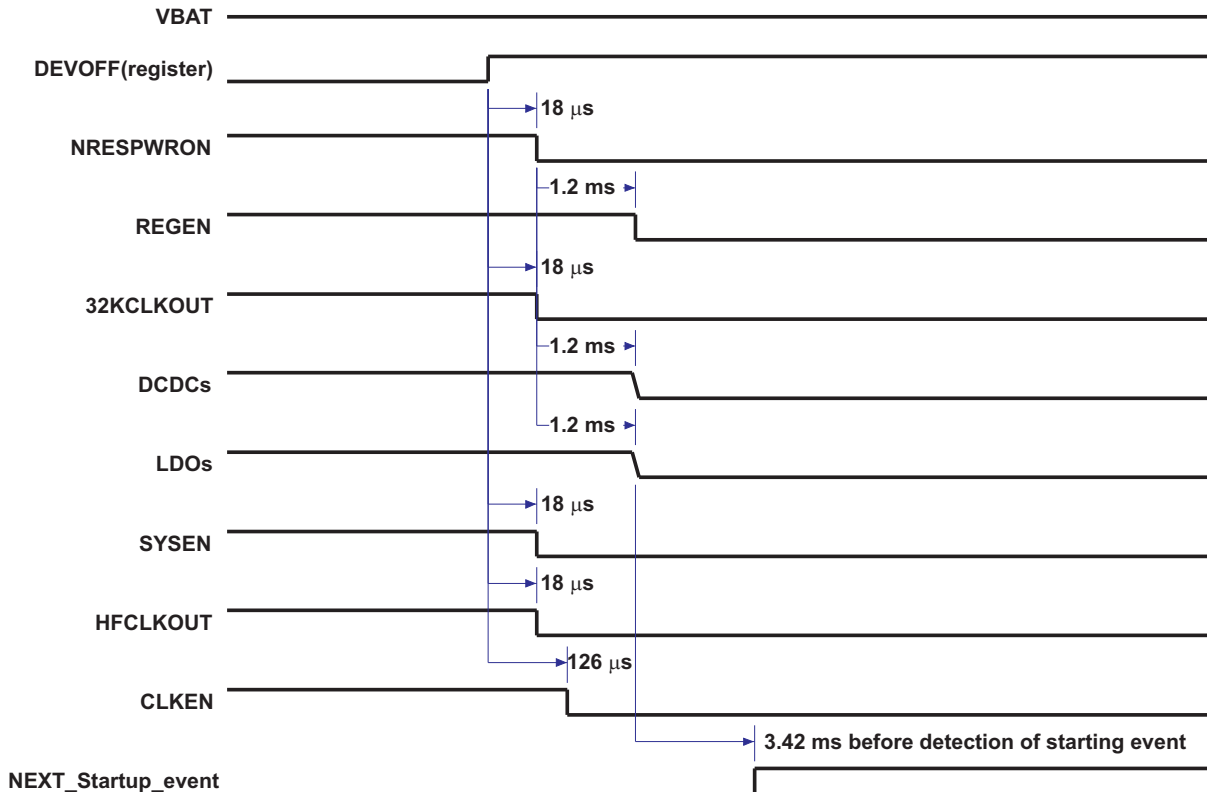
Figure 4-10. Timings—Power On in Slave\_C021 Mode

### 4.5.4 Power-Off Sequence

This section describes the signal behavior required to power down the system.

#### 4.5.4.1 Power-Off Sequence

Figure 4-11 shows the timing and control that occur during the power-off sequence in master modes.



037-055

NOTE: All of these timings are typical values with the default setup (depending on the resynchronization between power domains, state machinery priority, etc.).

**Figure 4-11. Power-Off Sequence in Master Modes**

Because of the internal frequency used by Power STM switching from 3 to 1.5 MHz when the HF clock value is 19.2 MHz, if the HF clock value is not 19.2 MHz (with HFCLK\_FREQ bit field values set accordingly in the CFG\_BOOT register), the delay between DEVOFF and NRESPWRON/CLK32KOUT/SYSEN/HFCLKOUT is divided by two (approximately 9 μs).

The DEVOFF event is PWRON falling edge in slave mode and DEVOFF internal register write in master mode.

## 5 Real-Time Clock and Embedded Power Controller

The TPS65930 and TPS65920 devices contain an RTC to provide clock and timekeeping functions and an EPC to provide battery supervision and control.

### 5.1 RTC

The RTC provides the following basic functions:

- Time information (seconds/minutes/hours) directly in binary-coded decimal (BCD) code
- Calendar information (day/month/year/day of the week) directly in BCD code
- Interrupt generation periodically (1 second/1 minute/1 hour/1 day) or at a precise time (alarm function)
- 32-kHz oscillator drift compensation and time correction
- Alarm-triggered system wake-up event

#### 5.1.1 Backup Battery

The TPS65030 and TPS65920 devices device implement a backup mode in which a backup battery can keep the RTC running to maintain clock and time information even if the main supply is not present. If the backup battery is rechargeable, the device also provides a backup battery charger so it can be recharged when the main battery supply is present.

The backup domain powers the following:

- Internal 32.768-kHz crystal oscillator
- RTC
- Eight general-purpose (GP) storage registers
- Backup domain low-power regulator (VBRTC)

### 5.2 EPC

The EPC provides five system states for optimal power use by the system, as listed in [Table 5-1](#).

**Table 5-1. System States**

| System State | Description  |
|--------------|--|
| NO SUPPLY    | The system is not powered by any battery.  |
| BACKUP       | The system is powered only with the backup battery and maintains only the VBRTC supply.                          |
| WAIT-ON      | The system is powered by the main battery and maintains only the VVRTC supply. It can accept switch-on requests. |
| ACTIVE       | The system is powered by the main battery; all supplies can be enabled with full current capability.             |
| SLEEP        | The main battery powers the system; selected supplies are enabled, but in low consumption mode.                  |

Three categories of events can trigger state transitions:

- Hardware events: Supply/battery insertion, wake-up requests, USB plug, and RTC alarm
- Software events: Switch-off commands, switch-on commands, and sleep on commands
- Monitoring events: Supply/battery level check, main battery removal, main battery fail, and thermal shutdown

## 6 Audio/Voice Module (TPS65930 Device Only)

### NOTE

This section applies only to the TPS65930 device.

Figure 6-1 is the audio/voice module block diagram.

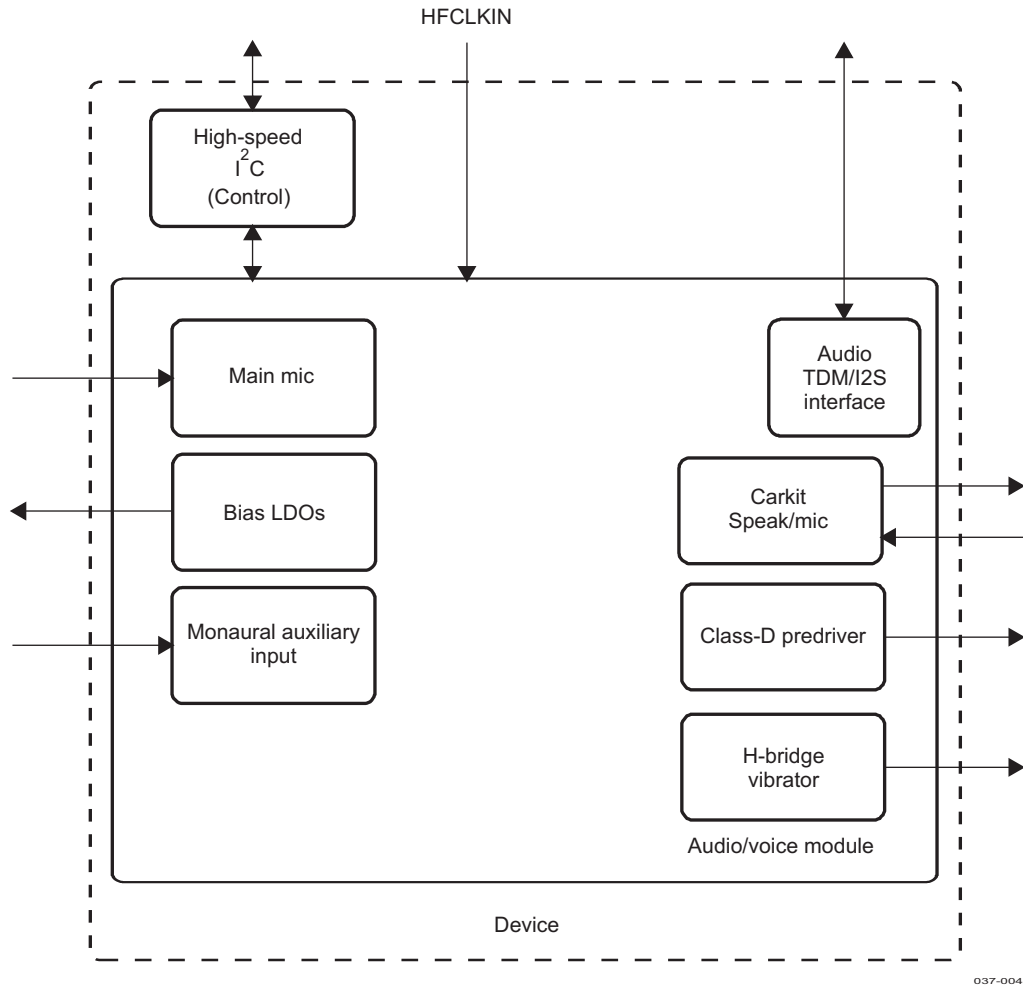


Figure 6-1. Audio/Voice Module Block Diagram

### 6.1 Audio/Voice Downlink (RX) Module

The audio/voice module includes the following output stages:

- Predriver output signals for external class-D amplifiers (single-ended)
- Vibrator H-bridge

#### 6.1.1 Predriver for External Class-D Amplifier

The external class-D amplifiers provide a stereo signal on terminals PreD.LEFT and PreD.RIGHT to drive the external class-D amplifier. These terminals are available if a stereo, single-ended, ac-coupled headset is used.

### 6.1.1.1 Predriver Output Characteristics

Table 6-1 lists the predriver output characteristics.

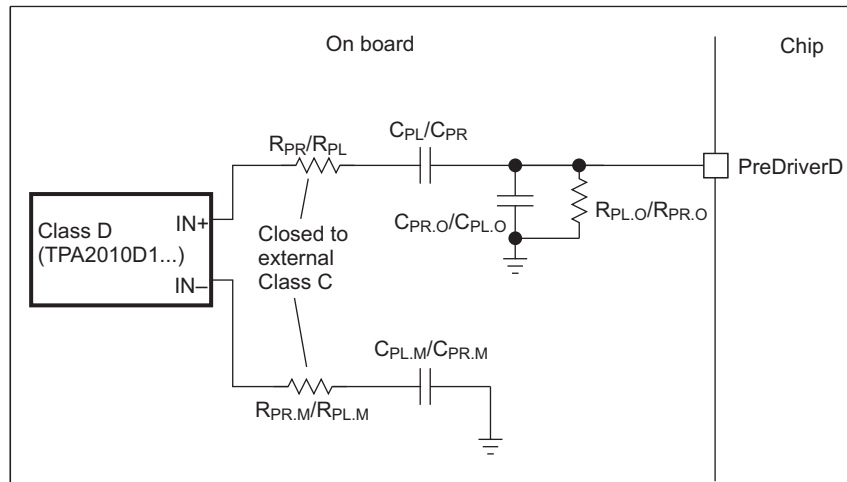
**Table 6-1. Predriver Output Characteristics**

| Parameter   | Test Conditions                            | Min | Typ | Max | Unit            |
|---|--|-----|-----|-----|-----------------|
| Load impedance  |  | 10  |     |     | kΩ              |
|   |  | 50  |     |     | pF              |
| Gain range <sup>(1)</sup>   | Audio path                                 | -92 |     | 30  | dB              |
|   | Voice path                                 | -66 |     | 30  |                 |
| Absolute gain error   |  | -1  |     | 1   | dB              |
| Peak-to-peak output voltage (0 dBFs)  | Default gain <sup>(2)</sup>                |     | 1.5 |     | V <sub>PP</sub> |
| Total harmonic distortion<br>Default gain <sup>(2)</sup><br>Load > 10 kΩ // 50 pF | At 0 dBFs                                  |     | -80 | -75 | dB              |
|   | At -6 dBFs                                 |     | -74 | -69 |                 |
|   | At -20 dBFs                                |     | -70 | -65 |                 |
|   | At -60 dBFs                                |     | -30 | -25 |                 |
| Idle channel noise (20 Hz to 20 kHz, A-weighted)                                  | Default gain <sup>(3)</sup><br>Load = 10 Ω |     | -90 | -85 | dB              |
| SNR (A-weighted over 20-kHz bandwidth)<br>Default gain <sup>(3)</sup>             | At 0 dBFs                                  | 83  | 88  |     | dB              |
|   | At -60 dBFs                                |     | 30  |     |                 |
| Output PSRR (for all gains)   | 20 Hz to 4 kHz                             |     | 90  |     | dB              |
|   | 20 Hz to 20 kHz                            |     | 70  |     |                 |

- (1) Audio digital filter = -62 to 0 dB (1-dB steps) and 0 to 12 dB (6-dB steps)  
 Voice digital filter = -3 to 12 dB (1-dB steps)  
 ARXPGA (volume control) = -24 to 12 dB (2-dB steps)  
 Output driver = -6 dB, 0 dB, 6 dB
- (2) The default gain setting assumes the ARXPGA has 0-dB gain setting (volume control) and output driver at 0-dB gain setting.
- (3) The default gain setting assumes the ARXPGA has 0-dB gain setting (volume control) and output driver at 0-dB gain setting.

### 6.1.1.2 External Components and Application Schematics

Figure 6-2 is a simplified schematic for the external class-D predriver.



037-054

Input resistor ( $R_{PR}$  or  $R_{PL}$ ) sets the gain of the external class D. For TPS2010D1, the gain is defined according to the following equation:  
 Gain (V/V) =  $2 \cdot 150 \cdot 10^3 / (R_{PR} \text{ or } R_{PL})$   
 $R_{PR}$  or  $R_{PL} > 15 \text{ k}\Omega$

**Figure 6-2. Predriver for External Class D**



**NOTE**

For other component values, see [Table 14-1](#).

**6.1.2 Vibrator H-Bridge**

A digital signal from the pulse width modulated generator is fed to the vibrator H-bridge driver. The vibrator H-bridge is a differential driver that drives vibrator motors. The differential output allows dual rotation directions.

**6.1.2.1 Vibrator H-Bridge Output Characteristics**

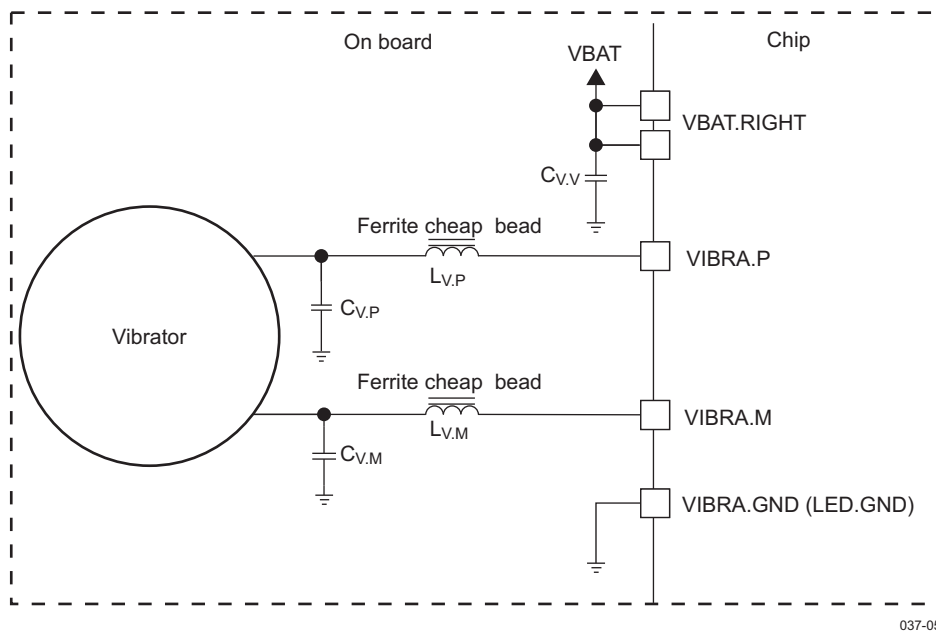
[Table 6-2](#) lists the vibrator H-bridge output characteristics.

**Table 6-2. Vibrator H-Bridge Output Characteristics**

| Parameter                                 | Test Conditions | Min | Typ | Max | Unit            |
|---|-----------------|-----|-----|-----|-----------------|
| VBAT voltage                              |                 | 2.8 | 3.6 | 4.8 | V               |
| Differential output swing (16-Ω load)     | VBAT = 2.8 V    | 3.6 |     |     | V <sub>PP</sub> |
|   | VBAT = 3.5 V    | 4.3 |     |     |                 |
| Output resistance (summed for both sides) |                 |     |     | 8   | Ω               |
| Load capacitance                          |                 |     |     | 100 | pF              |
| Load resistance                           |                 | 8   | 16  | 60  | Ω               |
| Load inductance                           |                 |     | 30  | 300 | μH              |
| Total harmonic distortion                 |                 |     |     | 10% |                 |
| Operating frequency                       |                 | 20  |     | 10k | Hz              |

**6.1.2.2 External Components and Application Schematics**

[Figure 6-3](#) is a simplified vibrator H-bridge schematic.



**Figure 6-3. Vibrator H-Bridge**

**NOTE**

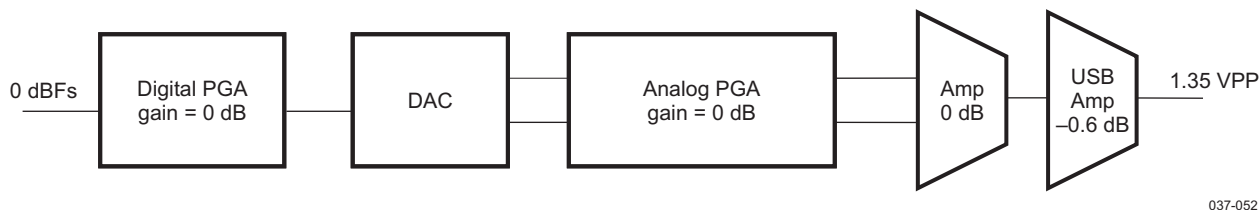
For other component values, see [Table 14-1](#).

Example of ferrite: BLM 18BD221SN1.

**6.1.3 Carkit Output**

The USB-CEA carkit uses the DP/DM pad to output audio signals (see the *CEA-936–Mini-USB Analog Carkit* specification).

Figure 6-4 shows the carkit output downlink full path characteristics for audio and USB.



**Figure 6-4. Carkit Output Downlink Path Characteristics**

Table 6-3 lists the USB-CEA carkit audio downlink electrical characteristics.

**Table 6-3. USB-CEA Carkit Audio Downlink Electrical Characteristics**

| Parameter   | Conditions                  | Min | Typ  | Max | Unit            |
|---|-----------------------------|-----|------|-----|-----------------|
| Output load   | USB-CEA (DP/DM)             | 20  |      |     | kΩ              |
| Gain range <sup>(1)</sup>                                   | Audio path                  | -92 |      | 30  | dB              |
|   | Voice path                  | -66 |      | 30  |                 |
| Absolute gain error   | At 1 kHz                    | -1  |      | 1   | dB              |
| Peak-to-peak differential output voltage (0 dBFS)           | Gain = 0 dB                 |     | 1.5  |     | V <sub>PP</sub> |
| Total harmonic distortion                                   | At 0 dBFS                   |     | -80  | -75 | dB              |
|   | At -6 dBFS                  |     | -74  | -69 |                 |
|   | At -20 dBFS                 |     | -70  | -65 |                 |
|   | At -60 dBFS                 |     | -30  | -25 |                 |
| THD+N (20 Hz to 20 kHz, A-weighted)                         | At 0 dBFS                   |     | 60   |     | dB              |
| Idle channel noise (20 Hz to 20 kHz, A-weighted)            | Default gain <sup>(2)</sup> |     | -90  | -85 | dB              |
| Output PSRR   | 20 Hz to 20 kHz             |     | 60   |     | dB              |
| Supply voltage (Vintana1)                                   |                             |     | 1.5  |     | V               |
| Common mode output voltage for USB-CEA                      |                             | 1.3 | 1.35 | 1.4 | V               |
| Isolation between D+/D- during audio mode (20 Hz to 20 kHz) |                             | 60  |      |     | dB              |
| Crosstalk between right and left channels                   | USB-CEA stereo              |     | -90  |     | dB              |
| Crosstalk RX/Tx (1 V <sub>PP</sub> output)                  | USB-CEA mono/stereo         |     |      | -60 | dB              |
| Signal noise ratio (20 Hz to 20 kHz, A-weighted)            | At 0 dBFS                   |     | 60   |     | dB              |
| Phone speaker amplifier output impedance at 1 kHz           | USB-CEA (DP/DM)             |     |      | 200 | Ω               |

(1) Audio digital filter = -62 to 0 dB (1-dB steps) and 0 to 12 dB (6-dB steps)  
 Voice digital filter = -36 to 12 dB (1-dB steps)  
 ARXPGA (volume control) = -24 to 12 dB (2-dB steps)  
 Output driver (USB-CEA) = -1 dB  
 (2) The default gain setting assumes the ARXPGA has 0-dB gain setting (volume control) and output driver at 0.6-dB gain setting.

### 6.1.4 Digital Audio Filter Module

Figure 6-5 shows the digital audio filter downlink full path characteristics for the audio interface.

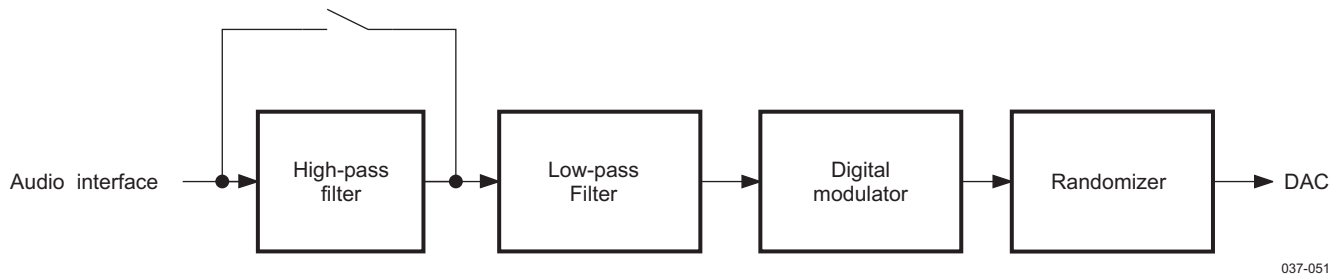


Figure 6-5. Digital Audio Filter Downlink Path Characteristics

The HPF can be bypassed. It is controlled by the MISC\_SET\_2 ARX\_HPFBYP bit set to address 0x49.

Table 6-4 lists the audio filter frequency responses relative to reference gain at 1 kHz.

Table 6-4. Digital Audio Filter RX Electrical Characteristics

| Parameter            | Conditions   | Min   | Typ                                | Max  | Unit           |
|----------------------|--|-------|------------------------------------|------|----------------|
| Passband             |  |       | 0.42                               |      | F <sub>S</sub> |
| Passband ripple      | 0 to 0.42F <sub>S</sub> <sup>(1)</sup>                                   | -0.25 | 0.1                                | 0.25 | dB             |
| Stopband             |  |       | 0.6                                |      | F <sub>S</sub> |
| Stopband attenuation | F = 0.6F <sub>S</sub> <sup>(1)</sup> to 0.8F <sub>S</sub> <sup>(1)</sup> | 60    | 75                                 |      | dB             |
| Group delay          |  |       | 15.8/F <sub>S</sub> <sup>(1)</sup> |      | μs             |
| Linear phase         |  | -1.4  |                                    | 1.4  | °              |

(1) F<sub>S</sub> is the sampling frequency (8, 11.025, 12, 16, 22.05, 24, 32, 44.1, or 48 kHz).

### 6.1.5 Boost Stage

The boost effect adds emphasis to low frequencies. It compensates for a HPF created by the capacitor resistor (CR) filter of the headset (in ac-coupling configuration).

There are four modes. Three effects are available, with slightly different frequency responses, and the fourth setting disables the boost effect:

- Boost effect 1
- Boost effect 2
- Boost effect 3
- Flat equalization: The boost effect is in bypass mode.

#### NOTE

Boost effect modes are defined in Table 6-5.

Table 6-5 and Table 6-6 include the typical values according to the frequency response versus input frequency and F<sub>S</sub> frequency.

**Table 6-5. Boost Electrical Characteristics Versus  $F_S$  Frequency ( $F_S \leq 22.05$  kHz)**

| Frequency (Hz) | $F_S = 8$ kHz |      |      | $F_S = 11.025$ kHz |      |      | $F_S = 12$ kHz |      |      | $F_S = 16$ kHz |      |      | $F_S = 22.05$ kHz |      |      | Unit |
|----------------|---------------|------|------|--------------------|------|------|----------------|------|------|----------------|------|------|-------------------|------|------|------|
|                | 1             | 2    | 3    | 1                  | 2    | 3    | 1              | 2    | 3    | 1              | 2    | 3    | 1                 | 2    | 3    |      |
| 10             | 4.51          | 5.13 | 5.62 | 5.10               | 5.51 | 5.80 | 5.22           | 5.58 | 5.83 | 5.54           | 5.77 | 5.92 | 5.76              | 5.89 | 5.97 | dB   |
| 12             | 4.08          | 4.83 | 5.46 | 4.80               | 5.32 | 5.71 | 4.95           | 5.41 | 5.76 | 5.36           | 5.66 | 5.87 | 5.65              | 5.83 | 5.94 |      |
| 15.2           | 3.43          | 4.32 | 5.18 | 4.28               | 4.97 | 5.54 | 4.47           | 5.11 | 5.61 | 5.03           | 5.47 | 5.79 | 5.45              | 5.71 | 5.90 |      |
| 18.2           | 2.91          | 3.86 | 4.89 | 3.82               | 4.63 | 5.36 | 4.04           | 4.80 | 5.45 | 4.71           | 5.26 | 5.69 | 5.24              | 5.59 | 5.84 |      |
| 20.5           | 2.56          | 3.53 | 4.65 | 3.49               | 4.37 | 5.21 | 3.72           | 4.56 | 5.32 | 4.45           | 5.09 | 5.60 | 5.06              | 5.49 | 5.79 |      |
| 29.4           | 1.62          | 2.49 | 3.78 | 2.45               | 3.42 | 4.57 | 2.68           | 3.74 | 4.73 | 3.51           | 4.39 | 5.24 | 4.35              | 5.02 | 5.59 |      |
| 39.7           | 1.05          | 1.71 | 2.93 | 1.67               | 2.55 | 3.84 | 1.88           | 2.80 | 4.06 | 2.66           | 3.63 | 4.72 | 3.67              | 4.45 | 5.27 |      |
| 50.4           | 0.71          | 1.20 | 2.26 | 1.17               | 1.91 | 3.17 | 1.33           | 2.13 | 3.41 | 2.01           | 2.95 | 4.19 | 2.89              | 3.85 | 4.88 |      |
| 60.3           | 0.51          | 0.92 | 1.79 | 0.89               | 1.49 | 2.65 | 1.00           | 1.68 | 2.89 | 1.57           | 2.43 | 3.72 | 2.39              | 3.35 | 4.52 |      |
| 76.7           | 0.32          | 0.61 | 1.26 | 0.59               | 1.05 | 1.99 | 0.69           | 1.18 | 2.22 | 1.11           | 1.79 | 3.04 | 1.76              | 2.66 | 3.94 |      |
| 97.5           | 0.20          | 0.39 | 0.87 | 0.38               | 0.70 | 1.43 | 0.44           | 0.79 | 1.62 | 0.75           | 1.27 | 2.36 | 1.24              | 2.00 | 3.28 |      |
| 131.5          | 0.12          | 0.21 | 0.50 | 0.20               | 0.39 | 0.88 | 0.25           | 0.47 | 1.02 | 0.42           | 0.78 | 1.59 | 0.75              | 1.30 | 2.41 |      |
| 157            | 0.08          | 0.15 | 0.36 | 0.15               | 0.28 | 0.65 | 0.17           | 0.33 | 0.75 | 0.31           | 0.57 | 1.22 | 0.55              | 0.99 | 1.93 |      |
| 200            | 0.05          | 0.09 | 0.22 | 0.09               | 0.17 | 0.41 | 0.11           | 0.21 | 0.49 | 0.19           | 0.37 | 0.82 | 0.36              | 0.66 | 1.38 |      |
| 240            | 0.03          | 0.06 | 0.15 | 0.06               | 0.12 | 0.29 | 0.07           | 0.14 | 0.35 | 0.14           | 0.26 | 0.60 | 0.25              | 0.48 | 1.04 |      |
| 304            | 0.02          | 0.04 | 0.09 | 0.04               | 0.07 | 0.18 | 0.04           | 0.09 | 0.22 | 0.08           | 0.16 | 0.38 | 0.16              | 0.30 | 0.70 |      |
| 463            | 0.00          | 0.01 | 0.03 | 0.01               | 0.03 | 0.07 | 0.02           | 0.04 | 0.09 | 0.03           | 0.07 | 0.17 | 0.07              | 0.13 | 0.32 |      |
| 704            | 0.00          | 0.00 | 0.01 | 0.00               | 0.01 | 0.03 | 0.01           | 0.01 | 0.03 | 0.01           | 0.03 | 0.07 | 0.03              | 0.06 | 0.14 |      |
| 1008           | 0.00          | 0.00 | 0.00 | 0.00               | 0.00 | 0.01 | 0.00           | 0.00 | 0.01 | 0.00           | 0.01 | 0.03 | 0.01              | 0.02 | 0.06 |      |
| 1444           | 0.00          | 0.00 | 0.00 | 0.00               | 0.00 | 0.00 | 0.00           | 0.00 | 0.00 | 0.00           | 0.00 | 0.00 | 0.00              | 0.01 | 0.02 |      |
| 2070           | 0.00          | 0.00 | 0.00 | 0.00               | 0.00 | 0.00 | 0.00           | 0.00 | 0.00 | 0.00           | 0.00 | 0.00 | 0.00              | 0.00 | 0.01 |      |
| 3770           | 0.00          | 0.00 | 0.00 | 0.00               | 0.00 | 0.00 | 0.00           | 0.00 | 0.00 | 0.00           | 0.00 | 0.00 | 0.00              | 0.00 | 0.00 |      |

**Table 6-6. Boost Electrical Characteristics Versus  $F_S$  Frequency ( $F_S \geq 24$  kHz)**

| Frequency (Hz) | $F_S = 24$ kHz |      |      | $F_S = 32$ kHz |      |      | $F_S = 44.1$ kHz |      |      | $F_S = 48$ kHz |      |      | $F_S = 96$ kHz |      |      | Unit |
|----------------|----------------|------|------|----------------|------|------|------------------|------|------|----------------|------|------|----------------|------|------|------|
|                | 1              | 2    | 3    | 1              | 2    | 3    | 1                | 2    | 3    | 1              | 2    | 3    | 1              | 2    | 3    |      |
| 10             | 5.79           | 5.90 | 5.97 | 5.89           | 5.89 | 5.99 | 5.95             | 5.98 | 6.04 | 5.96           | 5.99 | 6.01 | 5.71           | 5.83 | 5.90 | dB   |
| 12             | 5.70           | 5.85 | 5.95 | 5.84           | 5.84 | 5.98 | 5.92             | 5.97 | 6.03 | 5.94           | 5.98 | 6.00 | 5.54           | 5.68 | 5.81 |      |
| 15.2           | 5.53           | 5.76 | 5.91 | 5.73           | 5.73 | 5.96 | 5.87             | 5.94 | 6.02 | 5.89           | 5.95 | 5.99 | 5.40           | 5.57 | 5.73 |      |
| 18.2           | 5.35           | 5.65 | 5.87 | 5.62           | 5.62 | 5.93 | 5.80             | 5.90 | 6.00 | 5.83           | 5.93 | 5.98 | 5.28           | 5.48 | 5.68 |      |
| 20.5           | 5.19           | 5.56 | 5.83 | 5.52           | 5.52 | 5.91 | 5.74             | 5.87 | 5.99 | 5.78           | 5.90 | 5.97 | 5.19           | 5.42 | 5.64 |      |
| 29.4           | 4.55           | 5.18 | 5.64 | 5.10           | 5.07 | 5.79 | 5.51             | 5.75 | 5.94 | 5.57           | 5.79 | 5.92 | 4.87           | 5.18 | 5.48 |      |
| 39.7           | 3.81           | 4.62 | 5.37 | 4.52           | 4.52 | 5.64 | 5.12             | 5.53 | 5.85 | 5.26           | 5.59 | 5.84 | 4.47           | 4.91 | 5.30 |      |
| 50.4           | 3.14           | 4.06 | 5.02 | 3.94           | 3.95 | 5.43 | 4.69             | 5.27 | 5.72 | 4.88           | 5.37 | 5.73 | 4.08           | 4.63 | 5.11 |      |
| 60.3           | 2.62           | 3.51 | 4.69 | 3.46           | 3.54 | 5.21 | 4.30             | 5.00 | 5.59 | 4.49           | 5.13 | 5.62 | 3.72           | 4.37 | 4.95 |      |
| 76.7           | 1.97           | 2.90 | 4.15 | 2.76           | 2.76 | 4.78 | 3.68             | 4.52 | 5.34 | 3.91           | 4.70 | 5.40 | 3.18           | 3.92 | 4.67 |      |
| 97.5           | 1.41           | 2.22 | 3.51 | 2.10           | 2.09 | 4.27 | 2.99             | 3.94 | 4.99 | 3.24           | 4.15 | 5.07 | 2.59           | 3.41 | 4.33 |      |
| 131.5          | 0.88           | 1.49 | 2.65 | 1.40           | 1.40 | 3.49 | 2.15             | 3.10 | 4.35 | 2.38           | 3.35 | 4.51 | 1.86           | 2.69 | 3.75 |      |
| 157            | 0.65           | 1.13 | 2.15 | 1.04           | 1.04 | 2.96 | 1.70             | 2.58 | 3.90 | 1.90           | 2.82 | 4.08 | 1.47           | 2.24 | 3.35 |      |
| 200            | 0.41           | 0.76 | 1.55 | 0.70           | 0.70 | 2.28 | 1.19             | 1.93 | 3.23 | 1.35           | 2.15 | 3.44 | 1.03           | 1.68 | 2.77 |      |
| 240            | 0.30           | 0.55 | 1.18 | 0.50           | 0.50 | 1.81 | 0.89             | 1.51 | 2.71 | 1.02           | 1.70 | 2.92 | 0.77           | 1.31 | 2.32 |      |
| 304            | 0.18           | 0.35 | 0.80 | 0.33           | 0.32 | 1.27 | 0.58             | 1.04 | 2.05 | 0.68           | 1.19 | 2.24 | 0.51           | 0.90 | 1.75 |      |
| 463            | 0.08           | 0.16 | 0.37 | 0.14           | 0.14 | 0.64 | 0.27             | 0.50 | 1.12 | 0.31           | 0.58 | 1.25 | 0.23           | 0.43 | 0.95 |      |
| 704            | 0.03           | 0.06 | 0.16 | 0.06           | 0.06 | 0.29 | 0.12             | 0.23 | 0.56 | 0.14           | 0.27 | 0.62 | 0.10           | 0.20 | 0.46 |      |
| 1008           | 0.01           | 0.03 | 0.07 | 0.03           | 0.02 | 0.14 | 0.06             | 0.11 | 0.30 | 0.06           | 0.13 | 0.31 | 0.05           | 0.10 | 0.23 |      |
| 1444           | 0.00           | 0.01 | 0.03 | 0.01           | 0.01 | 0.06 | 0.03             | 0.05 | 0.16 | 0.03           | 0.06 | 0.15 | 0.02           | 0.05 | 0.11 |      |
| 2070           | 0.00           | 0.00 | 0.01 | 0.00           | 0.00 | 0.02 | 0.01             | 0.02 | 0.09 | 0.01           | 0.03 | 0.07 | 0.01           | 0.02 | 0.05 |      |
| 3770           | 0.00           | 0.00 | 0.00 | 0.00           | 0.00 | 0.00 | 0.00             | 0.00 | 0.04 | 0.00           | 0.00 | 0.01 | 0.00           | 0.00 | 0.01 |      |

## 6.2 Audio Uplink (TX) Module

The audio uplink path includes two input amplification stages:

- MIC\_MAIN\_P, MIC\_MAIN\_M (differential main handset input)
- AUXR (common terminal: single-ended auxiliary)

### NOTE

If two audio inputs are needed, and mic bias is not needed, the AUXR input can be used with MIC\_MAIN to provide the two inputs.

### 6.2.1 Microphone Bias Module

A bias generator provides an external voltage of 2.2 V to bias the analog microphones (MICBIAS1 terminal). The typical output current is 1 mA.

#### 6.2.1.1 Analog Microphone Bias Module Characteristics

Table 6-7 lists the characteristics of the analog microphone bias module.

**Table 6-7. Analog Microphone Bias Module Characteristics With Bias Resistor**

| Parameter           | Test Conditions             | Min  | Typ | Max  | Unit                       |
|---------------------|-----------------------------|------|-----|------|----------------------------|
| Bias voltage        |                             | 2.15 | 2.2 | 2.25 | V                          |
| Load current        |                             |      |     | 1    | mA                         |
| Output noise        | P-weighted 20 Hz to 6.6 kHz |      |     | 1.8  | $\mu\text{V}_{\text{RMS}}$ |
| External capacitor  |                             | 0    |     | 200  | pF                         |
| Internal resistance |                             | 50   | 60  | 70   | k $\Omega$                 |

### NOTE

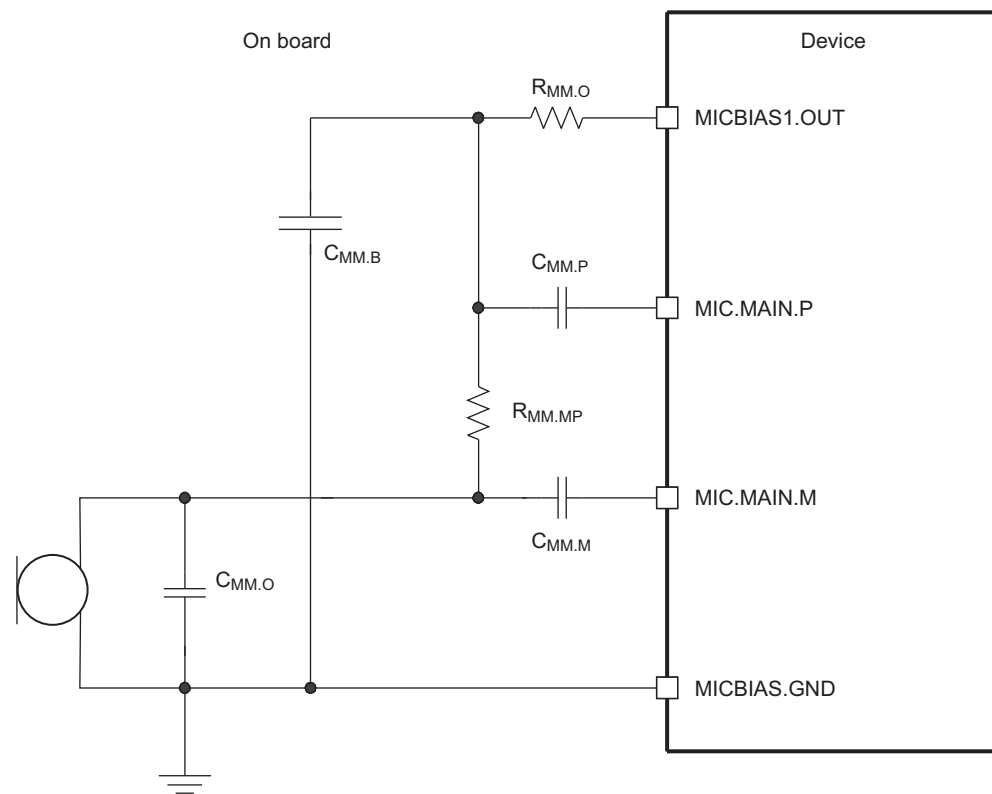
If the external capacitor is higher than 200 pF, the analog microphone bias becomes unstable. To stabilize it, add a serial resistor.

Table 6-8 lists the characteristics of the analog microphone bias module with a bias resistor.

**Table 6-8. Analog Microphone Bias Module Characteristics With Bias Resistor**

| Parameter                      | Test Conditions                        | Min | Typ        | Max | Unit       |
|--------------------------------|--|-----|------------|-----|------------|
| $R_{\text{SB}}$                | $C_{\text{B}} < 200 \text{ pF}$        | 0   |            |     | $\Omega$   |
|                                | $C_{\text{B}} = 100 \text{ pF}$        | 300 |            |     |            |
|                                | $C_{\text{B}} = 1 \text{ }\mu\text{F}$ | 500 |            |     |            |
| $R_{\text{B}} + R_{\text{SB}}$ |  |     | 2.2 to 2.7 |     | k $\Omega$ |

Figure 6-6 and Figure 6-7 show the external components and application schematics for the analog microphone.

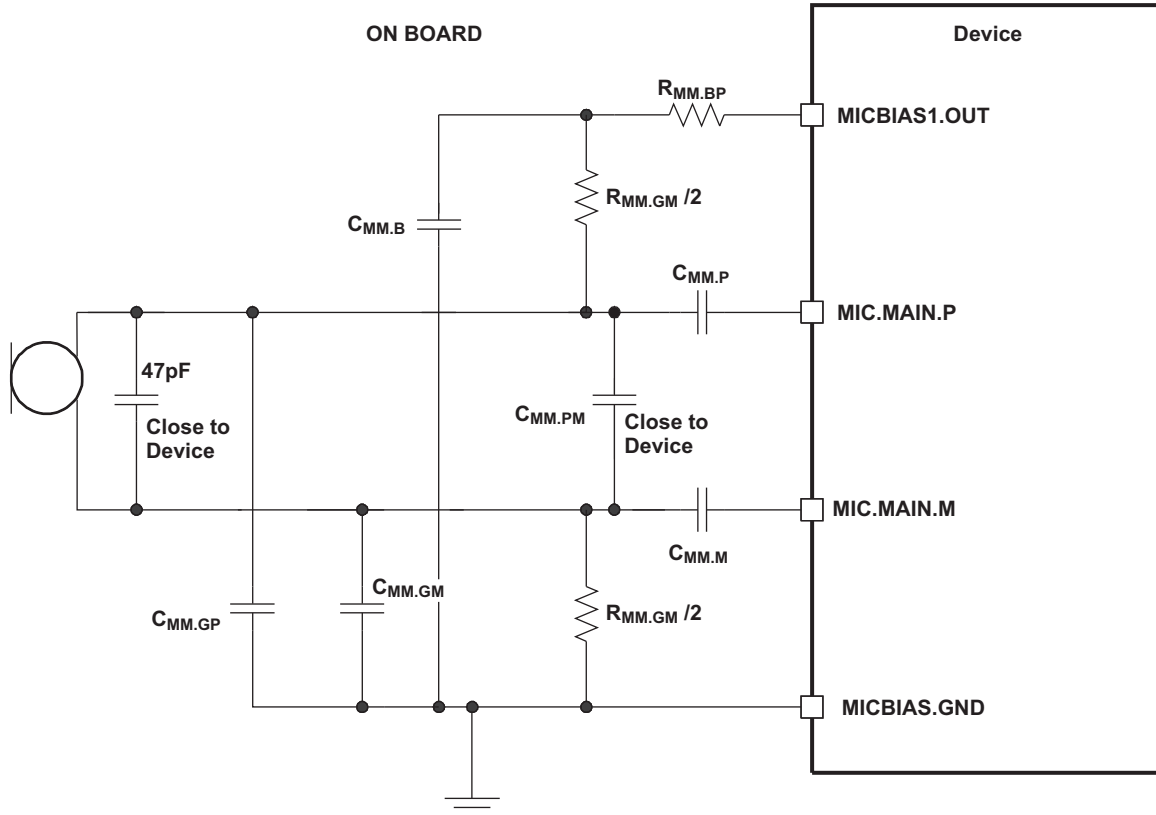


037-005

**Figure 6-6. Analog Microphone Pseudodifferential**

**NOTE**

For other component values, see [Table 14-1](#).



037-006

Figure 6-7. Analog Microphone Differential

**NOTE**

For other component values, see [Table 14-1](#).

**NOTE**

To improve the rejection, ensure that MICBIAS\_GND is as clean as possible. This ground must be shared with AGND of the TPS65920 or TPS65930 device and must not share with AVSS4, which is the ground used by RX class AB output stages.

In differential mode, adding a low-pass filter (made by  $R_{SB}$  and  $C_B$ ) is highly recommended if coupling between RX output stages and the microphone is too high (and not enough attenuation by the echo cancellation algorithm). The coupling can come from:

- The internal TPS65920/TPS65930 coupling between MICBIAS.OUT voltage and RX output stages
- Coupling noise between MICBIAS.GND and AVSS4

In pseudodifferential mode, the dynamic resistance of the microphone improves the rejection versus MICBIAS.OUT:

$$PSRR = 20 \cdot \log((R_B + R_{Dyn\_mic})/R_B).$$

**6.2.1.2 Silicon Microphone Module Characteristics**

Based on silicon micro-electrical-mechanical system (MEMS) technology, the new microphone achieves the same acoustic and electrical properties as conventional microphones, but is more rugged and exhibits higher heat resistance. These properties offer designers of a wide range of products greater flexibility and new opportunities to integrate microphones.

The silicon microphone is the integration of mechanical elements and electronics on a common silicon substrate through microfabrication technology.

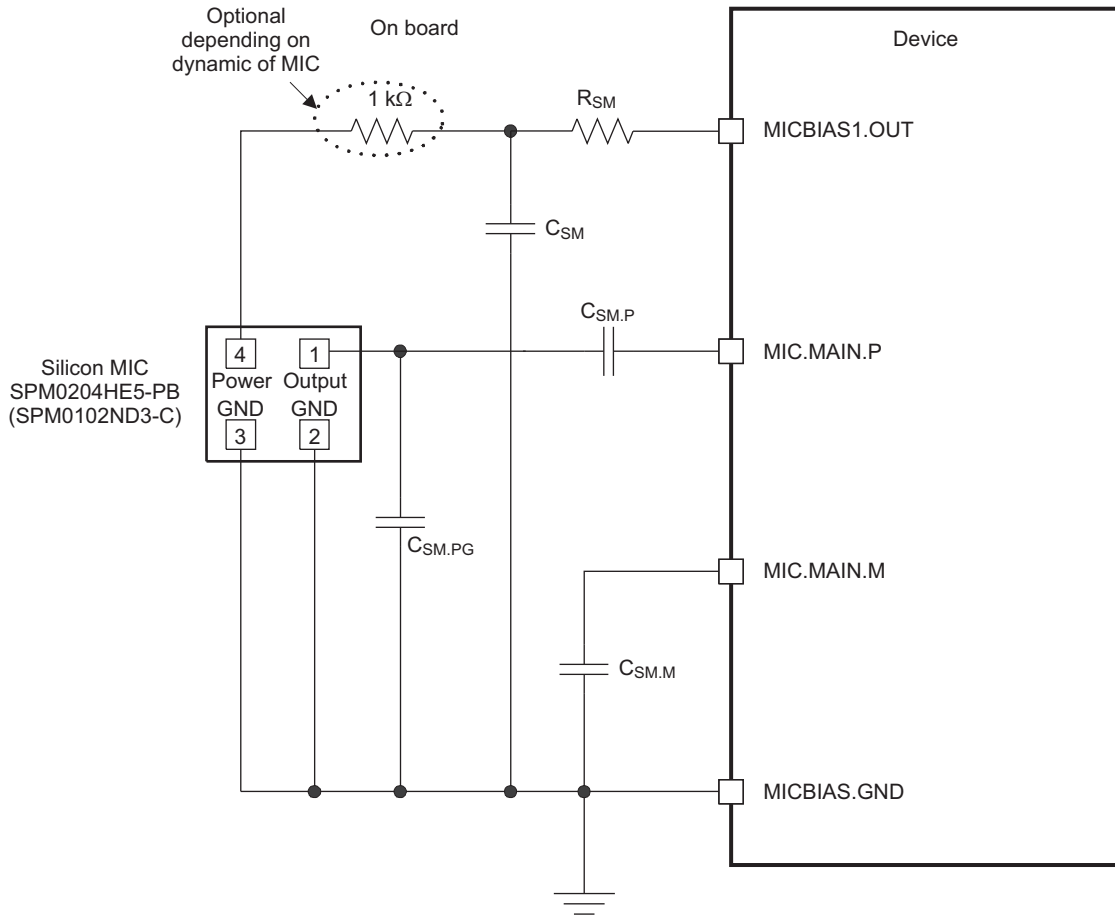
The complementary metal oxide semiconductor (CMOS) MEMS microphone is more like an analog IC than a classical microphone, or electric condenser microphone (ECM). It is powered as an IC with a direct connection to the power supply. The on-chip isolation between the power input and the rest of the system adds power supply rejection (PSR) to the component. This makes the CMOS MEMS microphone inherently more immune to power supply noise than an ECM and eliminates the need for additional filtering circuitry to keep the power supply line clean.

Table 6-9 lists the characteristics of the silicon microphone module.

**Table 6-9. Silicon Microphone Module Characteristics**

| Parameter    | Test Conditions             | Min | Typ | Max | Unit                       |
|--------------|-----------------------------|-----|-----|-----|----------------------------|
| Bias voltage |                             |     | 2.2 |     | V                          |
| Load current |                             |     |     | 1   | mA                         |
| Output noise | P-weighted 20 Hz to 6.6 kHz |     |     | 1.8 | $\mu\text{V}_{\text{RMS}}$ |

Figure 6-8 is a schematic for the silicon microphone.



037-007

**Figure 6-8. Silicon Microphone**

**NOTE**

For other component values, see Table 14-1.



## 6.2.2 FM Radio/Auxiliary Input

The auxiliary input AUXR/FMR can be used as FM radio input. The amplification stage output is connected to the ADC input. The FM radio input can also be output through an audio output stage.

### 6.2.2.1 External Components

Figure 6-9 shows the external components on the auxiliary input.

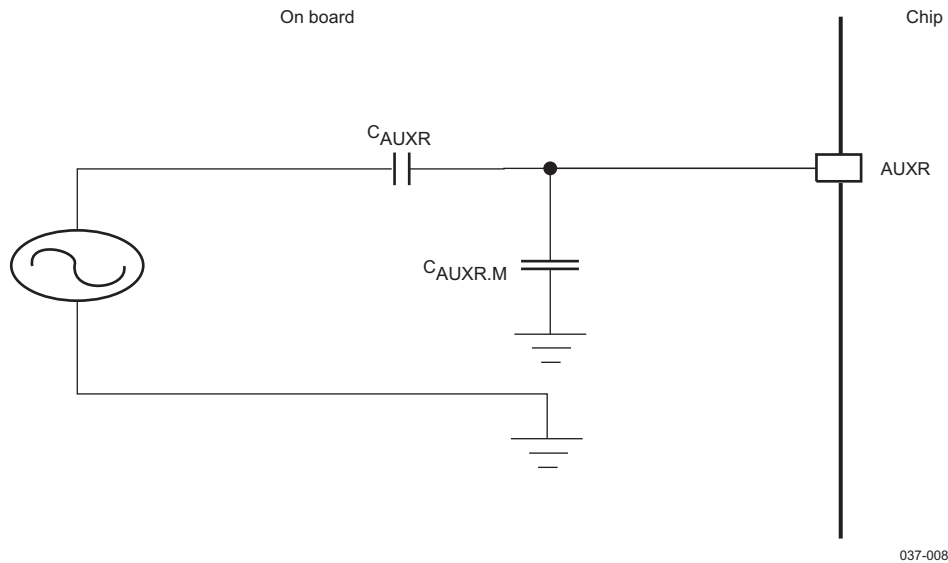


Figure 6-9. Audio Auxiliary Input

#### NOTE

For other component values, see Table 14-1.

## 6.2.3 Uplink Characteristics

Figure 6-10 shows the uplink amplifier. Table 6-10 lists the uplink characteristics.

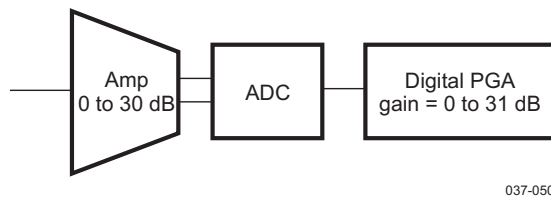


Figure 6-10. Uplink Amplifier

Table 6-10. Uplink Characteristics

| Parameter  | Test Conditions                             | Min | Typ | Max | Unit            |
|--|---|-----|-----|-----|-----------------|
| Speech delay                                     | Voice path                                  |     | 0.5 |     | ms              |
| Gain range <sup>(1)</sup>                        |   | 0   |     | 61  | dB              |
| Absolute gain                                    | 0 dBFs at 1.02 kHz                          | -1  |     | 1   | dB              |
| Peak-to-peak differential input voltage (0 dBFs) | For differential input<br>0 dB gain setting |     |     | 1.5 | V <sub>PP</sub> |

(1) Gain range is defined by: Preamplifier = 0 to 30 dB; Filter = 0 to 31 dB (1-dB steps)

**Table 6-10. Uplink Characteristics (continued)**

| Parameter   | Test Conditions                             | Min | Typ | Max | Unit            |
|---|---|-----|-----|-----|-----------------|
| Peak-to-peak single-ended input voltage (0 dBFs)  | For single-ended input<br>0 dB gain setting |     |     | 1.5 | V <sub>PP</sub> |
| Input impedance <sup>(2)</sup>                    |   | 40k |     | 70k | Ω               |
| Total harmonic distortion (sine wave at 1.02 kHz) | At -1 dBFs                                  |     | -80 | -75 | dB              |
|   | At -6 dBFs                                  |     | -74 | -69 |                 |
|   | At -10 dBFs                                 |     | -70 | -65 |                 |
|   | At -20 dBFs                                 |     | -60 | -55 |                 |
|   | At -60 dBFs                                 |     | -20 | -15 |                 |
| Idle channel noise                                | 20 Hz to 20 kHz, A-weighted, gain = 0 dB    |     | -85 | -78 | dBfs            |
|   | 16 kHz: < 20 Hz to 7 kHz, gain = 0 dB       |     | -90 |     |                 |
|   | 8 kHz: P-weighted voice, gain = 18 dB       |     | -87 |     |                 |
|   | 16 kHz: < 20 Hz to 7 kHz, gain = 18 dB      |     | -82 |     |                 |
| Crosstalk A/D to D/A                              | Gain = 0 dB                                 |     | -80 |     | dB              |
| Crosstalk path between two microphones            |   | -70 |     |     | dB              |
| Intermodulation distortion                        | 2-tone method                               |     |     | -60 | dB              |

(2) Impedance varies in the specified range with gain selection.

#### 6.2.4 Microphone Amplification Stage

The microphone amplification stages perform the single-to-differential conversion for single-ended inputs. Two programmable gains from 0 dB to 30 dB can be set:

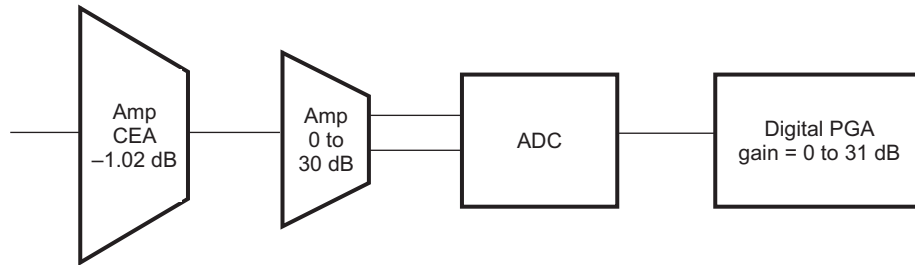
- Automatic level control for main microphone input. The gain step is 1 dB.
- Level control by register for line-in or carkit input. The gain step is 6 dB.

The amplification stage outputs are connected to the ADC input (ADC left and right).

### 6.2.5 Carkit Input

The USB-CEA carkit uses the DP pad to input the audio signal.

Figure 6-11 shows the uplink carkit full path uplink characteristics for audio and USB.



037-009

**Figure 6-11. Carkit Input Uplink Path Characteristics**

Table 6-11 lists the USB-CEA carkit audio electrical characteristics.

**Table 6-11. USB-CEA Carkit Audio Uplink Electrical Characteristics**

| Parameter  | Test Conditions              | Min  | Typ | Max   | Unit            |
|--|------------------------------|------|-----|-------|-----------------|
| Gain range <sup>(1)</sup>  |                              | -1   |     | 60    | dB              |
| Absolute gain, 0 dBFs at 1.02 kHz <sup>(1) (2)</sup>                   | USB-CEA default gain setting | -1.5 |     | 1.5   | dB              |
| Speech delay   | Voice path                   |      | 0.5 |       | ms              |
| Input common mode voltage <sup>(3)</sup>                               | USB-CEA                      | 1.3  |     | 1.9   | V               |
| Phone microphone amplifier input impedance at 1 kHz                    | USB-CEA                      | 8    | 120 |       | kΩ              |
| Peak-to-peak single-ended input voltage (0 dBFs)                       | Default setting              |      |     | 1.414 | V <sub>PP</sub> |
| Total harmonic distortion (sine wave at 1 kHz), default gain setting   | At -1 dBFs                   |      | -74 | -60   | dB              |
|  | At -6 dBFs                   |      |     |       |                 |
|  | At -10 dBFs                  |      |     |       |                 |
|  | At -20 dBFs                  |      |     |       |                 |
|  | At -60 dBFs                  |      |     |       |                 |
| THD+N (20 Hz to 20 kHz, A-weighted)                                    | At 0 dBFs                    |      | 60  |       | dB              |
| Signal noise ratio (20 Hz to 20 kHz, A-weighted)                       | At 0 dBFs                    |      | 60  |       | dB              |
| Idle channel noise (20 Hz to 20 kHz, A-weighted), default gain setting | USB-CEA                      |      | -77 |       | dBFs            |
| Output PSRR (20 Hz to 20 kHz, A-weighted)                              | USB-CEA                      |      | 50  |       | dB              |

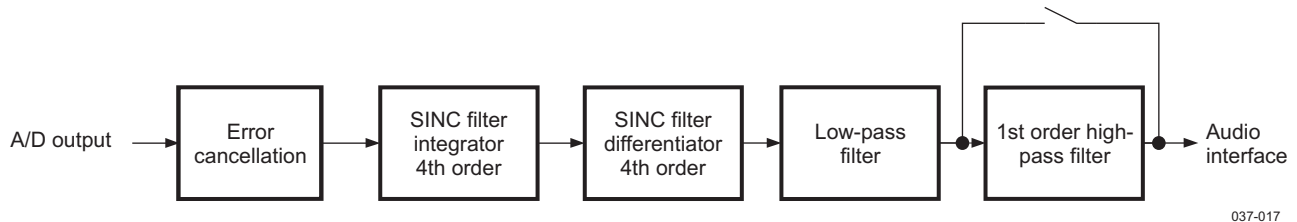
(1) Gain range is defined by: CEA amplifier = 0.56 to -1.02 dB; Preampifier = 0 to 30 dB; Filter = 0 to 31 dB (1-dB steps).

(2) The CEA default gain setting assumes 0 dB on the preampifier, 1 dB on digital filter, and CEA amplifier at -1.02 dB.

(3) Full-scale input voltage is 1 V minimum.

### 6.2.6 Digital Audio Filter Module

Figure 6-12 shows the digital audio filter uplink full path characteristics for the audio interface.



**Figure 6-12. Digital Audio Filter Uplink Path Characteristics**

The high-pass filter (HPF) can be bypassed. It is controlled by the MISC\_SET\_2 ATX\_HPF\_BYP bit set to address 0x49.

Table 6-12 lists the audio filter frequency responses relative to reference gain at 1 kHz.

**Table 6-12. Digital Audio Filter TX Electrical Characteristics**

| Parameter            | Test Conditions   | Min    | Typ        | Max  | Unit    |
|----------------------|---|--------|------------|------|---------|
| Passband             |   | 0.0005 |            | 0.42 | $F_S$   |
| Passband gain        | In region $0.0005 \cdot F_S$ to $0.42 \cdot F_S$ <sup>(1)</sup> | -0.25  |            | 0.25 | dB      |
| Stopband             |   |        | 0.6        |      | $F_S$   |
| Stopband attenuation | In region $0.6 \cdot F_S$ to $1 \cdot F_S$ <sup>(1)</sup>       |        | 60         |      | dB      |
| Group delay          |   |        | $15.8/F_S$ |      | $\mu s$ |

(1)  $F_S$  is the sampling frequency (8, 11.025, 12, 16, 22.05, 24, 32, 44.1, or 48 kHz).

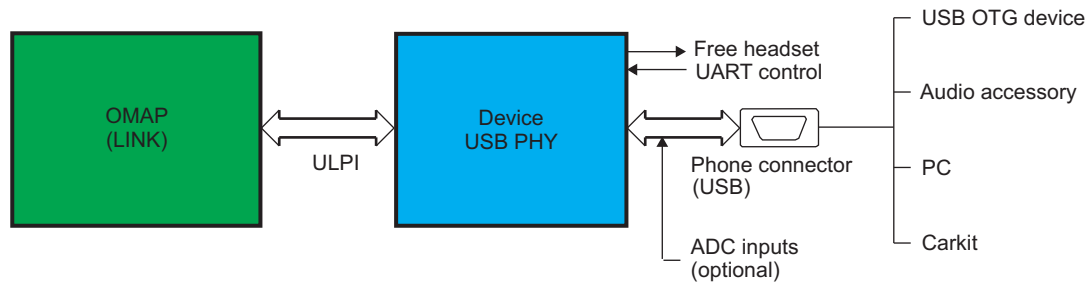
## 7 USB Transceiver

### 7.1 USB Transceiver

The TPS65920/TPS65930 device includes a USB OTG transceiver with the CEA carkit interface that supports USB 480 Mbps HS, 12 Mbps full-speed (FS), and USB 1.5 Mbps low-speed (LS) through a 4-pin ULPI.

The carkit block ensures the interface between the phone and a carkit device. The TPS65920/TPS65930 USB supports the CEA carkit standard.

Figure 7-1 is a block diagram of the USB 2.0 physical layer (PHY).



037-011

**Figure 7-1. USB 2.0 PHY Block Diagram**

#### 7.1.1 Features

The device has a USB OTG carkit transceiver that allows system implementation that complies with the following specifications:

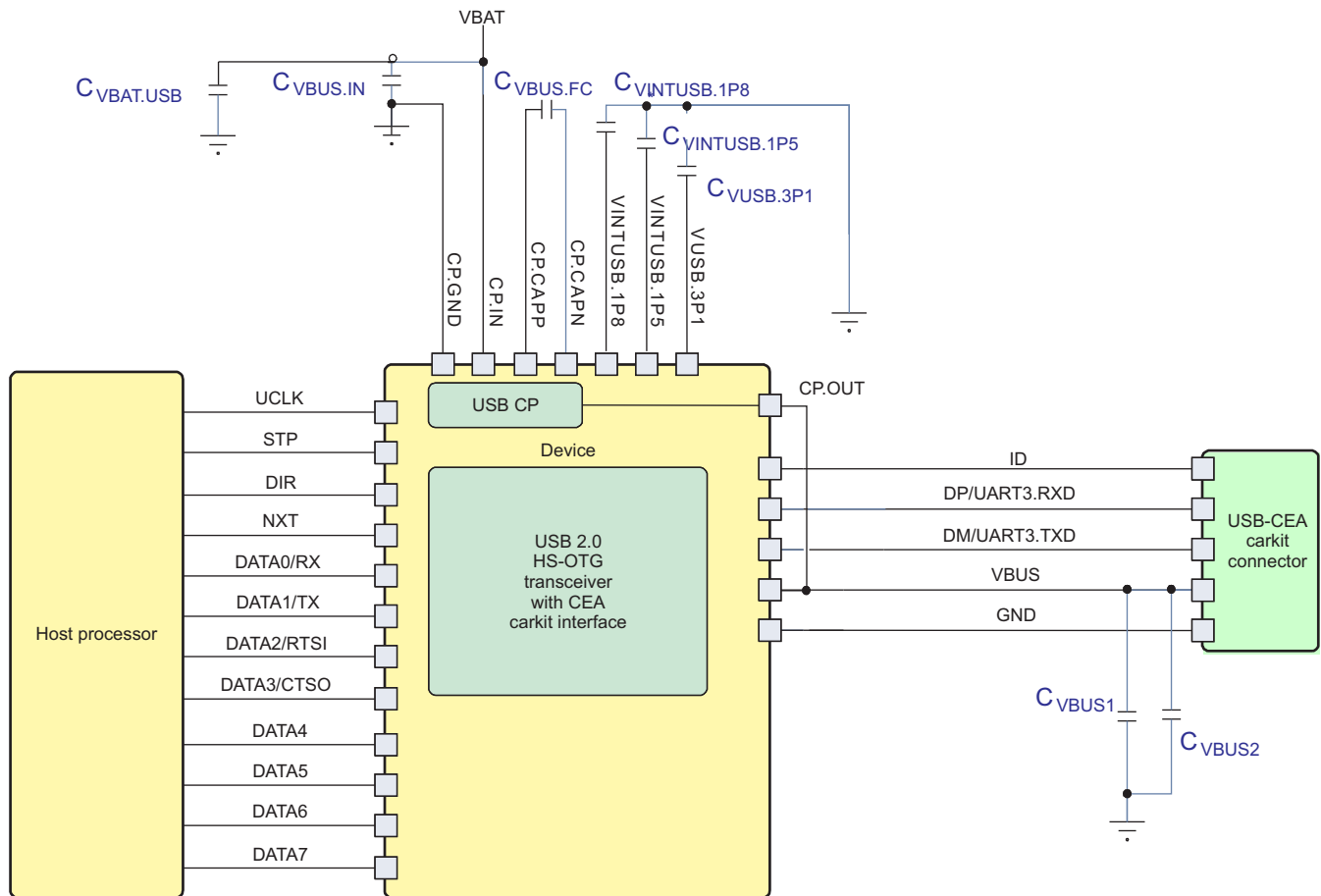
- *Universal Serial Bus 2.0 Specification*
- *On-The-Go Supplement to the USB 2.0 Specification*
- *CEA-2011: OTG Transceiver Interface Specification*
- *CEA-936A: Mini-USB Analog Carkit Specification*
- *UTMI+ Low Pin Interface Specification*

The features of the individual specifications are:

- *Universal Serial Bus 2.0 Specification* (hereafter referred to as the USB 2.0 specification):
  - 5-V-tolerant data line at HS/FS, FS-only, and LS-only transmission rates
  - 7-V-tolerant video bus (VBUS) line
  - Integrated data line serial termination resistors (factory-trimmed)
  - Integrated data line pullup and pulldown resistors
  - On-chip 480-MHz phase-locked loop (PLL) from the internal system clock (19.2, 26, and 38.4 MHz)
  - Synchronization (SYNC)/end-of-period (EOP) generation and checking
  - Data and clock recovery from the USB stream
  - Bit-stuffing/unstuffing and error detection
  - Resume signaling, wakeup, and suspend detection
  - USB 2.0 test modes
- *On-The-Go Supplement to the USB 2.0 Specification* (hereafter referred to as the OTG supplement to the USB 2.0 specification):
  - 3-pin LS/FS serial mode (DAT\_SE0)
  - 4-pin LS/FS serial mode (VP\_VM)
- *CEA-936A: Mini-USB Analog Carkit Interface Specification*:
  - 5-pin CEA mini-USB analog carkit interface

- UART signaling
- Audio (mono/stereo) signaling
- UART transactions during audio signaling
- Basic and smart 4-wire/5-wire carkit, chargers, and accessories
- ID CEA resistor comparators
- *UTMI+ Low Pin Interface Specification* (hereafter referred to as the ULPI specification):
  - 12-pin ULPI with 8-pin parallel data for USB signaling and register access
  - 60-MHz clock generation
  - Register mapping

Figure 7-2 is the USB system application schematic.



037-012

**Figure 7-2. USB System Application Schematic**

**NOTE**

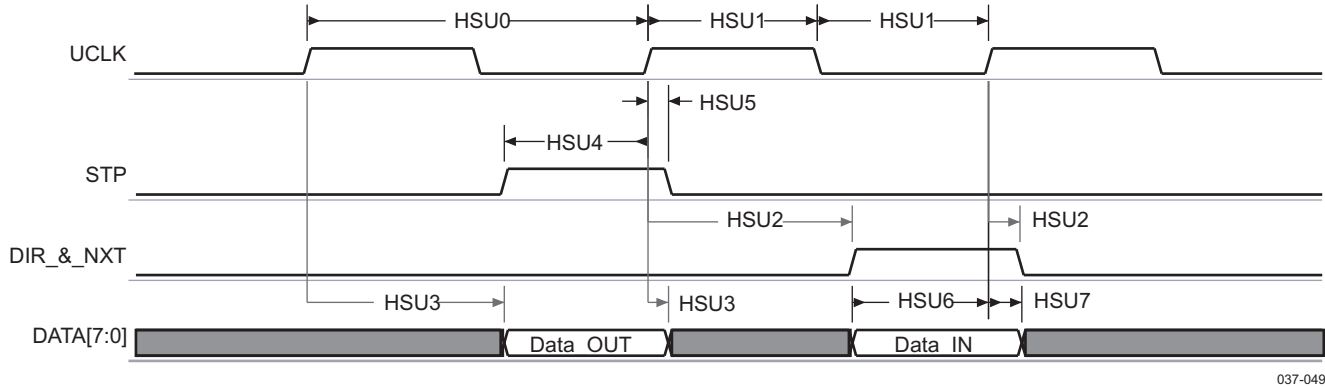
For the component values, see [Table 14-1](#).

**7.1.2 HS USB Port Timing**

The ULPI interface supports an 8-bit data bus and the internal clock mode. The 4-bit data bus and the external clock mode are not supported.

The HS functional mode supports an operating rate of 480 Mbps.

[Table 7-1](#) and [Table 7-2](#) assume testing over the recommended operating conditions (see [Figure 7-3](#)).



**Figure 7-3. HS-USB Interface—Transmit and Receive Modes (ULPI 8-bit)**

**NOTE**

ULPI data [7:0] lines are set to 1 after USB PHY power up, and before the clock signal is stable.

The input timing requirements are given by considering a rising or falling time of 1 ns (see [Table 7-1](#)).

**Table 7-1. HS-USB Interface Timing Requirements**

| Notation | Parameter           |   | Min | Max | Unit |
|----------|---------------------|---|-----|-----|------|
| HSU4     | $t_{s(STPV-CLKH)}$  | Setup time, STP valid before UCLK rising edge       | 6   |     | ns   |
| HSU5     | $t_{h(CLKH-STPIV)}$ | Hold time, STP valid after UCLK rising edge         | 0   |     | ns   |
| HSU6     | $t_{s(DATAV-CLKH)}$ | Setup time, DATA[0:7] valid before UCLK rising edge | 6   |     | ns   |
| HSU7     | $t_{h(CLKH-DATIV)}$ | Hold time, DATA[0:7] valid after UCLK rising edge   | 0   |     | ns   |

[Table 7-2](#) lists the HS-USB interface switching requirements.

**Table 7-2. HS-USB Interface Switching Requirements<sup>(1)</sup>**

| Notation | Parameter <sup>(1)</sup> |  |              | Min   | Typ | Max   | Unit |
|----------|--------------------------|--|--------------|-------|-----|-------|------|
| HSU0     | $f_{p(CLK)}$             | UCLK clock frequency                                 | Steady state | 58.42 | 60  | 61.67 | MHz  |
| HSU1     | $t_{W(CLK)}$             | UCLK duty cycle                                      | Steady state | 48.3% | 50% | 51.7% |      |
| HSU2     | $t_{d(CLKH-DIR)}$        | Delay time, UCLK rising edge to DIR transition       | Steady state | 0     |     | 9     | ns   |
|          | $t_{d(CLKH-NXTV)}$       | Delay time, UCLK rising edge to NXT transition       | Steady state | 0     |     | 9     | ns   |
| HSU3     | $t_{d(CLKH-DATIV)}$      | Delay time, UCLK rising edge to DATA[0:7] transition | Steady state | 0     |     | 9     | ns   |

(1) The capacitive load for output data and control load is 10 pF (rising and falling time is 2 ns).  
 The capacitive load for the CLK port is 6 pF (rising and falling time is 1 ns).  
 The HS-USB interface has only one state: the steady state.

**7.1.3 USB-CEA CarKit Port Timing**

This mode allows the link for communication through the USB PHY to a remote carkit in CEA audio + data during audio (DDA) mode as defined in the CEA-936A specification. In this mode, the ULPI data bus is redefined as a 2-pin UART interface, which exchanges data through a direct access to the FS/LS analog transmitter and receiver.

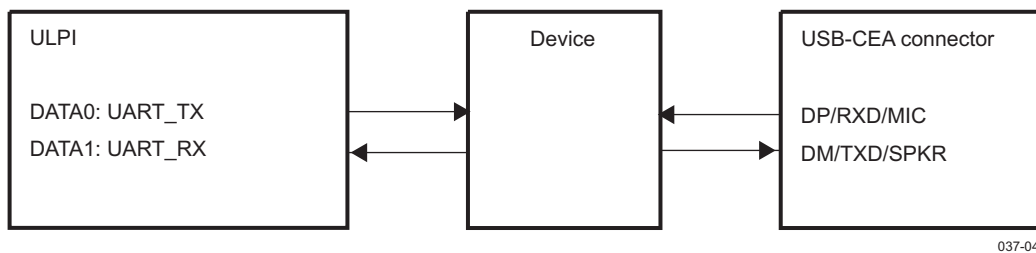
UART data are sent and received on the USB D+/D– pads. D+/D– are also used in this mode to carry audio I/O signals.

Table 7-3 assumes testing over the recommended operating conditions (see the CEA-936A specification).

**Table 7-3. USB-CEA Carkit Interface Timing Parameters**

| Parameter                 |  | Min | Max  | Unit |
|---------------------------|--|-----|------|------|
| t <sub>PH_DP_CON</sub>    | Phone D+ connect time                          | 100 |      | ms   |
| t <sub>CR_DP_CON</sub>    | Carkit D+ connect time                         | 150 | 300  | ms   |
| t <sub>PH_DM_CON</sub>    | Phone D– connect time                          |     | 10   | ms   |
| t <sub>PH_CMD_DLY</sub>   | Phone command delay                            | 2   |      | ms   |
| t <sub>PH_MONO_ACK</sub>  | Phone mono acknowledge                         |     | 10   | ms   |
| t <sub>PH_DISC_DET</sub>  | Phone D+ disconnect time                       | 150 |      | ms   |
| t <sub>CR_DISC_DET</sub>  | Carkit D– disconnect detect                    | 50  | 150  | ms   |
| t <sub>PH_AUD_BIAS</sub>  | Phone audio bias                               | 1   |      | ms   |
| t <sub>CR_AUD_DET</sub>   | Carkit audio detect                            | 400 | 800  | µs   |
| t <sub>CR_UART_DET</sub>  | Carkit UART detect (data-during-audio enabled) | 700 | 1200 | ns   |
| t <sub>PH_STLO_DET</sub>  | Phone stereo D+ low detect                     | 30  | 100  | ms   |
| t <sub>PH_PLS_POS</sub>   | Phone D– interrupt pulse width                 | 200 | 600  | ns   |
| t <sub>CR_PLS_NEG</sub>   | Carkit D+ interrupt pulse width                | 200 | 600  | ns   |
| t <sub>DAT_AUD_POL</sub>  | Data-during-audio polarity                     | 20  | 60   | ms   |
| t <sub>ACC_COL_DET</sub>  | Accessory ID collision detect                  | 2   | 3    | ms   |
| t <sub>ACC_INT_PW</sub>   | Accessory ID interrupt pulse width             | 200 | 400  | µs   |
| t <sub>ACC_INT_WAIT</sub> | Accessory ID interrupt wait time               | 10  | 15   | ms   |
| t <sub>ACC_CMD_WAIT</sub> | Accessory ID command wait time                 | 0   |      | ms   |
| t <sub>PH_INT_PW</sub>    | Phone ID interrupt pulse width                 | 4   | 8    | ms   |
| t <sub>PH_INT_WAIT</sub>  | Phone ID interrupt wait time                   | 4   | 8    | ms   |
| t <sub>PH_CMD_WAIT</sub>  | Phone ID command wait time                     | 0   |      | ms   |
| t <sub>PH_UART_RPT</sub>  | Phone command repeat time                      | 50  |      | ms   |
| t <sub>CR_UART_RSP</sub>  | Carkit UART response                           |     | 30   | ms   |
| t <sub>CR_INT_RPT</sub>   | Carkit interrupt repeat time                   | 50  |      | ms   |
| f <sub>UART_DFLT</sub>    | Default UART signaling rate (typical rate)     |     | 9600 | bps  |

Figure 7-4 shows the USB-CEA carkit UART data flow.



**Figure 7-4. USB-CEA Carkit UART Data Flow**

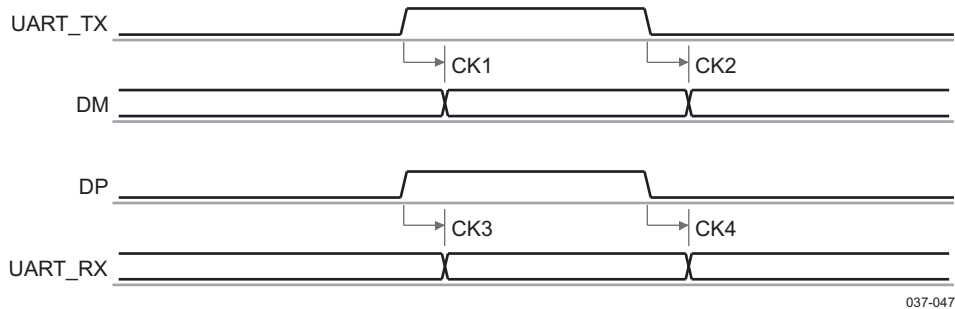
Table 7-4 lists the USB-CEA carkit UART timings.



**Table 7-4. USB-CEA Carkit UART Timings**

| Notation | Parameter             |   | Min         | Max | Unit |    |
|----------|-----------------------|---|-------------|-----|------|----|
| CK1      | $t_{d(UART\_TXH-DM)}$ | Delay time, UART_TX rising edge to DM transition  | 4.0         | 11  | ns   |    |
| CK2      | $t_{d(UART\_TXL-DM)}$ | Delay time, UART_TX falling edge to DM transition | 4.0         | 11  | ns   |    |
| CK3      | $t_{d(DPH-UART\_RX)}$ | Delay time, DP rising edge to UART_RX transition  | At 38.4 MHz | 205 | 234  | ns |
|          |                       |   | At 19.2 MHz | 310 | 364  |    |
| CK4      | $t_{d(DPL-UART\_RX)}$ | Delay time, DP falling edge to UART_RX transition | At 38.4 MHz | 205 | 234  | ns |
|          |                       |   | At 19.2 MHz | 310 | 364  |    |

Figure 7-5 shows the USB-CEA carkit UART timings.



**Figure 7-5. USB-CEA Carkit UART Timings**

### 7.1.4 PHY Electrical Characteristics

The PHY is the physical signaling layer of the USB 2.0. It contains the drivers and receivers for physical data and protocol signaling on the DP and DM lines.

The PHY interfaces with the USB controller through the UTMI.

The transmitters and receivers in the PHY are of two main classes:

- FS and LS transceivers (legacy USB1.x transceivers)
- HS transceivers

To bias the transistors and run the logic, the PHY also contains reference generation circuitry which consists of:

- A DPLL that does a frequency multiplication to achieve the 480-MHz low-jitter lock necessary for USB, and the clock required for the switched capacitor resistance block
- A switched capacitor resistance block that replicates an external resistor on chip

Built-in pullup and pulldown resistors are used as part of the protocol signaling.

The PHY also contains circuitry that protects it from an accidental 5-V short on the DP and DM lines and from 8-kV IEC ESD strikes.

#### 7.1.4.1 HS Differential Receiver

The HS receiver consists of the following blocks:

- A differential input comparator to receive the serial data
- A squelch detector to qualify the received data
- An oversampler-based clock data recovery scheme followed by a nonreturn to zero inverted (NRZI) decoder, bit unstuffing, and serial-to-parallel converter to generate the UTMI DATAOUT

Table 7-5 lists the characteristics of the HS differential receiver.

**Table 7-5. HS Differential Receiver**

| Parameter  |               | Comments                        | Min  | Typ | Max | Unit     |
|--|---------------|---------------------------------|------|-----|-----|----------|
| <b>Input Levels for HS</b>   |               |                                 |      |     |     |          |
| HS squelch detection threshold   | $V_{HSSQ}$    | (Differential signal amplitude) | 100  | 125 | 150 | mV       |
| HS disconnect detection threshold  | $V_{HSDSC}$   | (Differential signal amplitude) | 525  | 600 | 625 | mV       |
| HS data signaling common mode voltage range  | $V_{HSCM}$    |                                 | –50  | 200 | 500 | mV       |
| HS differential input sensitivity  | $V_{DIHS}$    | (Differential signal amplitude) | –100 |     | 100 | mV       |
| <b>Input Impedance for HS</b>  |               |                                 |      |     |     |          |
| Internal specification for input capacitance                                       | $C_{HSLOAD}$  |                                 |      | 11  |     | pF       |
| Internal $C_{HSLOAD}$ DP/DM matching   | $C_{HSLOADM}$ |                                 |      | 0.2 |     | pF       |
| <b>External Components With the Total Budget Combined (without USB cable load)</b> |               |                                 |      |     |     |          |
| External capacitance on DP or DM   |               |                                 |      |     | 2   | pF       |
| External series resistance on DP or DM   |               |                                 |      |     | 1   | $\Omega$ |

### 7.1.4.2 HS Differential Transmitter

The HS transmitter is always operated on the UTMI parallel interface. The parallel data on the interface is serialized, bit stuffed, NRZI encoded, and transmitted as a dc output current on DP or DM, depending on the data. Each line has an effective 22.5- $\Omega$  load to ground, which generates the voltage levels for signaling.

A disconnect detector is also part of the HS transmitter. A disconnect on the far end of the cable causes the impedance seen by the transmitter to double, thereby doubling the differential amplitude seen on the DP/DM lines.

Table 7-6 lists the characteristics of the HS differential transmitter.

**Table 7-6. HS Differential Transmitter**

| Parameter                     |               | Comments   | Min  | Typ  | Max  | Unit     |
|-------------------------------|---------------|--|------|------|------|----------|
| <b>Output Levels for HS</b>   |               |  |      |      |      |          |
| HS TX idle level              | $V_{HSOI}$    | Absolute voltage DP/DM – internal/external 45 $\Omega$ | –10  | 0    | 10   | mV       |
| HS TX data signaling high     | $V_{HSOH}$    | Absolute voltage DP/DM – internal/external 45 $\Omega$ | 360  | 400  | 440  | mV       |
| HS data signaling low         | $V_{HSOL}$    |  | –10  | 0    | 10   | mV       |
| Chirp J level                 | $V_{CHIRPJ}$  | Differential voltage                                   | 700  | 800  | 1100 | mV       |
| Chirp K level                 | $V_{CHIRPK}$  | Differential voltage                                   | –900 | –800 | –500 | mV       |
| HS TX disconnect threshold    | $V_{DISCOUT}$ | Absolute voltage DP/DM – no external 45 $\Omega$       | 700  |      |      | mV       |
| <b>Driver Characteristics</b> |               |  |      |      |      |          |
| Rise time                     | $t_{HSR}$     | (10%–90%)  | 500  |      |      | ps       |
| Fall time                     | $t_{HSF}$     | (10%–90%)  | 500  |      |      | ps       |
| Driver output resistance      | $Z_{HSDRV}$   | Also serves as HS termination                          | 40.5 | 45   | 49.5 | $\Omega$ |

### 7.1.4.3 CEA/UART Driver

Table 7-7 lists the characteristics of the CEA/UART driver.

**Table 7-7. CEA/UART Driver**

| Parameter                      |                           | Comments                         | Min | Typ | Max | Unit |
|--------------------------------|---------------------------|----------------------------------|-----|-----|-----|------|
| <b>UART Driver CEA</b>         |                           |                                  |     |     |     |      |
| Phone UART edge rates          | t <sub>PH_UART_EDGE</sub> | DP_PULLDOWN asserted             |     |     | 1   | μs   |
| Serial interface output high   | V <sub>OH_SER</sub>       | ISOURCE = 4 mA                   | 2.4 | 3.3 | 3.6 | V    |
| Serial interface output low    | V <sub>OL_SER</sub>       | ISINK = –4 mA                    | 0   | 0.1 | 0.4 | V    |
| <b>Carkit Pulse Driver</b>     |                           |                                  |     |     |     |      |
| Pulse match tolerance          | QPLS_MTCH                 | ZCR_SPKR_IN = 60 kΩ at f = 1 kHz |     |     | 5%  |      |
| Phone D– interrupt pulse width | t <sub>PH_PLS_POS</sub>   | ZCR_SPKR_IN = 60 kΩ at f = 1 kHz | 200 |     | 600 | ns   |
| Phone positive pulse voltage   | V <sub>PH_PLS_POS</sub>   | ZCR_SPKR_IN = 60 kΩ at f = 1 kHz | 2.8 |     | 3.6 | V    |

### 7.1.4.4 Pullup/Pulldown Resistors

Table 7-8 lists the characteristics of pullup/pulldown resistors.

**Table 7-8. Pullup/Pulldown Resistors**

| Parameter   |                           | Comments   | Min   | Typ | Max   | Unit |
|---|---------------------------|--|-------|-----|-------|------|
| <b>Pullup Resistors</b>                                     |                           |  |       |     |       |      |
| Bus pullup resistor on upstream port (idle bus)             | R <sub>PUI</sub>          | Bus idle   | 0.9   | 1.1 | 1.575 | kΩ   |
| Bus pullup resistor on upstream port (receiving)            | R <sub>PUA</sub>          | Bus driven/driver outputs unloaded                               | 1.425 | 2.2 | 3.09  |      |
| High (floating)   | V <sub>IHZ</sub>          | Pullups/pulldowns on DP and DM lines                             | 2.7   |     | 3.6   | V    |
| Phone D+ pullup voltage                                     | V <sub>PH_DP_UP</sub>     | Driver outputs unloaded  | 3     | 3.3 | 3.6   | V    |
| <b>Pulldown Resistors</b>                                   |                           |  |       |     |       |      |
| Phone D+/- pulldown   | R <sub>PH_DP_DWN</sub>    | Driver outputs unloaded  | 14.25 | 18  | 24.8  | kΩ   |
|   | R <sub>PH_DM_DWN</sub>    |  |       |     |       |      |
| High (floating)   | V <sub>IHZ</sub>          | Pullups/pulldowns on DP and DM lines                             | 2.7   |     | 3.6   | V    |
| <b>D+/- Data Line</b>                                       |                           |  |       |     |       |      |
| Upstream facing port  | C <sub>INUB</sub>         | [1.0]  |       | 22  | 75    | pF   |
| OTG device leakage  | V <sub>OTG_DATA_LKG</sub> | [2]  |       |     | 0.342 | V    |
| Input impedance exclusive of pullup/pulldown <sup>(1)</sup> | Z <sub>INP</sub>          | Driver outputs unloaded (waiver from USB.ORG Standard Committee) | 80    | 120 |       | kΩ   |

(1) Waiver received from usb.org standards committee on ZINP 300kmin specification

### 7.1.5 OTG Electrical Characteristics

The OTG block integrates three main functions:

- The USB plug detection function on VBUS and ID
- The ID resistor detection
- The VBUS level detection

### 7.1.5.1 OTG VBUS Electrical Characteristics

Table 7-9 lists the electrical characteristics of the OTG VBUS.

**Table 7-9. OTG VBUS Electrical Characteristics**

| Parameter  | Comments                     | Min  | Typ | Max   | Unit |
|--|------------------------------|--|-----|-------|------|
| <b>VBUS Wake-Up Comparator</b>   |                              |  |     |       |      |
| VBUS wake-up delay   | DEL_VBUS_WK_UP               |  |     | 15    | μs   |
| VBUS wake-up threshold   | V_VBUS_WK_UP                 | 0.5  | 0.6 | 0.7   | V    |
| <b>VBUS Comparators</b>  |                              |  |     |       |      |
| A-device session valid   | V_A_SESS_VLD                 | 0.8  | 1.1 | 1.4   | V    |
| A-device V <sub>BUS</sub> valid  | V_A_VBUS_VLD                 | 4.4  | 4.5 | 4.6   | V    |
| B-device session end   | V_B_SESS_END                 | 0.2  | 0.5 | 0.8   | V    |
| B-device session valid   | V_B_SESS_VLD                 | 2.1  | 2.4 | 2.7   | V    |
| <b>VBUS Line</b>   |                              |  |     |       |      |
| A-device V <sub>BUS</sub> input impedance to ground                          | R_A_BUS_IN                   | SRP (V <sub>BUS</sub> pulsing) capable A-device not driving V <sub>BUS</sub> |     | 100   | kΩ   |
| B-device V <sub>BUS</sub> SRP pulldown                                       | R_B_SRP_DWN                  | 5.25 V/8 mA, pullup voltage = 3 V  |     | 0.656 | 10   |
| B-device V <sub>BUS</sub> SRP pullup   | R_B_SRP_UP                   | (5.25 V – 3 V)/8 mA, pullup voltage = 3 V                                    |     | 0.281 | 1    |
| B-device V <sub>BUS</sub> SRP rise time maximum for OTG-A communication      | t <sub>RISE_SRP_UP_Max</sub> | 0 to 2.1 V with < 13 μF load   |     | 36    | ms   |
| B-device V <sub>BUS</sub> SRP rise time minimum for standard host connection | t <sub>RISE_SRP_UP_Min</sub> | 0.8 to 2.0 V with > 97 μF load   |     | 60    | ms   |
| VBUS line maximum voltage  |                              | If VBUS_CHRG bit is low  |     | 7     | V    |

### 7.1.5.2 OTG ID Electrical Characteristics

Table 7-10 lists the electrical characteristics of OTG ID.

**Table 7-10. OTG ID Electrical Characteristics**

| Parameter   | Comments   | Min  | Typ | Max  | Unit |
|---|------------|--|-----|------|------|
| <b>ID Wake-Up Comparator</b>                                |            |  |     |      |      |
| ID wake-up comparator                                       | R_ID_WK_UP | Wake-up when ID shorted to ground through a resistor lower than 445 kΩ (±1%)       |     | 445  | kΩ   |
| <b>ID Comparators — ID External Resistor Specifications</b> |            |  |     |      |      |
| ID ground comparator  | R_ID_GND   | ID_GND interrupt when ID shorted to ground through a resistor lower than 10 Ω      |     | 0    | 5    |
| ID 100k comparators   | R_ID_100K  | ID_100K interrupt when 102 kΩ (1%) resistor plugged in                             |     | 101  | 102  |
| ID 200k comparators   | R_ID_200K  | ID_200K interrupt when 200 kΩ (1%) resistor plugged in                             |     | 198  | 200  |
| ID 440k comparators   | R_ID_440K  | ID_440K interrupt when 440 kΩ (1%) resistor plugged in                             |     | 435  | 440  |
| ID Float comparator   | R_ID_FLOAT | ID_FLOAT interrupt when ID shorted to ground through a resistor higher than 560 kΩ |     | 1400 |      |
| <b>ID Line</b>  |            |  |     |      |      |
| Phone I <sub>D</sub> pullup to V <sub>PH_ID_UP</sub>        | R_PH_ID_UP | ID unloaded (VRUSB)  |     | 70   | 200  |
| Phone I <sub>D</sub> pullup voltage                         | V_PH_ID_UP | Connected to VRUSB   |     | 2.5  | 3.2  |
| ID line maximum voltage                                     |            |  |     |      | 5.25 |



## 8 MADC

### 8.1 General Description

The TPS65920/TPS65930 device provides the MADC resource to the host processors in the system (hardware and software conversion modes).

The MADC generates interrupt signals to the host processors. Interrupts are handled primarily by the MADC internal secondary interrupt handler and secondly at the upper level (outside the MADC) by the TPS65920/TPS65930 interrupt primary handler.

### 8.2 MADC Electrical Characteristics

Table 8-1 lists the electrical characteristics of the MADC.

**Table 8-1. MADC Electrical Characteristics**

| Parameter   | Conditions                                | Min   | Typ | Max  | Unit |
|---|---|-------|-----|------|------|
| Resolution  |   |       | 10  |      | Bit  |
| ADIN2 input dynamic range for external input  |   | 0     |     | 2.5  | V    |
| MADC voltage reference  |   |       | 1.5 |      | V    |
| ADIN0 differential nonlinearity   |   | –1    |     | 1    | LSB  |
| ADIN0 integral nonlinearity   | Best fitting                              | –2    |     | 2    | LSB  |
| Integral nonlinearity for ADIN2   | Best fitting for codes 230 to maximum     | –2    |     | 2    | LSB  |
|   | Best fitting considering offset of 25 LSB | –3.75 |     | 3.75 | LSB  |
| Offset  | Best fitting                              | –28.5 |     | 28.5 | mV   |
| Input bias  |   |       | 1   |      | μA   |
| Input capacitor C <sub>BANK</sub>   |   |       |     | 10   | pF   |
| Maximum source input resistance R <sub>s</sub> (for all 16 internal or external inputs) |   |       |     | 100  | kΩ   |
| Input current leakage (for all 16 internal or external inputs)                          |   |       |     | 1    | μA   |

### 8.3 Channel Voltage Input Range

Table 8-2 lists the analog input voltage minimum and maximum values.

**Table 8-2. Analog Input Voltage Range**

| Channel                                     | Min | Typ | Max | Unit | Prescaler   |
|---|-----|-----|-----|------|---|
| ADIN0: General-purpose input                | 0   |     | 1.5 | V    | No prescaler<br>DC current source for battery identification through external resistor (10 $\mu$ A typical) |
| ADIN2: General-purpose input <sup>(1)</sup> | 0   |     | 2.5 | V    | Prescaler in the MADC to be in range 0 to >1.5 V  |

(1) General-purpose inputs must be tied to ground when TPS65920/TPS65930 internal power supplies (VINTANA1 and VINTANA2) are off.

#### 8.3.1 Sequence Conversion Time (Real-Time or Nonaborted Asynchronous)

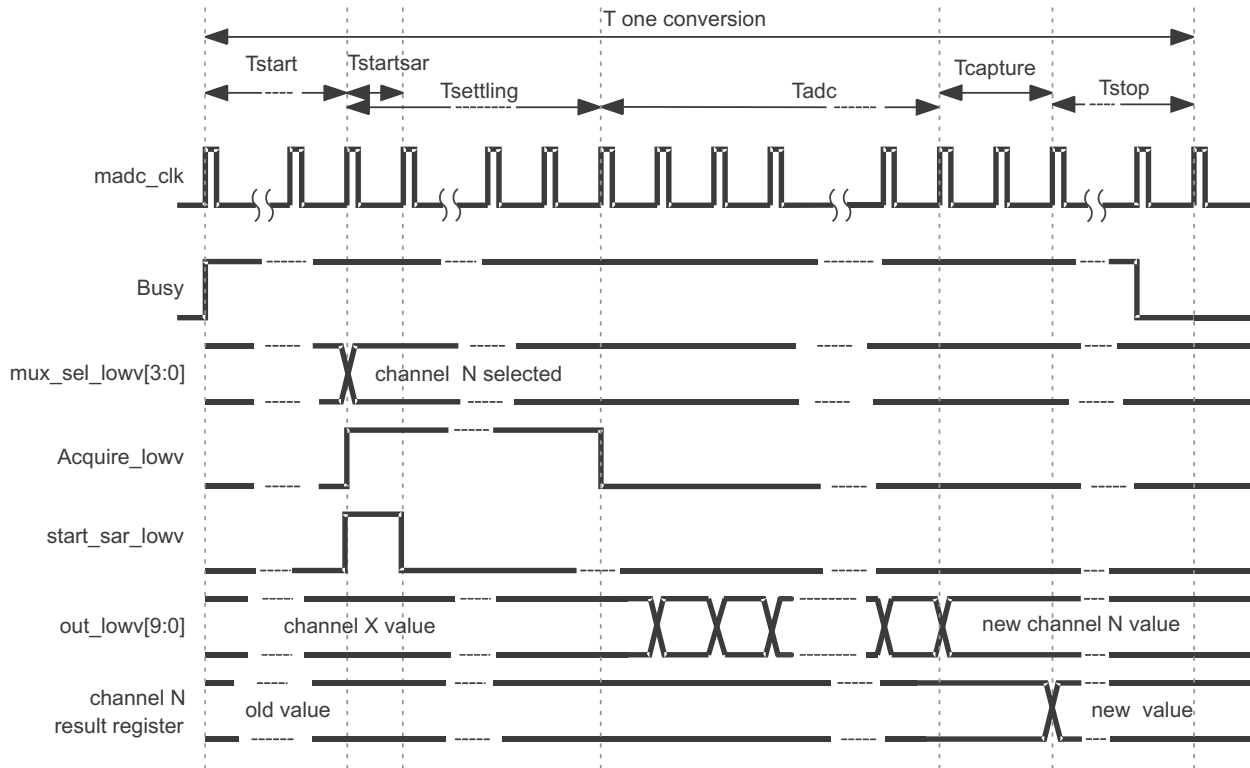
Table 8-3 lists the sequence conversion timing characteristics.

**Table 8-3. Sequence Conversion Timing Characteristics**

| Parameter                     | Comments   | Min  | Typ | Max | Unit    |
|-------------------------------|--|------|-----|-----|---------|
| F                             | Running frequency  |      | 1   |     | MHz     |
| T = 1/F                       | Clock period   |      | 1   |     | $\mu$ s |
| N                             | Number of analog inputs to convert in a single sequence  | 0    |     | 2   |         |
| Tstart                        | SW1, SW2, or USB asynchronous request or real-time STARTADC request  | 3    |     | 4   | $\mu$ s |
| Tsettling time                | Settling time to wait before sampling a stable analog input (capacitor bank charge time)<br><br>Tsettling is calculated from the $\max((R_s + R_{on}) \cdot C_{bank})$ of the two possible input sources (internal or external). $R_{on}$ is the resistance of the selection analog input switches (5 k $\Omega$ ). This time is software-programmable by the open-core protocol (OCP) register. | 5    | 12  | 20  | $\mu$ s |
| Tstartsar                     | The successive approximation registers ADC start time  |      | 1   |     | $\mu$ s |
| Tadc time                     | The successive approximation registers ADC conversion time   |      | 10  |     | $\mu$ s |
| Tcapture time                 | Tcapture time is the conversion result capture time.   |      | 2   |     | $\mu$ s |
| Tstop                         |  | 1    |     | 2   | $\mu$ s |
| Full-conversion sequence time | One channel (N = 1) <sup>(1)</sup>   | 22   |     | 39  | $\mu$ s |
|                               | Both channels <sup>(1)</sup>   | 352  |     | 624 |         |
| Conversion sequence time      | Without Tstart and Tstop: One channel (N = 1) <sup>(1)</sup>   | 18   |     | 33  | $\mu$ s |
|                               | Without Tstart and Tstop: Both channels <sup>(1)</sup>   | 288  |     | 528 |         |
| STARTADC pulse duration       | STARTADC period is T.  | 0.33 |     | 24  | $\mu$ s |

(1) Total sequence conversion time general formula: Tstart+N\*(1+Tsettling+Tadc+Tcapture) +Tstop

Table 8-3 is illustrated in Figure 8-1, which is a conversion sequence general timing diagram. The *Busy* parameter indicates that a conversion sequence is running, and the *channel N result register* parameter corresponds to the result register of the RT/GP selected channel.



037-046

Figure 8-1. Conversion Sequence General Timing Diagram



## 9 LED Drivers

### 9.1 General Description

Two arrays of parallel LEDs are driven (dedicated for the phone light). The parallel LEDs are supplied by VBAT, and the external resistor value is given for each LED. The TPS65920/TPS65930 device supports two open-drain LED drivers for the keypad backlight, having drain connections tolerant of the main battery voltage.

Figure 9-1 is the LED driver block diagram. Table 9-1 lists the electrical characteristics of the LED driver.

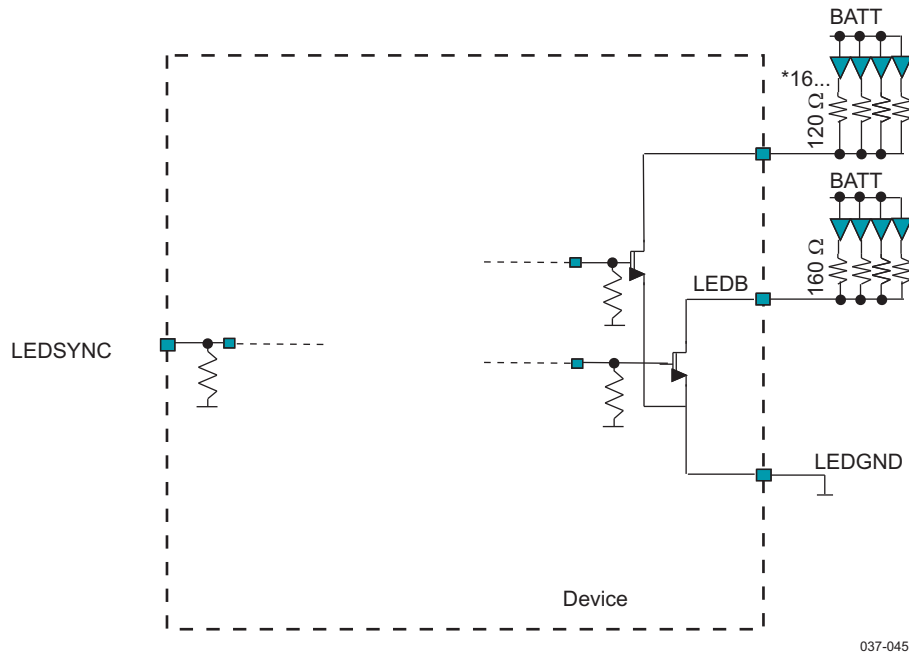


Figure 9-1. LED Driver Block Diagram

#### NOTE

For the component values, see Table 14-1.

Table 9-1. LED Driver Electrical Characteristics

| Parameter        | Conditions             | Min | Typ | Max | Unit     |
|------------------|------------------------|-----|-----|-----|----------|
| SW On resistance | $I_O = 160 \text{ mA}$ |     | 3   | 4   | $\Omega$ |
|                  | $I_O = 60 \text{ mA}$  |     | 10  | 12  |          |

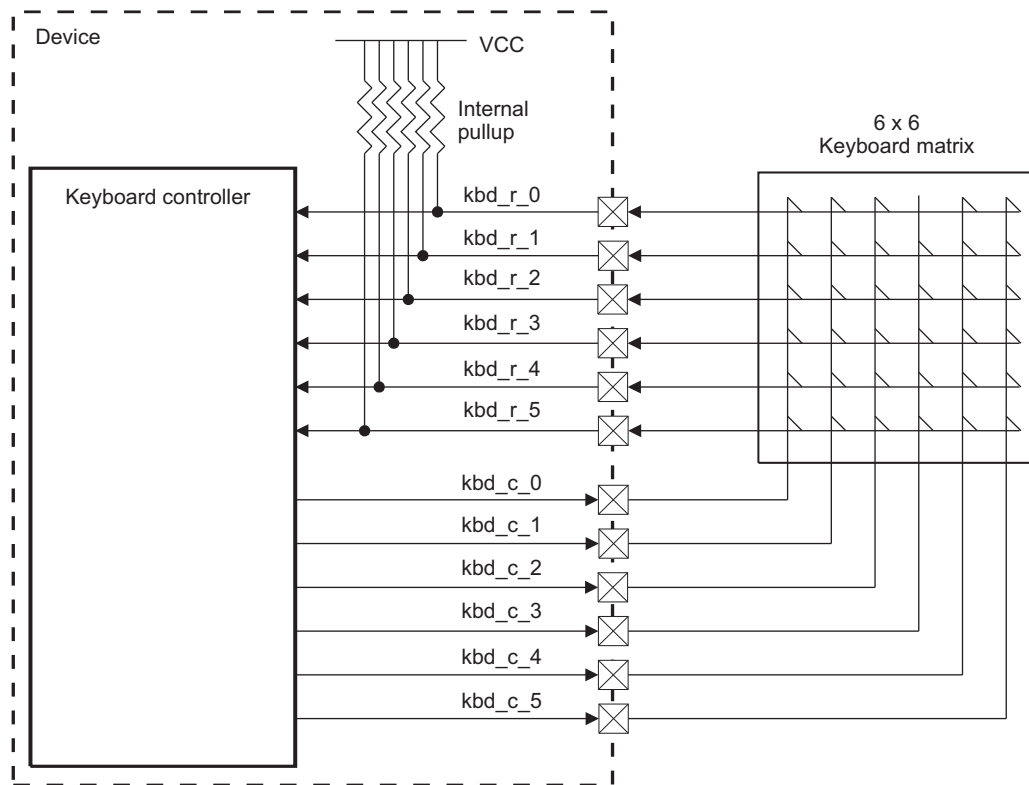
## 10 Keyboard

### 10.1 Keyboard Connection

The keyboard is connected to the chip using:

- KBR (5 :0) input pins for row lines
- KBC (5 :0) output pins for column lines

Figure 10-1 shows the keyboard connection.



037-014

**Figure 10-1. Keyboard Connection**

When a key button of the keyboard matrix is pressed, the corresponding row and column lines are shorted together. To allow key press detection, all input pins (KBR) are pulled up to  $V_{CC}$  and all output pins (KBC) are driven to a low level.

Any action on a button generates an interrupt to the sequencer.

The decoding sequence is written to allow detection of simultaneous press actions on several key buttons.

The keyboard interface can be used with a smaller keyboard area than  $6 \times 6$ . To use a  $3 \times 3$  keyboard, KBR(4) and KBR(5) must be tied high to prevent any scanning process distribution.

## 11 Clock Specifications

The TPS65920/TPS65930 device includes several I/O clock pins. The TPS65920/TPS65930 device has two sources of high-stability clock signals: the external high-frequency clock (HFCLKIN) input and an onboard 32-kHz oscillator (an external 32-kHz signal can be provided). Figure 11-1 is the clock overview.

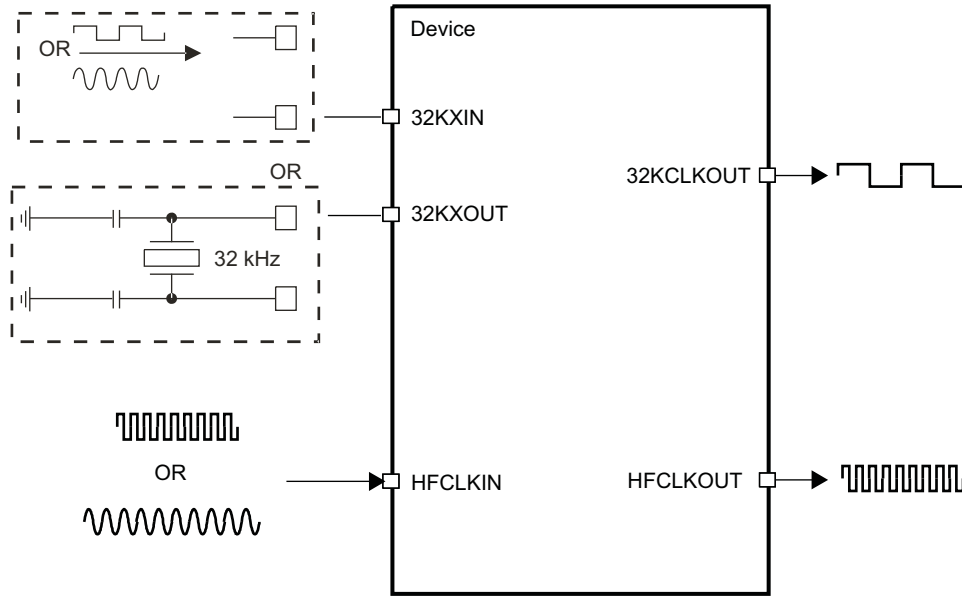


Figure 11-1. Clock Overview

### 11.1 Clock Features

The TPS65920/TPS65930 device accepts two sources of high-stability clock signals:

- 32KXIN/32KXOUT: Onboard 32-kHz crystal oscillator (an external 32-kHz input clock can be provided)
- HFCLKIN: External high-frequency clock (19.2, 26, or 38.4 MHz).

The TPS65920/TPS65930 device can provide:

- 32KCLKOUT digital output clock
- HFCLKOUT digital output clock with the same frequency as the HFCLKIN input clock

## 11.2 Input Clock Specifications

The clock system accepts two input clock sources:

- 32-kHz crystal oscillator clock or sinusoidal/squared clock
- HFCLKIN high-frequency input clock

### 11.2.1 Clock Source Requirements

Table 11-1 lists the input clock requirements.

**Table 11-1. TPS65920/TPS65930 Input Clock Source Requirements**

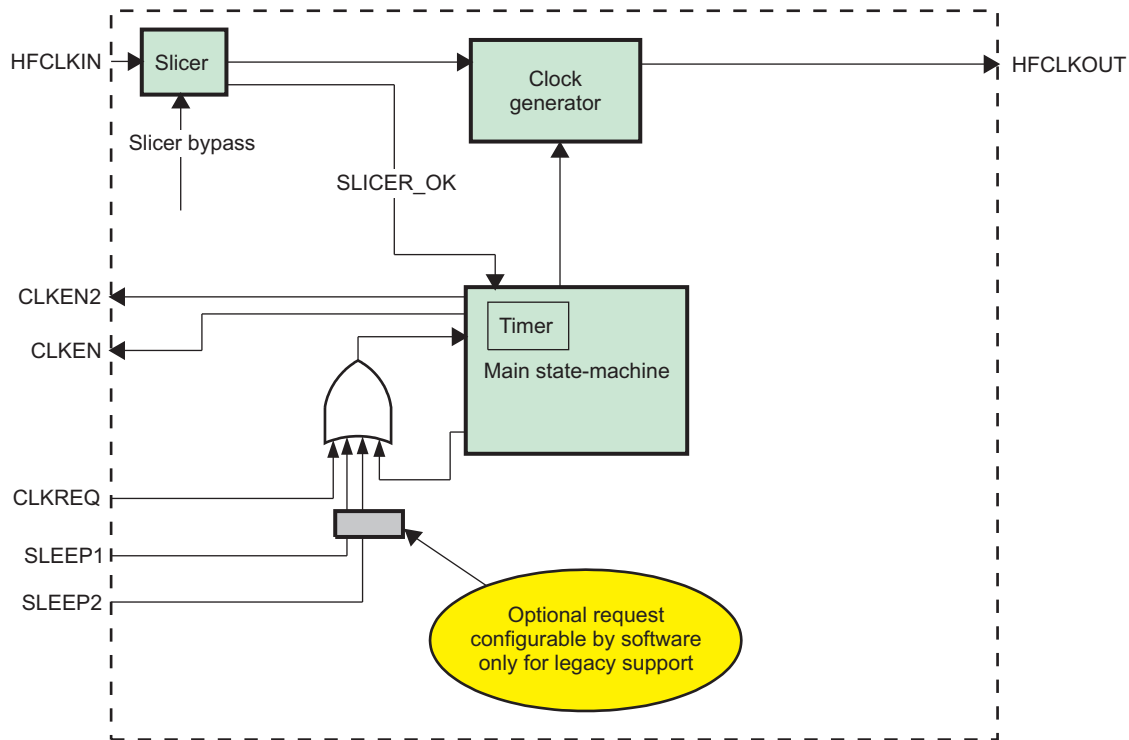
| Pad               | Clock Frequency    |             | Stability | Duty Cycle         |
|-------------------|--------------------|-------------|-----------|--------------------|
| 32KXIN<br>32KXOUT | 32.768 kHz         | Crystal     | ±30 ppm   | 40%/60%            |
|                   |                    | Square wave | –         | 45%/55%            |
|                   |                    | Sine wave   | –         | –                  |
| HFCLKIN           | 19.2, 26, 38.4 MHz | Square wave | ±150 PPM  | See <sup>(1)</sup> |
|                   |                    | Sine wave   | –         | –                  |

(1) HFCLK duty cycle and frequency is not altered by the internal circuit. The input clock accuracy must match that of the system requirement; for example, OMAP device.

### 11.2.2 HFCLKIN

HFCLKIN can be a square- or a sine-wave input clock. If a square-wave input clock is provided, it is recommended to switch the block to bypass mode to avoid loading the clock.

Figure 11-2 shows the HFCLKIN clock distribution.



037-044

**Figure 11-2. HFCLKIN Clock Distribution**

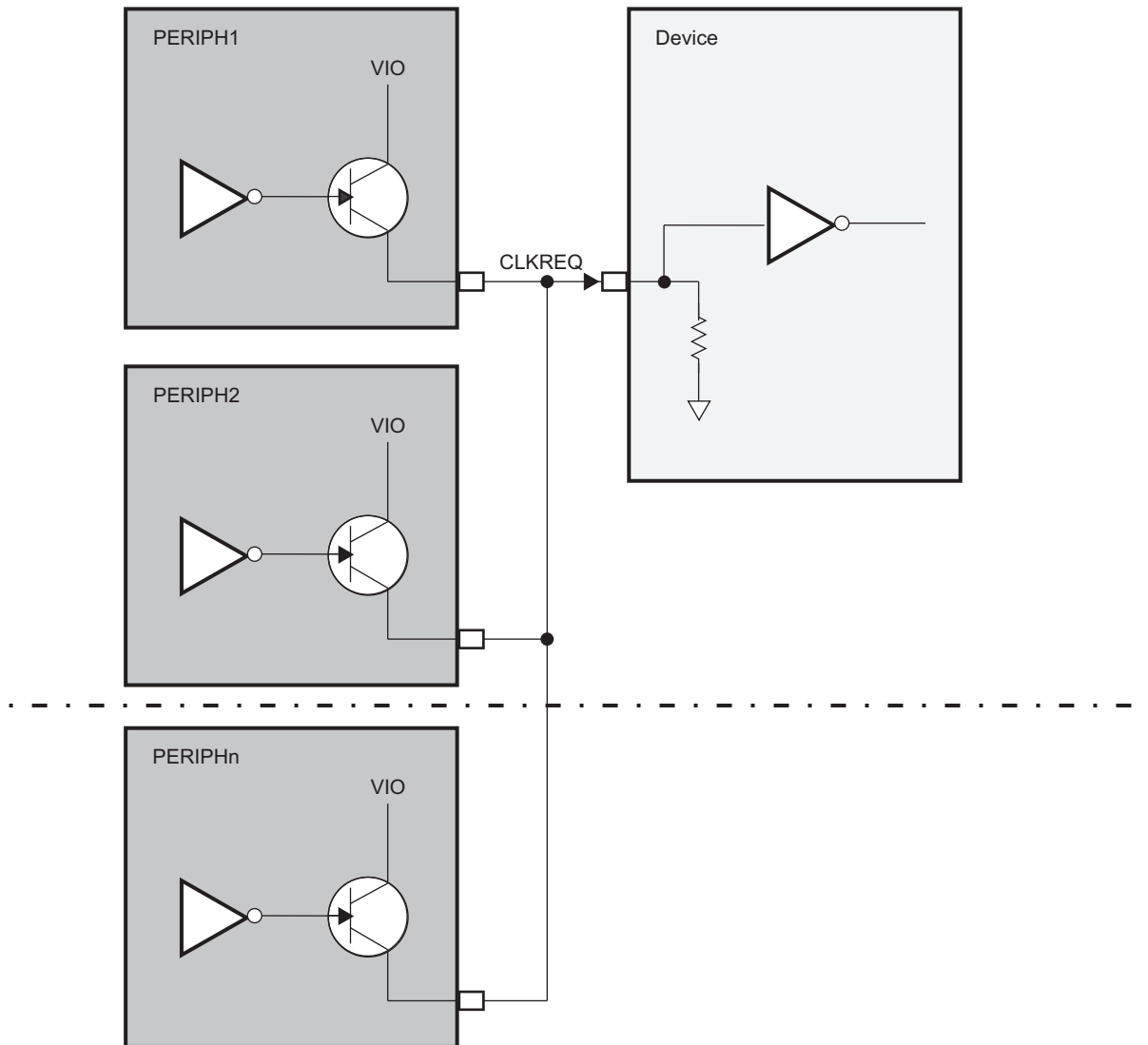
When a device needs a clock signal other than 32.768 kHz, it makes a clock request and activates the

CLKREQ pin. As a result, the TPS65920/TPS65930 device immediately sets CLKEN to 1 to warn the clock provider in the system about the clock request and starts a timer (maximum of 5.2 ms using the 32.768-kHz clock). When the timer expires, the TPS65920/TPS65930 device opens a gated clock, the timer automatically reloads the defined value, and a high-frequency output clock signal is available through the HFCLKOUT pin. The output drive of HFCLKOUT is programmable (minimum load 10 pF, maximum load 40 pF) and must be at 40 pF by default.

With a register setting, the mirroring of CLKEN can be enabled on CLKEN2. When this mirroring feature is not enabled, CLKEN2 can be used as a general-purpose output controlled through I<sup>2</sup>C accesses.

CLKREQ, when enabled, has a weak pulldown resistor to support the wired-OR clock request.

Figure 11-3 shows an example of the wired-OR clock request.



037-043

**Figure 11-3. Example of Wired-OR Clock Request**

The timer default value must be the worst case (10 ms) for the clock providers. For legacy or workaround support, the NSLEEP1 and NSLEEP2 signals can also be used as a clock request even if it is not their primary goal. By default, this feature is disabled and must be enabled individually by setting the register bits associated with each signal.

When the external clock signal is present on the HFCLKIN ball, it is possible to use this clock instead of the internal RC oscillator and then synchronize the system on the same clock. The RC oscillator can then go to idle mode.

Table 11-2 lists the input clock electrical characteristics of the HFCLKIN input clock.

**Table 11-2. HFCLKIN Input Clock Electrical Characteristics**

| Parameter Description   | Configuration Mode Slicer                          | Min                      | Typ | Max  | Unit            |
|---|--|--------------------------|-----|------|-----------------|
| Frequency   |  | 19.2, 26, or 38.4        |     |      | MHz             |
| Start-up time   | LP <sup>(1)</sup> /HP <sup>(2)</sup> (sine wave)   |                          |     |      | 4<br>μs         |
| Input dynamic range   | LP/HP (sine wave)                                  | 0.3                      | 0.7 | 1.45 | V <sub>PP</sub> |
|   | BP <sup>(3)</sup> /PD <sup>(4)</sup> (square wave) | 0<br>1.85 <sup>(5)</sup> |     |      |                 |
| Current consumption   | LP   |                          |     |      | 175<br>μA       |
|   | HP   |                          |     |      | 235             |
|   | BP/PD  |                          |     |      | 39<br>nA        |
| Harmonic content of input signal (with 0.7-V <sub>PP</sub> amplitude): second component | LP/HP (sine wave)                                  |                          |     |      | -25<br>dBc      |
| V <sub>IH</sub> Voltage input high  | BP (square wave)                                   | 1                        |     |      | V               |
| V <sub>IL</sub> Voltage input low   | BP (square wave)                                   |                          |     |      | 0.6<br>V        |

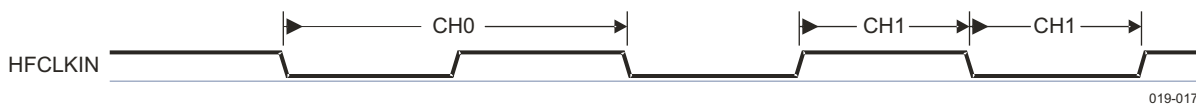
- (1) LP = Low-power mode
- (2) HP = High-power mode
- (3) BP = Bypass mode
- (4) PD = Power-down mode
- (5) Bypass input max voltage is the same as the maximum voltage provided for the I/O interface (IO.1P8V).

Table 11-3 lists the input clock timing requirements of the HFCLKIN input clock when the source is a square wave. Figure 11-4 shows the HFCLKIN squared input clock timings.

**Table 11-3. HFCLKIN Square Input Clock Timing Requirements with Slicer in Bypass**

| Name | Parameter                 | Description                         | Min                          | Typ | Max                          | Unit    |
|------|---------------------------|-------------------------------------|------------------------------|-----|------------------------------|---------|
| CH0  | 1/t <sub>C(HFCLKIN)</sub> | Frequency, HFCLKIN                  | 19.2, 26, or 38.4            |     |                              | MHz     |
| CH1  | t <sub>W(HFCLKIN)</sub>   | Pulse duration, HFCLKIN low or high | 0.45*t <sub>C(HFCLKIN)</sub> |     | 0.55*t <sub>C(HFCLKIN)</sub> | ns      |
| CH3  | t <sub>R(HFCLKIN)</sub>   | Rise time, HFCLKIN <sup>(1)</sup>   |                              |     |                              | 5<br>ns |
| CH4  | t <sub>F(HFCLKIN)</sub>   | Fall time, HFCLKIN <sup>(1)</sup>   |                              |     |                              | 5<br>ns |

- (1) Default drive capability is 40 pF.



**Figure 11-4. HFCLKIN Squared Input Clock**

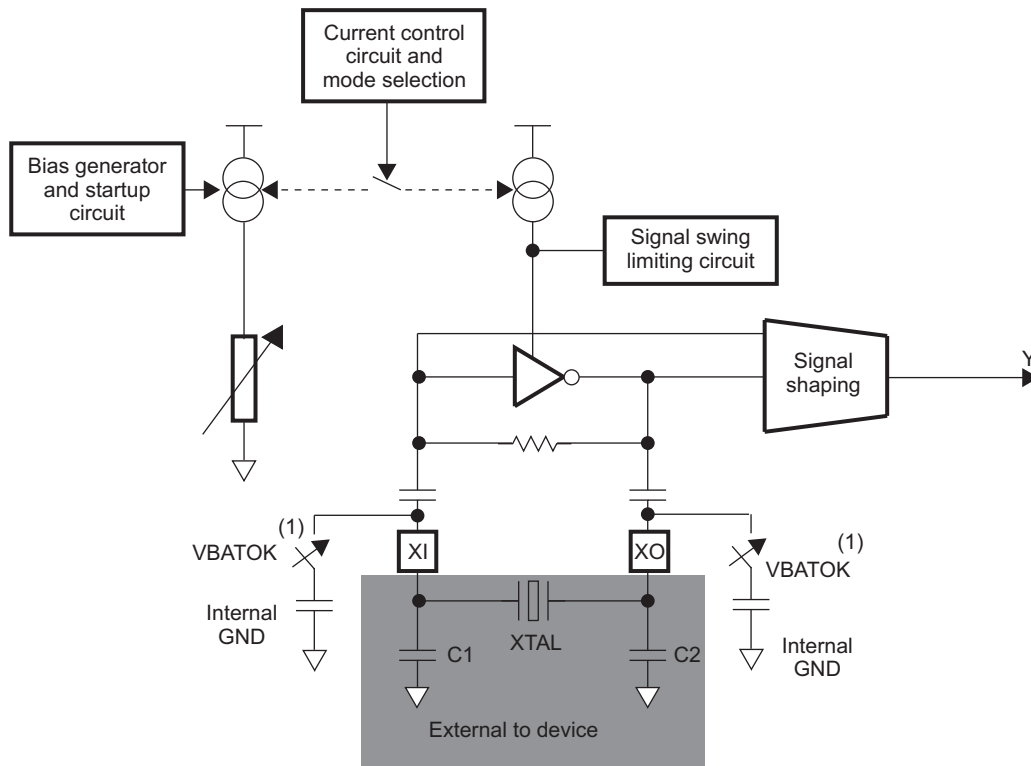
### 11.2.3 32-kHz Input Clock

A 32.768-kHz input clock (often abbreviated to 32-kHz) generates the clocks for the RTC. It has a low-jitter mode where the current consumption increases for lower jitter. It is possible to use the 32-kHz input clock with an external crystal or clock source. Depending on the mode chosen, the 32K oscillator is configured one of two ways:

- An external 32.768-kHz crystal through the 32KXIN/32KXOUT balls (see Figure 11-5). This configuration is available only for master mode (for more information, see Section 12).
- An external square/sine wave of 32.768 kHz through 32KXIN with amplitude equal to 1.8 or 1.85 V (see Figure 11-7, Figure 11-8, and Figure 11-9). This configuration is available for the master and slave modes (for more information, see Section 12).

11.2.3.1 External Crystal Description

Figure 11-5 shows the 32-kHz oscillator block diagram with crystal in master mode.



037-042

NOTE: Switches close by default and open only if register access enables very-low-power mode when VBAT < 2.7 V.

Figure 11-5. 32-kHz Oscillator Block Diagram In Master Mode With Crystal

CXIN and CXOUT represent the total capacitance of the printed circuit board (PCB) and components, excluding the crystal. Their values depend on the datasheet of the crystal, the internal capacitors, and the parallel capacitor. The frequency of the oscillations depends on the value of the capacitors. The crystal must be in the fundamental mode of operation and parallel resonant.

NOTE

For the values of CXIN and CXOUT, see Table 14-1.

Table 11-4 lists the required electrical constraints.

Table 11-4. Crystal Electrical Characteristics

| Parameter   | Min                                   | Typ    | Max  | Unit |
|---|---------------------------------------|--------|------|------|
| Parallel resonance crystal frequency                                    |                                       | 32.768 |      | kHz  |
| Input voltage, Vin (normal mode)  | 1.0                                   | 1.3    | 1.55 | V    |
| Internal capacitor on each input (Cint)                                 |                                       | 10     |      | pF   |
| Parallel input capacitance (Cpin)                                       |                                       |        | 1    | pF   |
| Nominal load cap on each oscillator input CXIN and CXOUT <sup>(1)</sup> | CXIN = CXOUT = Cosc*2 – (Cint + Cpin) |        |      | pF   |
| Pin-to-pin capacitance  |                                       | 1.6    | 1.8  | pF   |

(1) Nominal load capacitor on each oscillator input defined as CXIN = CXOUT = Cosc\*2 – (Cint + Cpin). Cosc is the load capacitor defined in the crystal oscillator specification, Cint is the internal capacitor, and Cpin is the parallel input capacitor.

**Table 11-4. Crystal Electrical Characteristics (continued)**

| Parameter  | Min  | Typ | Max | Unit |
|--|------|-----|-----|------|
| Crystal ESR <sup>(2)</sup>                                 |      |     | 75  | kΩ   |
| Crystal shunt capacitance, C <sub>O</sub>                  |      |     | 1   | pF   |
| Crystal tolerance at room temperature, 25°C                | –30  |     | 30  | ppm  |
| Crystal tolerance versus temperature range (–40°C to 85°C) | –200 |     | 200 | ppm  |
| Maximum drive power  |      |     | 1   | μW   |
| Operating drive level                                      |      |     | 0.5 | μW   |

(2) The crystal motional resistance R<sub>m</sub> relates to the equivalent series resistance (ESR) by the following formula:

$$ESR = R_m \left( 1 + \frac{C_O}{C_L} \right)^2$$

Measured with the load capacitance specified by the crystal manufacturer. If CXIN = CXOUT = 10 pF, C<sub>L</sub> = 5 pF. Parasitic capacitance from the package and board must also be considered.

When selecting a crystal, the system design must consider the temperature and aging characteristics of a crystal versus the user environment and expected lifetime of the system.

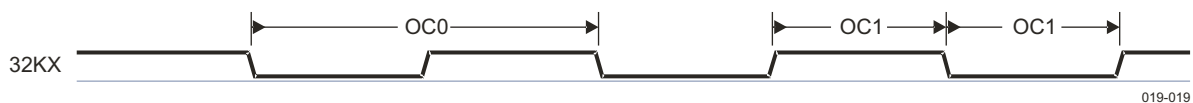
Table 11-5 and Table 11-6 list the switching characteristics of the oscillator and the timing requirements of the 32.768-kHz input clock. Figure 11-6 shows the crystal oscillator output in normal mode.

**Table 11-5. Base Oscillator Switching Characteristics**

| Name             | Parameter Description      | Min                      | Typ    | Max | Unit |
|------------------|----------------------------|--------------------------|--------|-----|------|
| f <sub>P</sub>   | Oscillation frequency      |                          | 32.768 |     | kHz  |
| t <sub>SX</sub>  | Start-up time              |                          |        | 0.5 | s    |
| I <sub>DDA</sub> | Active current consumption | LOJIT <1:0> = 00         |        | 1.8 | μA   |
|                  |                            | LOJIT <1:0> = 11         |        | 8   |      |
| I <sub>DDQ</sub> | Current consumption        | Low battery mode (1.2 V) |        | 1   | μA   |
|                  |                            | Startup                  |        | 8   |      |

**Table 11-6. 32-kHz Crystal Input Clock Timing Requirements**

| Name | Parameter Description                                    | Min                        | Typ    | Max                        | Unit |
|------|--|----------------------------|--------|----------------------------|------|
| OC0  | 1/t <sub>C(32KHZ)</sub> Frequency, 32 kHz                |                            | 32.768 |                            | kHz  |
| OC1  | t <sub>W(32KHZ)</sub> Pulse duration, 32 kHz low or high | 0.40*t <sub>C(32KHZ)</sub> |        | 0.60*t <sub>C(32KHZ)</sub> | μs   |



**Figure 11-6. 32-kHz Crystal Input**

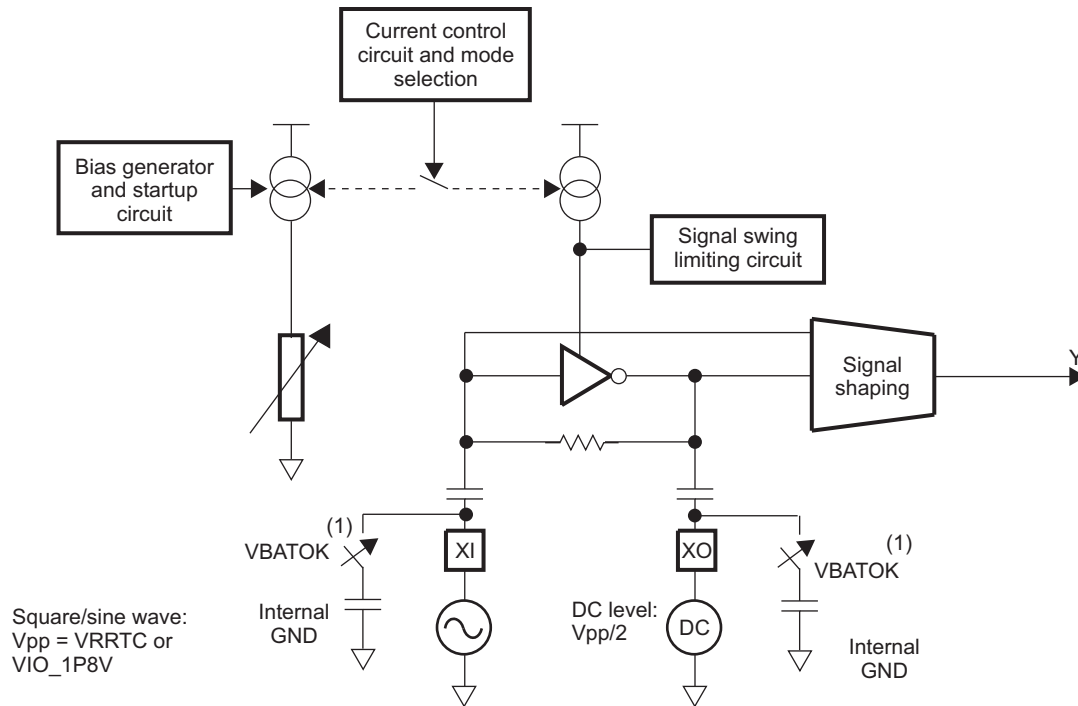
### 11.2.3.2 External Clock Description

When an external 32K clock is used instead of a crystal, three configuration can be used:

- A square- or sine-wave input can be applied to the 32KXIN pin with amplitude of 1.85 or 1.8 V. The 32KXOUT pin can be driven to a dc value of the square- or sine-wave amplitude divided by 2. This configuration, shown in Figure 11-7, is recommended if a large load is applied on the 32KXOUT pin.
- A square- or sine-wave input can be applied to the 32KXIN pin with amplitude of 1.85 or 1.8 V. The 32KXOUT pin can be left floating. This configuration, showed in Figure 11-8, is used if no charge is applied on the 32KXOUT pin.
- The oscillator is in bypass mode and a square-wave input can be applied to the 32KXIN pin with amplitude of 1.8 V. The 32KXOUT pin can be left floating. This configuration, shown in Figure 11-9, is



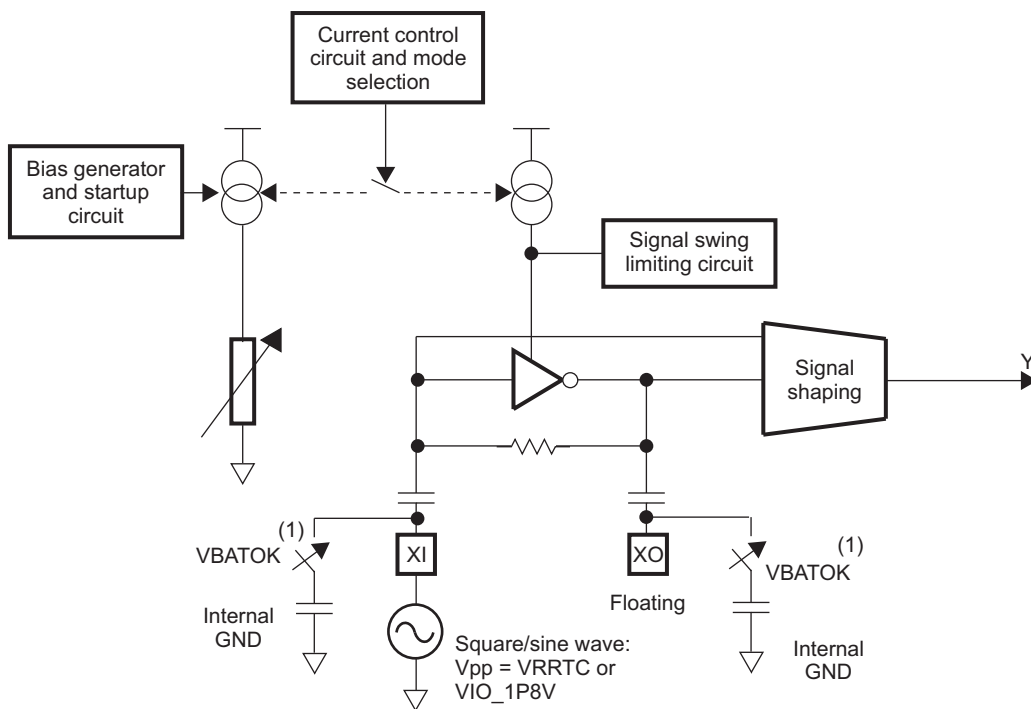
used if the oscillator is in bypass mode.



037-041

(1) Switches close by default and open only if register access enables very-low-power mode when VBAT < 2.7 V.

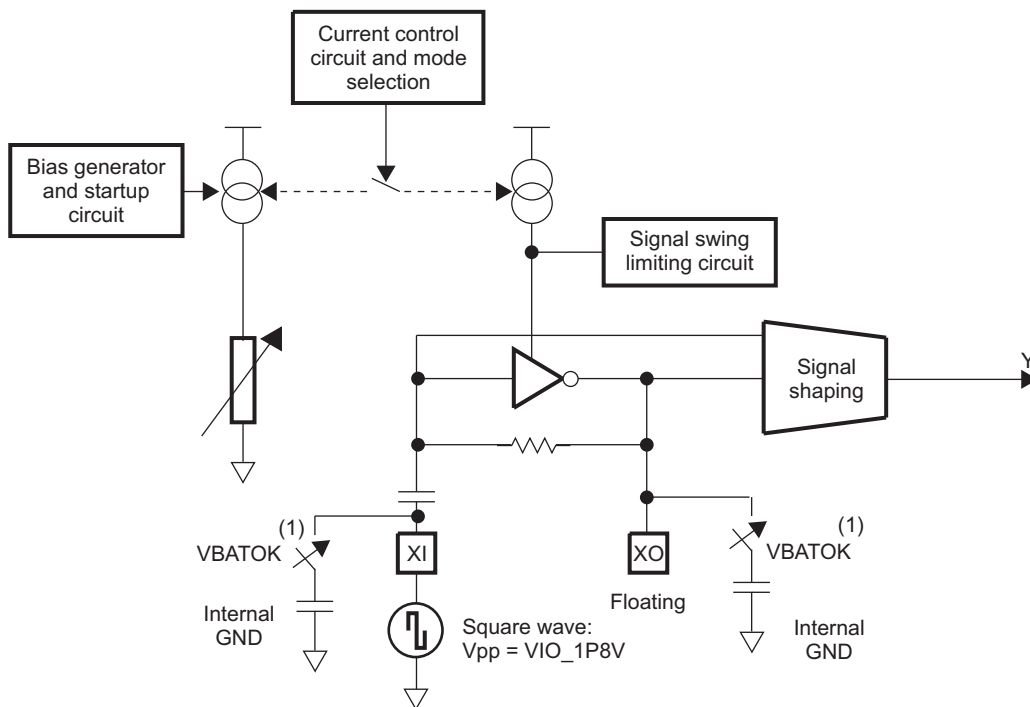
**Figure 11-7. 32-kHz Oscillator Block Diagram Without Crystal Option 1**



037-039

(1) Switches close by default and open only if register access enables very-low-power mode when VBAT < 2.7 V.

**Figure 11-8. 32-kHz Oscillator Block Diagram Without Crystal Option 2**



037-040

(1) Switches close by default and open only if register access enables very-low-power mode when VBAT < 2.7 V.

**Figure 11-9. 32-kHz Oscillator in Bypass Mode Block Diagram Without Crystal Option 3**

Table 11-7 lists the electrical constraints required by the 32-kHz input square- or sine-wave clock.

**Table 11-7. 32-kHz Input Square- or Sine-Wave Clock Source Electrical Characteristics**

| Name            | Parameter Description   | Min | Typ                | Max | Unit |
|-----------------|---|-----|--------------------|-----|------|
| f               | Frequency   |     | 32.768             |     | kHz  |
| C <sub>I</sub>  | Input capacitance   |     | 35                 |     | pF   |
| C <sub>FI</sub> | On-chip foot capacitance to GND on each input (see Figure 11-7, Figure 11-8, and Figure 11-9) |     | 10                 |     | pF   |
| V <sub>PP</sub> | Square-/sine-wave amplitude in bypass mode or not   |     | 1.8 <sup>(1)</sup> |     | V    |
| V <sub>IH</sub> | Voltage input high, square wave in bypass mode  | 0.8 |                    |     | V    |
| V <sub>IL</sub> | Voltage input low, square wave in bypass mode   |     |                    | 0.6 | V    |

(1) Bypass input maximum voltage is the same as the maximum voltage provided for the I/O interface.

Table 11-8 lists the timing requirements of the 32-kHz square-wave input clock.

**Table 11-8. 32-kHz Square-Wave Input Clock Source Timing Requirements**

| Name | Parameter               | Description                        | Min                        | Typ    | Max                        | Unit |
|------|-------------------------|------------------------------------|----------------------------|--------|----------------------------|------|
| CK0  | 1/t <sub>C(32KHZ)</sub> | Frequency, 32 kHz                  |                            | 32.768 |                            | MHz  |
| CK1  | t <sub>W(32KHZ)</sub>   | Pulse duration, 32 kHz low or high | 0.45*t <sub>C(32KHZ)</sub> |        | 0.55*t <sub>C(32KHZ)</sub> | μs   |
| CK3  | t <sub>R(32KHZ)</sub>   | Rise time, 32 kHz <sup>(1)</sup>   |                            |        | 0.1*t <sub>C(32KHZ)</sub>  | μs   |
| CK4  | t <sub>F(32KHZ)</sub>   | Fall time, 32 kHz <sup>(1)</sup>   |                            |        | 0.1*t <sub>C(32KHZ)</sub>  | μs   |

(1) The capacitive load is 30 pF.

Figure 11-10 shows the 32-kHz square- or sine-wave input clock.

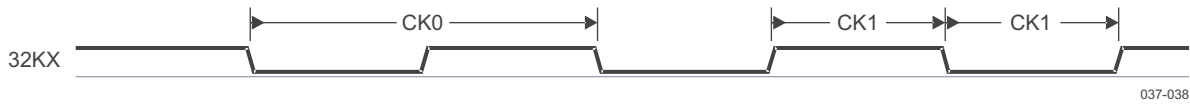


Figure 11-10. 32-kHz Square- or Sine-Wave Input Clock

### 11.3 Output Clock Specifications

The TPS65920/TPS65930 device provides two output clocks:

- 32KCLKOUT
- HFCLKOUT

#### 11.3.1 32KCLKOUT Output Clock

Figure 11-11 is the block diagram for the 32.768-kHz clock output.

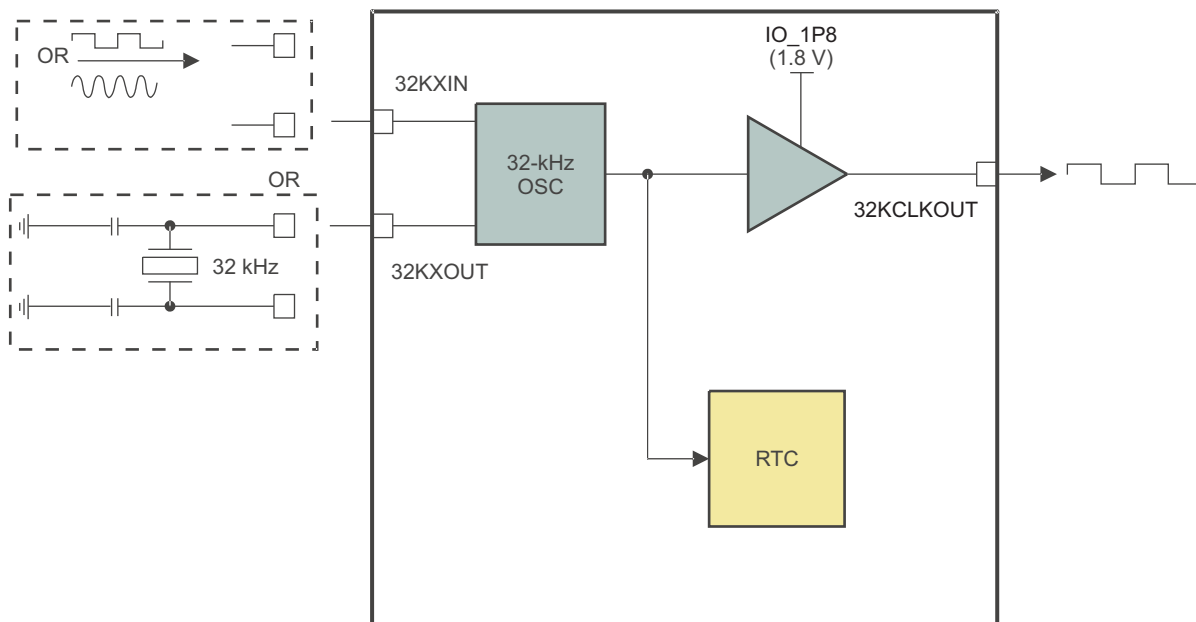


Figure 11-11. 32.768-kHz Clock Output Block Diagram

The TPS65920/TPS65930 device has an internal 32.768-kHz oscillator connected to an external 32.768-kHz crystal through the 32KXIN/32KXOUT balls or an external digital 32.768-kHz clock through the 32KXIN input (see Figure 11-11). The TPS65920/TPS65930 device also generates a 32.768-kHz digital clock through the 32KCLKOUT pin and can broadcast it externally to the application processor or any other devices. The 32KCLKOUT clock is broadcast by default in TPS65920/TPS65930 active mode, but can be disabled if it is not used.

The 32.768-kHz clock (or signal) is also used to clock the RTC embedded in the TPS65920/TPS65930 device. The RTC is not enabled by default. The host processor must set the correct date and time and enable the RTC functionality.

The 32KCLKOUT output buffer can drive several devices (up to 40-pF load). At startup, 32KCLKOUT must be stabilized (frequency/duty cycle) before the signal output. Depending on the startup conditions, this can delay the startup sequence.

Table 11-9 lists the electrical characteristics of the 32KCLKOUT output clock.

**Table 11-9. 32KCLKOUT Output Clock Electrical Characteristics**

| Name             | Parameter Description  | Min                     | Typ                | Max              | Unit |
|------------------|--|-------------------------|--------------------|------------------|------|
| f                | Frequency  |                         | 32.768             |                  | kHz  |
| C <sub>L</sub>   | Load capacitance   |                         |                    | 40               | pF   |
| V <sub>OUT</sub> | Output clock voltage, depending on output reference level IO_1P8 (see Section 2) |                         | 1.8 <sup>(1)</sup> |                  | V    |
| V <sub>OH</sub>  | Voltage output high  | V <sub>OUT</sub> – 0.45 |                    | V <sub>OUT</sub> | V    |
| V <sub>OL</sub>  | Voltage output low   | 0                       |                    | 0.45             | V    |

(1) The output voltage depends on the output reference level, which is IO\_1P8 (see Section 2, Terminal Description).

Table 11-10 lists the output clock switching characteristics. Figure 11-12 shows the 32KCLKOUT output clock waveform.

**Table 11-10. 32KCLKOUT Output Clock Switching Characteristics**

| Name | Parameter                   | Description                           | Min                            | Typ    | Max                            | Unit |
|------|-----------------------------|---------------------------------------|--------------------------------|--------|--------------------------------|------|
| CK0  | 1/t <sub>C(32KCLKOUT)</sub> | Frequency                             |                                | 32.768 |                                | MHz  |
| CK1  | t <sub>W(32KCLKOUT)</sub>   | Pulse duration, 32KCLKOUT low or high | 0.40*t <sub>C(32KCLKOUT)</sub> |        | 0.60*t <sub>C(32KCLKOUT)</sub> | ns   |
| CK2  | t <sub>R(32KCLKOUT)</sub>   | Rise time, 32KCLKOUT <sup>(1)</sup>   |                                |        | 16                             | ns   |
| CK3  | t <sub>F(32KCLKOUT)</sub>   | Fall time, 32KCLKOUT <sup>(1)</sup>   |                                |        | 16                             | ns   |

(1) The output capacitive load is 30 pF.



**Figure 11-12. 32KCLKOUT Output Clock**

### 11.3.2 HFCLKOUT Output Clock

Table 11-11 lists the electrical characteristics of the HFCLKOUT output clock.

**Table 11-11. HFCLKOUT Output Clock Electrical Characteristics**

| Name             | Parameter Description  | Min                     | Typ                | Max              | Unit |
|------------------|--|-------------------------|--------------------|------------------|------|
| f                | Frequency  | 19.2, 26, or 38.4       |                    |                  | MHz  |
| C <sub>L</sub>   | Load capacitance   |                         |                    | 30               | pF   |
| V <sub>OUT</sub> | Output clock voltage, depending on output reference level IO_1P8 (see Section 2) |                         | 1.8 <sup>(1)</sup> |                  | V    |
| V <sub>OH</sub>  | Voltage output high  | V <sub>OUT</sub> – 0.45 |                    | V <sub>OUT</sub> | V    |
| V <sub>OL</sub>  | Voltage output low   | 0                       |                    | 0.45             | V    |

(1) The output voltage depends on the output reference level, which is IO\_1P8 (see Section 2).

Table 11-12 lists the switching characteristics of the HFCLKOUT output clock.

**Table 11-12. HFCLKOUT Output Clock Switching Characteristics**

| Name | Parameter                  | Description                          | Min                           | Typ               | Max                           | Unit |
|------|----------------------------|--------------------------------------|-------------------------------|-------------------|-------------------------------|------|
| CHO1 | 1/t <sub>C(HFCLKOUT)</sub> | Frequency                            |                               | 19.2, 26, or 38.4 |                               | MHz  |
| CHO2 | t <sub>W(HFCLKOUT)</sub>   | Pulse duration, HFCLKOUT low or high | 0.40*t <sub>C(HFCLKOUT)</sub> |                   | 0.60*t <sub>C(HFCLKOUT)</sub> | ns   |
| CHO3 | t <sub>R(HFCLKOUT)</sub>   | Rise time, HFCLKOUT <sup>(1)</sup>   |                               |                   | 2.6                           | ns   |
| CHO4 | t <sub>F(HFCLKOUT)</sub>   | Fall time, HFCLKOUT <sup>(1)</sup>   |                               |                   | 2.6                           | ns   |

(1) The output capacitive load is 30 pF.

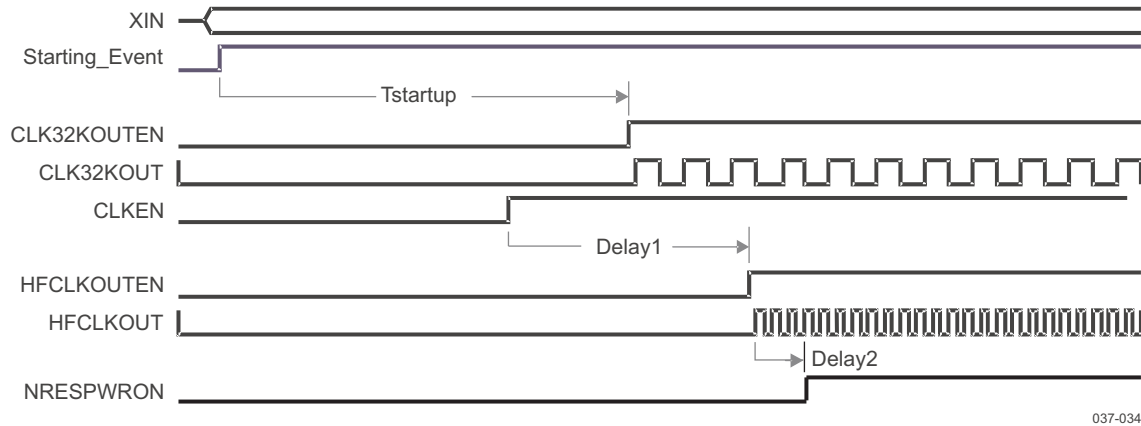
Figure 11-13 shows the HFCLKOUT output clock waveform.



Figure 11-13. HFCLKOUT Output Clock

### 11.3.3 Output Clock Stabilization Time

Figure 11-14 shows the 32KCLKOUT and HFCLKOUT clock stabilization time.



NOTE: Tstartup, Delay1, and Delay2 depend on the boot mode (see Section 4.5, Power Management).

NOTE: Ensure that the high frequency oscillator start-up time is in spec for the boot mode used. During power-up the internal delay, Delay1 above is fixed (5.2 ms and 5.3 ms depending on boot mode). The start-up time for the oscillator must be less than the fixed delay.

Figure 11-14. 32KCLKOUT and HFCLKOUT Clock Stabilization Time

Figure 11-15 shows the HFCLKOUT behavior.

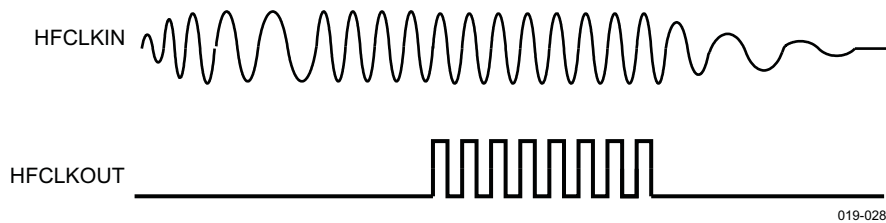


Figure 11-15. HFCLKOUT Behavior

## 12 Timing Requirements and Switching Characteristics

### 12.1 Timing Parameters

The timing parameter symbols used in the timing requirement and switching characteristic tables are created in accordance with JEDEC Standard 100. To shorten the symbols, some pin names and other related terminologies are abbreviated, as shown in [Table 12-1](#).

**Table 12-1. Timing Parameters**

| Subscripts |  |
|------------|--|
| Symbol     | Parameter                              |
| c          | Cycle time (period)                    |
| d          | Delay time                             |
| dis        | Disable time                           |
| en         | Enable time                            |
| h          | Hold time                              |
| su         | Setup time                             |
| START      | Start bit                              |
| t          | Transition time                        |
| v          | Valid time                             |
| w          | Pulse duration (width)                 |
| X          | Unknown, changing, or don't care level |
| H          | High                                   |
| L          | Low                                    |
| V          | Valid                                  |
| IV         | Invalid                                |
| AE         | Active edge                            |
| FE         | First edge                             |
| LE         | Last edge                              |
| Z          | High impedance                         |

## 12.2 Target Frequencies

Table 12-2 assumes testing over the recommended operating conditions.

**Table 12-2. TPS65920/TPS65930 Interface Target Frequencies**

| I/O Interface  | Interface Designation   |                       | Target Frequency<br>1.5 V           |
|--|-------------------------|-----------------------|-------------------------------------|
| SmartReflex inter-integrated circuit (I <sup>2</sup> C™)<br>General-purpose I <sup>2</sup> C | I <sup>2</sup> C        | Slave HS mode         | 3.6 Mbps                            |
|  |                         | Slave fast-speed mode | 400 Kbps                            |
|  |                         | Slave standard mode   | 100 Kbps                            |
| USB  | USB                     | HS                    | 480 Mbps                            |
|  |                         | FS                    | 12 Mbps                             |
|  |                         | LS                    | 1.5 Mbps                            |
| JTAG   | Real/View® ICE tool     |                       | 30 MHz                              |
|  | XDS560 and XDS510 tools |                       | 30 MHz                              |
|  | Lauterbach™ tool        |                       | 30 MHz                              |
| TDM/inter-IC sound (I2S™)  | I2S                     |                       | $1/(64 * F_s)^{(1)}$                |
|  | Right-justified         |                       | $1/(64 * F_s)^{(1)}$                |
|  | Left-justified          |                       | $1/(64 * F_s)^{(1)}$                |
|  | TDM                     |                       | $1/(128 * F_s)^{(1)}$               |
| Voice/Bluetooth® pulse code modulation (PCM) interface                                       | PCM (master mode)       |                       | $1/(65 * F_s)^{(2)}$                |
|  | PCM (slave mode)        |                       | $1/(33 \text{ to } 65 * F_s)^{(2)}$ |

(1)  $F_s$  = 8 to 48 kHz; 96 kHz for RX path only (TDM/I2S interface)

(2)  $F_s$  = 8 or 16 kHz (voice/Bluetooth PCM interface)

### 12.3 I<sup>2</sup>C Timing

The TPS65920/TPS65930 device provides two I<sup>2</sup>C HS slave interfaces (one for general-purpose and one for SmartReflex). These interfaces support standard mode (100 Kbps), fast mode (400 Kbps), and HS mode (3.4 Mbps). The general-purpose I<sup>2</sup>C module embeds four slave hard-coded addresses (ID1 = 48h, ID2 = 49h, ID3 = 4Ah, and ID4 = 4Bh). The SmartReflex I<sup>2</sup>C module uses one slave hard-coded address (ID5). The master mode is not supported.

Table 12-3 and Table 12-4 assume testing over the recommended operating conditions (see Figure 12-1).

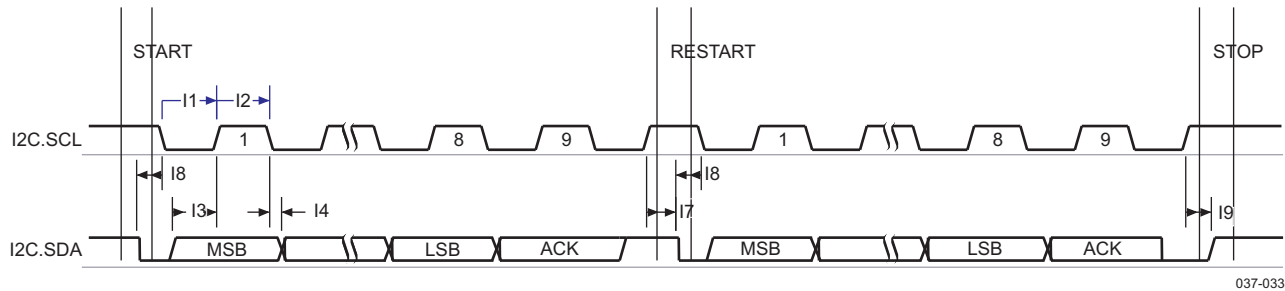


Figure 12-1. I<sup>2</sup>C Interface—Transmit and Receive in Slave Mode

Table 12-3. I<sup>2</sup>C Interface—Timing Requirements<sup>(1)</sup> <sup>(2)</sup>

| Notation                     | Parameter                   | Min | Max | Unit |
|------------------------------|-----------------------------|-----|-----|------|
| <b>Slave HS Mode</b>         |                             |     |     |      |
| I3                           | t <sub>su</sub> (SDA-SCLH)  | 10  |     | ns   |
| I4                           | t <sub>h</sub> (SCLL-SDA)   | 0   | 70  | ns   |
| I7                           | t <sub>su</sub> (SCLH-SDAL) | 160 |     | ns   |
| I8                           | t <sub>h</sub> (SDAL-SCLL)  | 160 |     | ns   |
| I9                           | t <sub>su</sub> (SDAH-SCLH) | 160 |     | ns   |
| <b>Slave Fast-Speed Mode</b> |                             |     |     |      |
| I3                           | t <sub>su</sub> (SDA-SCLH)  | 100 |     | ns   |
| I4                           | t <sub>h</sub> (SCLL-SDA)   | 0   | 0.9 | ns   |
| I7                           | t <sub>su</sub> (SCLH-SDAL) | 0.6 |     | ns   |
| I8                           | t <sub>h</sub> (SDAL-SCLL)  | 0.6 |     | ns   |
| I9                           | t <sub>su</sub> (SDAH-SCLH) | 0.6 |     | ns   |
| <b>Slave Standard Mode</b>   |                             |     |     |      |
| I3                           | t <sub>su</sub> (SDA-SCLH)  | 250 |     | ns   |
| I4                           | t <sub>h</sub> (SCLL-SDA)   | 0   |     | ns   |
| I7                           | t <sub>su</sub> (SCLH-SDAL) | 4.7 |     | ns   |
| I8                           | t <sub>h</sub> (SDAL-SCLL)  | 4   |     | ns   |
| I9                           | t <sub>su</sub> (SDAH-SCLH) | 4   |     | ns   |

(1) The input timing requirements are given by considering a rising or falling time of:  
 80 ns in HS mode (3.4 Mbps)  
 300 ns in fast-speed mode (400 Kbps)  
 1000 ns in standard mode (100 Kbps)

(2) SDA is equal to I2C.SR.SDA or I2C.CNTL.SDA.  
 SCL is equal to I2C.SR.SCL or I2C.CNTL.SCL.

Table 12-4 lists the switching requirements of the I<sup>2</sup>C interface.



**Table 12-4. I<sup>2</sup>C Interface—Switching Requirements<sup>(1)</sup> (2)**

| Notation                     | Parameter     |                          | Min                | Max | Unit    |
|------------------------------|---------------|--------------------------|--------------------|-----|---------|
| <b>Slave HS Mode</b>         |               |                          |                    |     |         |
| I1                           | $t_{w(SCLL)}$ | Pulse duration, SCL low  | 160                |     | ns      |
| I2                           | $t_{w(SCLH)}$ | Pulse duration, SCL high | 60                 |     | ns      |
| <b>Slave Fast-Speed Mode</b> |               |                          |                    |     |         |
| I1                           | $t_{w(SCLL)}$ | Pulse duration, SCL low  | 1.3 <sup>(3)</sup> |     | $\mu$ s |
| I2                           | $t_{w(SCLH)}$ | Pulse duration, SCL high | 0.6                |     | $\mu$ s |
| <b>Slave Standard Mode</b>   |               |                          |                    |     |         |
| I1                           | $t_{w(SCLL)}$ | Pulse duration, SCL low  | 4.7                |     | $\mu$ s |
| I2                           | $t_{w(SCLH)}$ | Pulse duration, SCL high | 4                  |     | $\mu$ s |

- (1) The capacitive load is:  
100 pF in HS mode (3.4 Mbps)  
400 pF in fast-speed mode (400 Kbps)  
400 pF in standard mode (100 Kbps)
- (2) SDA is equal to I2C.SR.SDA or I2C.CNTL.SDA  
SCL is equal to I2C.SR.SCL or I2C.CNTL.SCL
- (3) SCL low timing for slave fast-speed mode is compatible with 0.79  $\mu$ s.

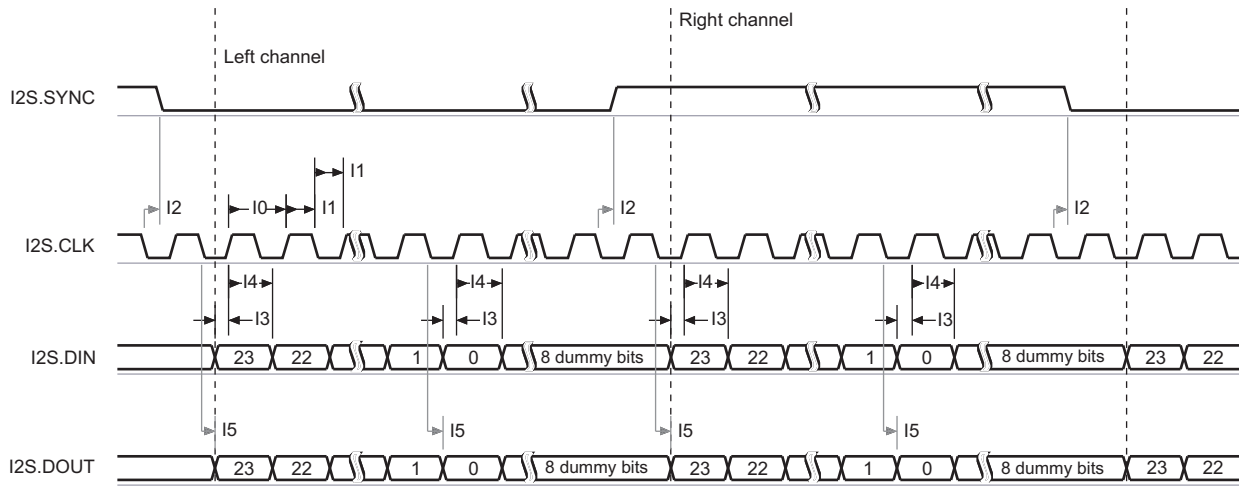
## 12.4 Audio Interface: TDM/I2S Protocol

The TPS65920/TPS65930 device acts as a master for the TDM and I2S interfaces or as a slave for only the I2S interface. If the TPS65920/TPS65930 device is the master, it must provide the frame synchronization (TDM/I2S\_SYNC) and bit clock (TDM/I2S\_CLK) to the host processor. If it is the slave, the TPS65920/TPS65930 device receives frame synchronization and the bit clock.

The TPS65920/TPS65930 device supports the I2S, TDM, left-justified, and right-justified data formats, but does not support TDM slave mode.

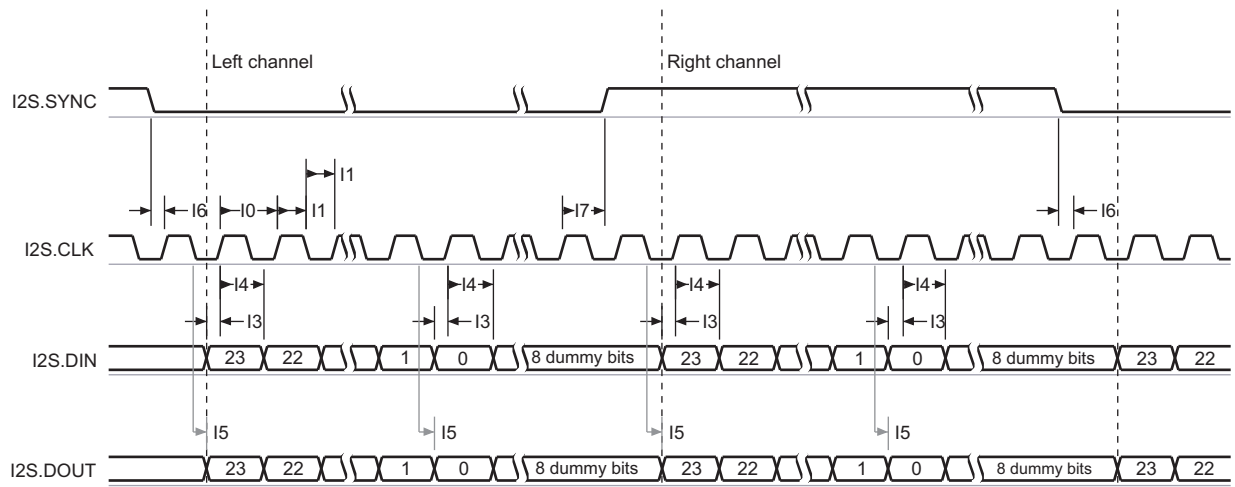
### 12.4.1 I2S Right- and Left-Justified Data Format

Table 12-5 and Table 12-6 assume testing over the recommended operating conditions (see Figure 12-2 and Figure 12-3).



037-031

Figure 12-2. I2S Interface—I2S Master Model



037-032

Figure 12-3. I2S Interface—I2S Slave Mode

The timing requirements listed in Table 12-5 are valid on the following conditions of input slew and output load:

- Rise and fall time range of inputs (SYNC, DIN) is  $t_R/t_F = 1.0 \text{ ns}/6.5 \text{ ns}$
- Capacitance load range of outputs (CLK, SYNC, DOUT) is  $C_{Load} = 1 \text{ pF}/30 \text{ pF}$

The input timing requirements in [Table 12-5](#) are given by considering a rising or falling time of 6.5 ns.

**Table 12-5. I2S Interface—Timing Requirements**

| Notation           | Parameter           |  | Min          | Max        | Unit |
|--------------------|---------------------|--|--------------|------------|------|
| <b>Master Mode</b> |                     |  |              |            |      |
| I3                 | $t_{su}(DIN-CLKH)$  | Setup time, I2S.DIN valid to I2S.CLK high <sup>2</sup> | 25           |            | ns   |
| I4                 | $t_h(DIN-CLKH)$     | Hold time, I2S.DIN valid from I2S.CLK high.            | 0            |            | ns   |
| <b>Slave Mode</b>  |                     |  |              |            |      |
| I0                 | $t_c(CLK)$          | Cycle time, I2S.CLK <sup>(1)</sup>                     | $1/64 * F_s$ |            | ns   |
| I1                 | $t_w(CLK)$          | Pulse duration, I2S.CLK high or low <sup>(2)</sup>     | $0.45 * P$   | $0.55 * P$ | ns   |
| I3                 | $t_{su}(DIN-CLKH)$  | Setup time, I2S.DIN valid to I2S.CLK high              | 5            |            | ns   |
| I4                 | $t_h(DIN-CLKH)$     | Hold time, I2S.DIN valid from I2S.CLK high.            | 5            |            | ns   |
| I6                 | $t_{su}(SYNC-CLKH)$ | Setup time, I2S.SYNC valid to I2S.CLK high             | 5            |            | ns   |
| I7                 | $t_h(SYNC-CLKH)$    | Hold time, I2S.SYNC valid from I2S.CLK high            | 5            |            | ns   |

(1)  $F_s = 8$  to 48 kHz; 96 kHz for RX path only

(2)  $P = I2S.CLK$  period

The capacitive load for [Table 12-6](#) is 7 pF. [Table 12-6](#) lists the switching characteristics for the I2S interface.

**Table 12-6. I2S Interface—Switching Characteristics**

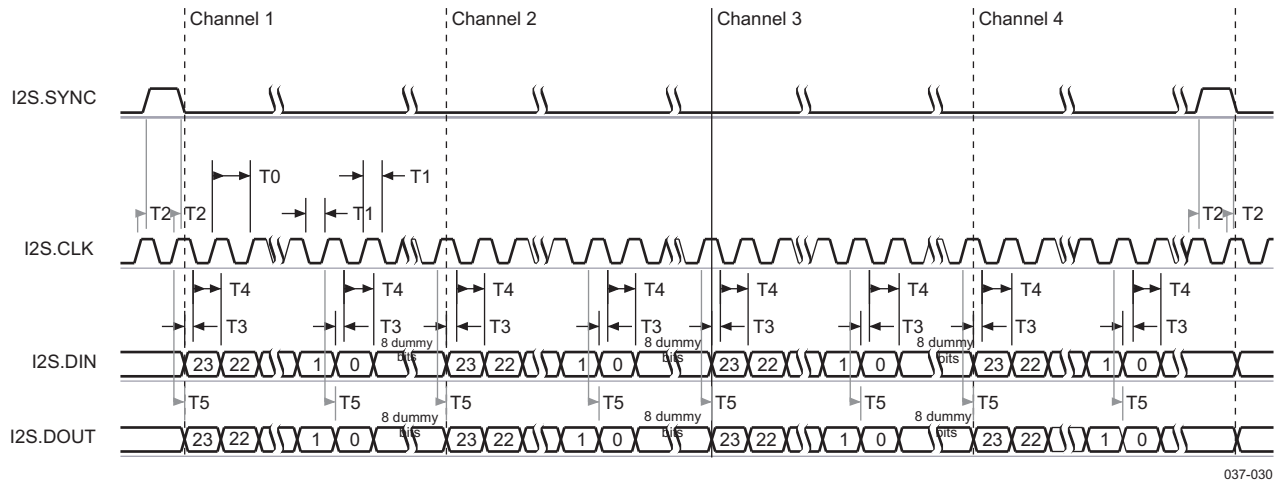
| Notation           | Parameter        |   | Min          | Max        | Unit |
|--------------------|------------------|---|--------------|------------|------|
| <b>Master Mode</b> |                  |   |              |            |      |
| I0                 | $t_c(CLK)$       | Cycle time, I2S.CLK <sup>(1)</sup>                      | $1/64 * F_s$ |            | ns   |
| I1                 | $t_w(CLK)$       | Pulse duration, I2S.CLK high or low <sup>(2)</sup>      | $0.45 * P$   | $0.55 * P$ | ns   |
| I2                 | $t_d(CLKL-SYNC)$ | Delay time, I2S.CLK falling edge to I2S.SYNC transition | -10          | 10         | ns   |
| I5                 | $t_d(CLKL-DOUT)$ | Delay time, I2S.CLK falling edge to I2S.DOUT transition | -10          | 10         | ns   |
| <b>Slave Mode</b>  |                  |   |              |            |      |
| I5                 | $t_d(CLKL-DOUT)$ | Delay time, I2S.CLK falling edge to I2S.DOUT transition | 0            | 20         | ns   |

(1)  $F_s = 8$  to 48 kHz; 96 kHz for RX path only

(2)  $P = I2S.CLK$  period

### 12.4.2 TDM Data Format

Table 12-7 and Table 12-8 assume testing over the recommended operating conditions (see Figure 12-4).



037-030

Figure 12-4. TDM Interface—TDM Master Mode

The timing requirements listed in [Table 12-7](#) are valid on the following conditions of input slew and output load:

- Rise and fall time range of inputs (SYNC, DIN) is  $t_R/t_F = 1.0 \text{ ns}/6.5 \text{ ns}$
- Capacitance load range of outputs (CLK, SYNC, DOUT) is  $C_{\text{Load}} = 1 \text{ pF}/30 \text{ pF}$

**Table 12-7. TDM Interface Master Mode—Timing Requirements**

| Notation | Parameter                        |  | Min | Max | Unit |
|----------|----------------------------------|--|-----|-----|------|
| T3       | $t_{\text{su}}(\text{DIN-CLKH})$ | Setup time, TDM.DIN valid to TDM.CLK high  | 25  |     | ns   |
| T4       | $t_{\text{h}}(\text{DIN-CLKH})$  | Hold time, TDM.DIN valid from TDM.CLK high | 0   |     | ns   |

[Table 12-8](#) lists the switching characteristics of the TDM interface master mode.

**Table 12-8. TDM Interface Master Mode—Switching Characteristics**

| Notation | Parameter                        |  | Min          | Max        | Unit |
|----------|----------------------------------|--|--------------|------------|------|
| T0       | $t_{\text{c}}(\text{CLK})$       | Cycle time, TDM.CLK <sup>(1)</sup>                     | $1/64 * F_s$ |            | ns   |
| T1       | $t_{\text{w}}(\text{CLK})$       | Pulse duration, TDM.CLK high or low <sup>(2)</sup>     | $0.45 * P$   | $0.55 * P$ | ns   |
| T2       | $t_{\text{d}}(\text{CLKL-SYNC})$ | Delay time, TDM.CLK rising edge to TDM.SYNC transition | -10          | 10         | ns   |
| T5       | $t_{\text{d}}(\text{CLKL-DOUT})$ | Delay time, TDM.CLK rising edge to TDM.DOUT transition | -10          | 12         | ns   |

(1)  $F_s = 8$  to  $48 \text{ kHz}$ ;  $96 \text{ kHz}$  for RX path only

(2)  $P = \text{TDM.CLK period}$

## 12.5 JTAG Interfaces

The TPS65920/TPS65930 device JTAG TAP controller handles standard IEEE JTAG interfaces. This section describes the timing requirements for the tools used to test TPS65920/TPS65930 device power management.

The JTAG/TAP module provides a JTAG interface according to IEEE Std1149.1a. This interface uses the four I/O pins TMS, TCK, TDI, and TDO. The TMS, TCK, and TDI inputs contain a pullup device, which makes their state high when they are not driven. The output TDO is a 3-state output, which is high impedance except when data are shifted between TDI and TDO.

- TCK is the test clock signal.
- TMS is the test mode select signal.
- TDI is the scan path input.
- TDO is the scan path output.

TMS and TDO are multiplexed at the top level with the GPIO0 and GPIO1 pins. The dedicated external TEST pin switches from functional mode (GPIO0/GPIO1) to JTAG mode (TMS/TDO). The JTAG operations are controlled by a state-machine that follows the IEEE Std1149.1a state diagram. This state-machine is reset by the TPS65920/TPS65930 internal power-on reset (POR). A test mode is selected by writing a 6-bit word (instruction) into the instruction register and then accessing the related data register.

[Table 12-9](#) and [Table 12-10](#) assume testing over the recommended operating conditions (see [Figure 12-5](#)).

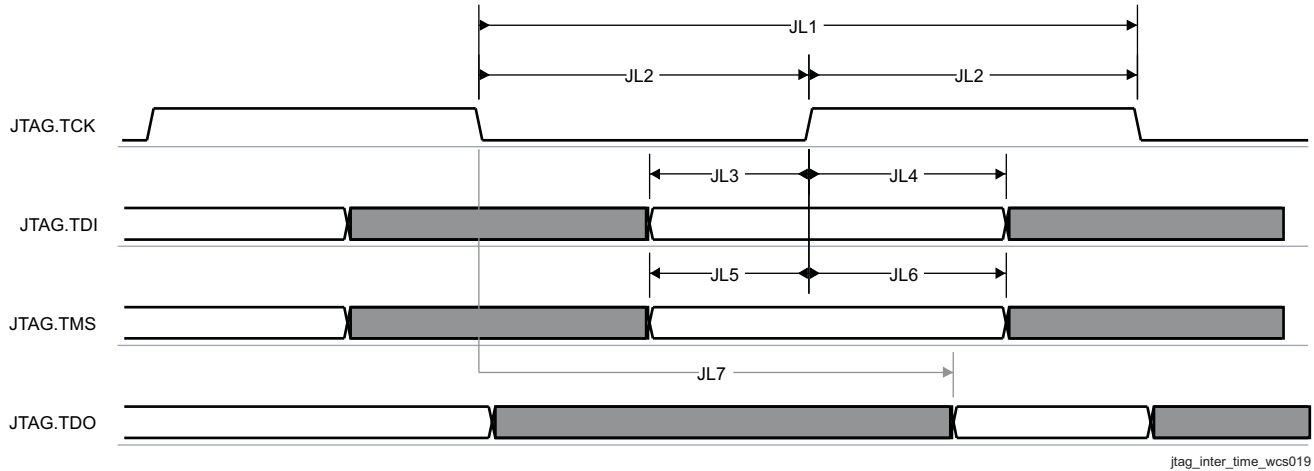


Figure 12-5. JTAG Interface Timing

The input timing requirements are given by considering a rising or falling edge of 7 ns.

Table 12-9. JTAG Interface—Timing Requirements

| Notation           | Parameter           |   | Min    | Max    | Unit |
|--------------------|---------------------|---|--------|--------|------|
| <b>Clock</b>       |                     |   |        |        |      |
| JL1                | $t_{c(TCK)}$        | Cycle time, JTAG.TCK period                         | 30     |        | ns   |
| JL2                | $t_{w(TCK)}$        | Pulse duration, JTAG.TCK high or low <sup>(1)</sup> | 0.48*P | 0.52*P | ns   |
| <b>Read Timing</b> |                     |   |        |        |      |
| JL3                | $t_{su(TDIV-TCKH)}$ | Setup time, JTAG.TDI valid before JTAG.TCK high     | 8      |        | ns   |
| JL4                | $t_{h(TDIV-TCKH)}$  | Hold time, JTAG.TDI valid after JTAG.TCK high       | 5      |        | ns   |
| JL5                | $t_{su(TMSV-TCKH)}$ | Setup time, JTAG.TMS valid before JTAG.TCK high     | 8      |        | ns   |
| JL6                | $t_{h(TMSV-TCKH)}$  | Hold time, JTAG.TMS valid after JTAG.TCK high       | 5      |        | ns   |

(1) P = JTAG.TCK clock period

The capacitive load is 35 pF.

Table 12-10. JTAG Interface—Switching Characteristics

| Notation            | Parameter         |   | Min | Max | Unit |
|---------------------|-------------------|---|-----|-----|------|
| <b>Write Timing</b> |                   |   |     |     |      |
| JL7                 | $t_{d(TCK-TDOV)}$ | Delay time, JTAG, TCK active edge to JTAG.TDO valid | 0   | 14  | ns   |

### 13 Debouncing Time

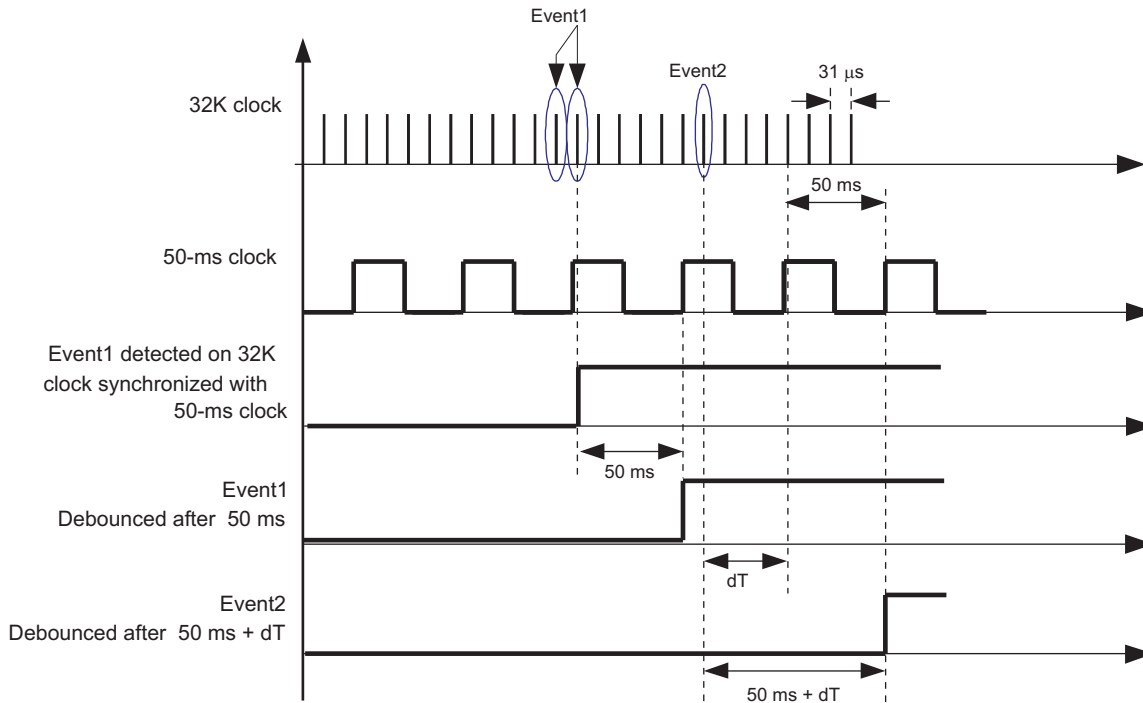
Table 13-1 lists the characteristics of debouncing.

**Table 13-1. Debouncing**

| Debouncing Functions   | Block             | Programmable | Debouncing Time                        | Default  |
|--|-------------------|--------------|--|----------|
| USB plug detection   | USB               | No           | 9x50 ms                                | 9x50 ms  |
| Plug/unplug detection VBUS <sup>(1)</sup>  | USB               | Yes          | 0 to 250 ms<br>(32/32468-second steps) | 28 ms    |
| Plug/unplug detection ID <sup>(2)</sup>  | USB               | Yes          | 0 to 250 ms<br>(32/32468-second steps) | 50 ms    |
| Debouncing function interrupt generation debounce for VBUS and ID <sup>(3)</sup> | Power             | Yes          | 0 to 250 ms                            | 30 ms    |
| Hot-die detection  | Thermistor        | No           | 60 μs                                  | 60 μs    |
| Thermal shutdown detection   |                   | No           | 60 μs                                  | 60 μs    |
| PWRON <sup>(4)</sup>   | Start/stop button | No           | 31.25 ms                               | 31.25 ms |
| NRESWARM   | Button reset      | No           | 60 μs                                  | 60 μs    |
| SIM card plug/unplug   | GPIO              | Yes          | 0 or 30 ms ± 1 ms                      | 0 ms     |
| MMC1 (plug/unplug)   | GPIO              | Yes          | 0 or 30 ms ± 1 ms                      | 0 ms     |

- (1) Programmable in the VBUS\_DEBOUNCE register
- (2) Programmable in the ID\_DEBOUNCE register
- (3) Programmable in the RESERVED\_E[2:0] CFG\_VBUSDEB register
- (4) The PWRON signal is debounced 1024\*CLK32K (maximum 1026\*CLK32K) falling edge in master mode.

Figure 13-1 is a sample debouncing sequence chronogram.



**Figure 13-1. Debouncing Sequence Chronogram Example**

Event1 is correctly debounced after 5 ms. Event2 is debounced after 50ms + dT because the capture of the event is considered after the next rising edge of the 50-ms clock.

## 14 External Components

Table 14-1 lists the TPS65920/TPS65930 device external components.

**Table 14-1. TPS65920/TPS65930 External Components**

| Function              | Component | Reference                   | Value      | Note   | Link                     |
|-----------------------|-----------|-----------------------------|------------|--|--------------------------|
| <b>Power Supplies</b> |           |                             |            |  |                          |
| VDD1                  | Capacitor | C <sub>VDD1.IN</sub>        | 10 $\mu$ F | Range $\pm$ 50%<br>ESR min = 1 m $\Omega$<br>ESR max = 20 m $\Omega$<br>Taiyo Yuden: JMK212BJ106KD | Figure 4-1               |
|                       | Capacitor | C <sub>VDD1.OUT</sub>       | 10 $\mu$ F | Range $\pm$ 50%<br>ESR min = 1 m $\Omega$<br>ESR max = 20 m $\Omega$<br>Taiyo Yuden: JMK212BJ106KD |                          |
|                       | Inductor  | L <sub>VDD1</sub>           | 1 $\mu$ H  | Range $\pm$ 30%<br>DCR max = 100 m $\Omega$  |                          |
| VDD2                  | Capacitor | C <sub>VDD2.IN</sub>        | 10 $\mu$ F | Range $\pm$ 50%<br>ESR min = 1 m $\Omega$<br>ESR max = 20 m $\Omega$<br>Taiyo Yuden: JMK212BJ106KD | Figure 4-1               |
|                       | Capacitor | C <sub>VDD2.OUT</sub>       | 10 $\mu$ F | Range $\pm$ 50%<br>ESR min = 1 m $\Omega$<br>ESR max = 20 m $\Omega$<br>Taiyo Yuden: JMK212BJ106KD |                          |
|                       | Inductor  | L <sub>VDD2</sub>           | 1 $\mu$ H  | Range $\pm$ 30%<br>DCR max = 100 m $\Omega$  |                          |
| VIO                   | Capacitor | C <sub>VIO.IN</sub>         | 10 $\mu$ F | Range $\pm$ 50%<br>ESR min = 1 m $\Omega$<br>ESR max = 20 m $\Omega$<br>Taiyo Yuden: JMK212BJ106KD | Figure 4-1               |
|                       | Capacitor | C <sub>VIO.OUT</sub>        | 10 $\mu$ F | Range $\pm$ 50%<br>ESR min = 1 m $\Omega$<br>ESR max = 20 m $\Omega$<br>Taiyo Yuden: JMK212BJ106KD |                          |
|                       | Inductor  | L <sub>VIO</sub>            | 1 $\mu$ H  | Range $\pm$ 30%<br>DCR max = 100 m $\Omega$  |                          |
| VRUSB_3V              | Capacitor | C <sub>VUSB.3P1</sub>       | 1 $\mu$ F  | Range: 0.3 to 2.7 $\mu$ F<br>ESR min = 20 m $\Omega$<br>ESR max = 300 m $\Omega$                   | Figure 4-1<br>Figure 7-2 |
| VRUSB_1V5             | Capacitor | C <sub>VINTUSB1P5.OUT</sub> | 1 $\mu$ F  | Range: 0.3 to 2.7 $\mu$ F<br>ESR min = 20 m $\Omega$<br>ESR max = 600 m $\Omega$                   | Figure 4-1<br>Figure 7-2 |
| VRUSB_1V8             | Capacitor | C <sub>VINTUSB1P8.OUT</sub> | 1 $\mu$ F  | Range: 0.3 to 2.7 $\mu$ F<br>ESR min = 20 m $\Omega$<br>ESR max = 600 m $\Omega$                   | Figure 4-1<br>Figure 7-2 |
| VDAC                  | Capacitor | C <sub>VDAC.IN</sub>        | 1 $\mu$ F  | Range: 0.3 to 2.7 $\mu$ F<br>ESR min = 20 m $\Omega$<br>ESR max = 600 m $\Omega$                   | Figure 4-1               |
|                       | Capacitor | C <sub>VDAC.OUT</sub>       | 1 $\mu$ F  | Range: 0.3 to 2.7 $\mu$ F<br>ESR min = 20 m $\Omega$<br>ESR max = 600 m $\Omega$                   |                          |
| VPLLA3R               | Capacitor | C <sub>VPLLA3R.IN</sub>     | 1 $\mu$ F  | Range: 0.3 to 2.7 $\mu$ F<br>ESR min = 20 m $\Omega$<br>ESR max = 600 m $\Omega$                   | Figure 4-1               |
| VPLL1                 | Capacitor | C <sub>VPLL1.OUT</sub>      | 1 $\mu$ F  | Range: 0.3 to 2.7 $\mu$ F<br>ESR min = 20 m $\Omega$<br>ESR max = 600 m $\Omega$                   | Figure 4-1               |



**Table 14-1. TPS65920/TPS65930 External Components (continued)**

| Function                         | Component    | Reference                 | Value                 | Note   | Link                        |
|----------------------------------|--------------|---------------------------|-----------------------|--|-----------------------------|
| VMC1                             | Capacitor    | C <sub>VMMC1.IN</sub>     | 1 $\mu$ F             | Range: 0.3 to 2.7 $\mu$ F<br>ESR min = 20 m $\Omega$<br>ESR max = 600 m $\Omega$ | <a href="#">Figure 4-1</a>  |
|                                  | Capacitor    | C <sub>VMMC1.OUT</sub>    | 1 $\mu$ F             | Range: 0.3 to 2.7 $\mu$ F<br>ESR min = 20 m $\Omega$<br>ESR max = 600 m $\Omega$ |                             |
| VAUX12S                          | Capacitor    | C <sub>VAUX12S.IN</sub>   | 1 $\mu$ F             | Range: 0.3 to 2.7 $\mu$ F<br>ESR min = 20 m $\Omega$<br>ESR max = 600 m $\Omega$ | <a href="#">Figure 4-1</a>  |
| VAUX2                            | Capacitor    | C <sub>VAUX2.OUT</sub>    | 1 $\mu$ F             | Range: 0.3 to 2.7 $\mu$ F<br>ESR min = 20 m $\Omega$<br>ESR max = 600 m $\Omega$ | <a href="#">Figure 4-1</a>  |
| VINT                             | Capacitor    | C <sub>VINT.IN</sub>      | 1 $\mu$ F             | Range: 0.3 to 2.7 $\mu$ F<br>ESR min = 20 m $\Omega$<br>ESR max = 600 m $\Omega$ | <a href="#">Figure 4-1</a>  |
| VINTANA1                         | Capacitor    | C <sub>VINTANA1.OUT</sub> | 1 $\mu$ F             | Range: 0.3 to 2.7 $\mu$ F<br>ESR min = 20 m $\Omega$<br>ESR max = 600 m $\Omega$ | <a href="#">Figure 4-1</a>  |
| VINTANA2                         | Capacitor    | C <sub>VINTANA2.OUT</sub> | 1 $\mu$ F             | Range: 0.3 to 2.7 $\mu$ F<br>ESR min = 20 m $\Omega$<br>ESR max = 600 m $\Omega$ | <a href="#">Figure 4-1</a>  |
| VINTDIG                          | Capacitor    | C <sub>VINTDIG.OUT</sub>  | 1 $\mu$ F             | Range: 0.3 to 2.7 $\mu$ F<br>ESR min = 20 m $\Omega$<br>ESR max = 600 m $\Omega$ | <a href="#">Figure 4-1</a>  |
| VBAT.USB                         | Capacitor    | C <sub>VBAT.USB</sub>     | 1 $\mu$ F             | Range: 0.3 to 2.7 $\mu$ F<br>ESR min = 20 m $\Omega$<br>ESR max = 600 m $\Omega$ | <a href="#">Figure 7-2</a>  |
| USB CP                           | Capacitor    | C <sub>VBUS.FC</sub>      | 2.2 $\mu$ F $\pm$ 40% | ESR max = 20 m $\Omega$  | <a href="#">Figure 7-2</a>  |
|                                  | Capacitor    | C <sub>VBUS.IN</sub>      | 10 $\mu$ F            |  |                             |
|                                  | Capacitor    | C <sub>VBUS</sub>         | 4.7 $\mu$ F $\pm$ 40% | ESR max = 20 m $\Omega$  |                             |
| <b>32.768 kHz</b>                |              |                           |                       |  |                             |
| 32K OSC                          | Capacitor    | C <sub>XIN</sub>          | 10 pF                 | Range: 9 pF to 12.5 pF   | <a href="#">Figure 11-5</a> |
|                                  | Capacitor    | C <sub>XOUT</sub>         | 10 pF                 |  |                             |
|                                  | Quartz       | X <sub>32.768kHz</sub>    | 32.768 kHz            | $\pm$ 30 ppm (at 25°C)<br>$\pm$ 200 ppm (–40°C to 85°C)                          |                             |
| <b>Audio</b>                     |              |                           |                       |  |                             |
| External class-D predriver left  | Capacitor    | C <sub>PL.O</sub>         | 50 pF                 |  | <a href="#">Figure 6-2</a>  |
|                                  | Capacitor    | C <sub>PL</sub>           | 1 $\mu$ F             |  |                             |
|                                  | Resistor     | R <sub>PL</sub>           | >15 k $\Omega$        |  |                             |
|                                  | Resistor     | R <sub>PL.M</sub>         | >15 k $\Omega$        |  |                             |
|                                  | Resistor     | R <sub>PL.O</sub>         | 10 k $\Omega$         |  |                             |
|                                  | Capacitor    | C <sub>PL.M</sub>         | 1 $\mu$ F             |  |                             |
| External class-D predriver right | Capacitor    | C <sub>PR.O</sub>         | 50 pF                 |  | <a href="#">Figure 6-2</a>  |
|                                  | Capacitor    | C <sub>PR</sub>           | 1 $\mu$ F             |  |                             |
|                                  | Resistor     | R <sub>PR</sub>           | >15 k $\Omega$        |  |                             |
|                                  | Resistor     | R <sub>PR.M</sub>         | >15 k $\Omega$        |  |                             |
|                                  | Resistor     | R <sub>PR.O</sub>         | 10 k $\Omega$         |  |                             |
|                                  | Capacitor    | C <sub>PR.M</sub>         | 1 $\mu$ F             |  |                             |
| Vibrator H-bridge                | Ferrite bead | L <sub>V.M</sub>          |                       | BLM18BD221S1N  | <a href="#">Figure 6-3</a>  |
|                                  | Ferrite bead | L <sub>V.P</sub>          |                       | BLM18BD221S1N  |                             |
|                                  | Capacitor    | C <sub>V.V</sub>          | 1 $\mu$ F             |  |                             |
|                                  | Capacitor    | C <sub>V.M</sub>          | 1 nF                  |  |                             |
|                                  | Capacitor    | C <sub>V.P</sub>          | 1 nF                  |  |                             |

**Table 14-1. TPS65920/TPS65930 External Components (continued)**

| Function                                  | Component | Reference              | Value   | Note   | Link         |
|---|-----------|------------------------|---|--|--------------|
| MIC main<br>(pseudo<br>differential mode) | Capacitor | C <sub>MM.M</sub>      | 100 nF  |  | Figure 6-6   |
|   | Capacitor | C <sub>MM.P</sub>      | 100 nF  |  |              |
|   | Capacitor | C <sub>MM.O</sub>      | 47 pF   |  |              |
|   | Resistor  | R <sub>MM.O</sub>      | ~500 Ω  |  |              |
|   | Resistor  | R <sub>MM.MP</sub>     | ~1.7 kΩ   |  |              |
|   | Capacitor | C <sub>MM.B</sub>      | 0 to 200 pF   | If greater than 200 pF, a serial resistor is required for bias stability |              |
| MIC main<br>(differential mode)           | Capacitor | C <sub>MM.M</sub>      | 100 nF  |  | Figure 6-7   |
|   | Capacitor | C <sub>MM.P</sub>      | 100 nF  |  |              |
|   | Capacitor | C <sub>MM.PM</sub>     | 47 pF   |  |              |
|   | Capacitor | C <sub>MM.O</sub>      | 47 pF   |  |              |
|   | Capacitor | C <sub>MM.GM</sub>     | 47 pF   |  |              |
|   | Capacitor | C <sub>MM.GP</sub>     | 47 pF   |  |              |
|   | Resistor  | R <sub>MM.BP</sub>     | 1 kΩ  |  |              |
|   | Resistor  | R <sub>MM.GM</sub>     | 1 kΩ  |  |              |
|   | Capacitor | C <sub>MM.B</sub>      | 0 to 200 pF   | If greater than 200 pF, a serial resistor is required for bias stability |              |
| VMIC1                                     | Capacitor | C <sub>VMIC1.OUT</sub> | 1 μF  | Range: 0.3 μF to 3.3 μF<br>ESR min = 20 mΩ<br>ESR max = 600 mΩ           |              |
| Silicon MIC                               | Capacitor | C <sub>SM</sub>        | 1 μF  |  | Figure 6-8   |
|   | Capacitor | C <sub>SM.P</sub>      | 100 nF  |  |              |
|   | Capacitor | C <sub>SM.M</sub>      | 100 nF  |  |              |
|   | Capacitor | C <sub>SM.PG</sub>     | 47 nF   |  |              |
|   | Resistor  | R <sub>SM</sub>        | >500 Ω  |  |              |
| Auxiliary right                           | Capacitor | C <sub>AUXR</sub>      | 100 nF  |  | Figure 6-9   |
|   | Capacitor | C <sub>AUXR.M</sub>    | 47 pF   |  |              |
| <b>LED Driver</b>                         |           |                        |   |  |              |
| LED                                       | Resistor  | R <sub>LED.A</sub>     | 120 Ω   | Needed for each LED  | Figure 9-1   |
|   | Resistor  | R <sub>LED.B</sub>     | 160 kΩ  | Needed for each LED  |              |
| <b>I<sup>2</sup>C Bus—External Pullup</b> |           |                        |   |  |              |
| I <sup>2</sup> C SmartReflex              | Resistor  | R <sub>PSR.SDA</sub>   | Pullups for various bus capacitances (C <sub>L</sub> ) and I <sup>2</sup> C speeds (Std, Fast, and HS)<br>If C <sub>L</sub> = 10 pF: Std = 118 kΩ, Fast = 35.4 kΩ, HS = 4.7 kΩ<br>If C <sub>L</sub> = 12 pF: Std = 98.3 kΩ, Fast = 29.5 kΩ, HS = 3.9 kΩ<br>If C <sub>L</sub> = 50 pF: Std = 23.6 kΩ, Fast = 7.1 kΩ, HS = 940 Ω<br>If C <sub>L</sub> = 100 pF: Std = 11.8 kΩ, Fast = 3.54 kΩ, HS = 470 Ω<br>If C <sub>L</sub> ≤ 12 pF, there is no need for an external pullup, the internal 3-kΩ pullup can be used.<br>If an external pullup is used, disable the internal 3-kΩ pullup (reference the GPPUPDCTR1 register; see the TRM). |  | Section 12.3 |
|   | Resistor  | R <sub>PSR.SCL</sub>   |   |  |              |
| I <sup>2</sup> C control                  | Resistor  | R <sub>CNTL.SD:</sub>  |   |  |              |
|   | Resistor  | R <sub>CNTL.SCL</sub>  |   |  |              |

## 15 TPS65920/TPS65930 Package

### 15.1 TPS65920/TPS65930 Standard Package Symbols

Figure 15-1 shows the printed device reference.

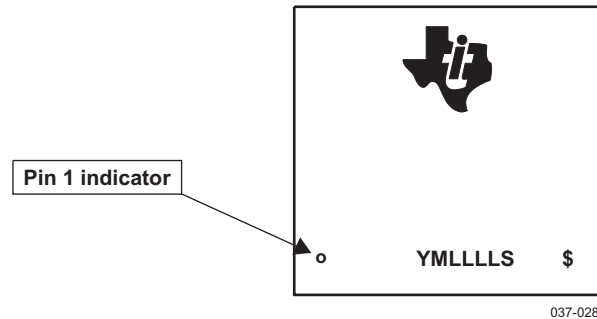


Figure 15-1. Printed Device Reference

Table 15-1 lists the fields and their meanings.

Table 15-1. TPS65920/TPS65930 Nomenclature Description

| Field | Meaning   |
|-------|---|
| P     | Marking used to note prototype (X), preproduction (P), or qualified/production device (blank) <sup>(1)</sup>                      |
| A     | Mask set version descriptor (initial silicon = BLANK, first silicon revision = A, second silicon revision = B,...) <sup>(2)</sup> |
| YM    | Year month  |
| LLLLS | Lot code  |
| \$    | Fab planning code   |

(1) A blank in the symbol or part number is collapsed so there are no gaps between characters.

(2) Initial silicon version is ES1.0; first revision can be named ES2.0, ES1.1, or ES1.01, depending on the level of change.  
Note: The device name is a maximum of 10 characters.

### 15.2 Package Thermal Resistance Characteristics

Table 15-2 and Table 15-3 list the thermal resistance characteristics for the TPS65920 and TPS65930 devices, respectively.

Table 15-2. TPS65920 Thermal Resistance Characteristics

| $R_{\theta JA}$ (°C/W) | $R_{\theta JB}$ (°C/W) | $R_{\theta JC}$ (°C/W) | Board Type          |
|------------------------|------------------------|------------------------|---------------------|
| 33.40                  | 13.80                  | 6.74 <sup>(1)</sup>    | 2S2P <sup>(2)</sup> |
| 57.04                  | 14.50                  | 6.74 <sup>(1)</sup>    | 1S0P <sup>(2)</sup> |

(1) This measurement is not affected by the board on which the device is mounted.

(2) The board types are defined by JEDEC (reference JEDEC standard JESD51-9, Test Board for Area Array Surface Mount Package Thermal Measurements).

Table 15-3. TPS65930 Thermal Resistance Characteristics

| $R_{\theta JA}$ (°C/W) | $R_{\theta JB}$ (°C/W) | $R_{\theta JC}$ (°C/W) | Board Type          |
|------------------------|------------------------|------------------------|---------------------|
| 33.42                  | 13.81                  | 6.74 <sup>(1)</sup>    | 2S2P <sup>(2)</sup> |
| 57.05                  | 14.51                  | 6.74 <sup>(1)</sup>    | 1S0P <sup>(2)</sup> |

(1) This measurement is not affected by the board on which the device is mounted.

(2) The board types are defined by JEDEC (reference JEDEC standard JESD51-9, Test Board for Area Array Surface Mount Package Thermal Measurements).

### 15.3 Mechanical Data

Figure 15-2 is the bottom view of the TPS65920/TPS65930 mechanical package.

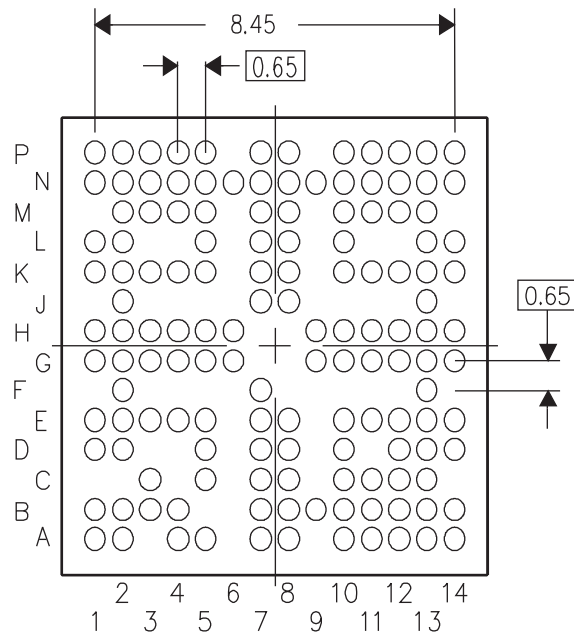


Figure 15-2. TPS65920/TPS65930 Mechanical Package Bottom View

Figure 15-3 shows the ball size.

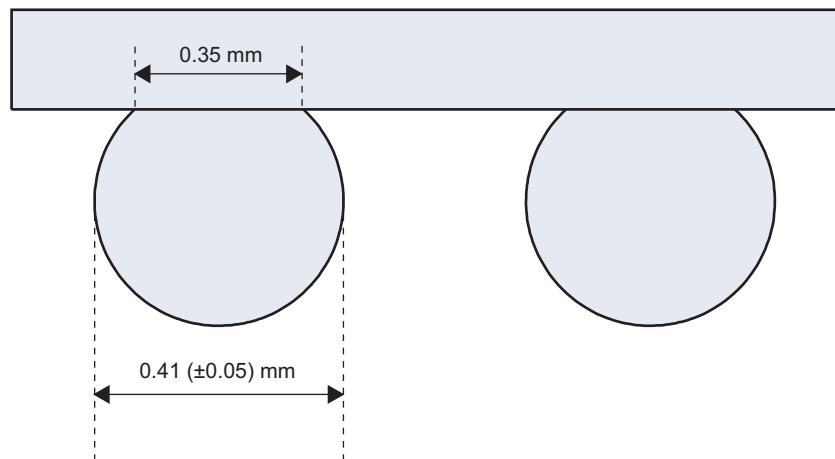


Figure 15-3. Ball Size

## 15.4 ESD Specifications

The device has built-in ESD protection to the limits specified below. It is recommended that the leads are shorted together, or the device placed in conductive foam, during storage or handling to prevent electrostatic damage.

| ESD Method                | Standard Reference | Performance          |
|---------------------------|--------------------|----------------------|
| Human Body Model (HBM)    | EIA / JESD22-A114D | 2000V <sup>(1)</sup> |
| Charge Device Model (CDM) | EIA / JESD22-C101C | 500V                 |

(1) The pin CLK32KOUT is 1500V HBM compliant.

## 16 Glossary

|                  |   |
|------------------|---|
| ADC              | Analog-to-digital converter                   |
| ALC              | Automatic level control                       |
| ASIC             | Application-specific integrated circuit       |
| BGA              | Ball grid array                               |
| BW               | Signal bandwidth                              |
| CMOS             | Complementary metal oxide semiconductor       |
| CMT              | Cellular mobile telephone                     |
| CPU              | Central processing unit                       |
| DAC              | Digital-to-analog converter                   |
| DBB              | Digital baseband                              |
| DCR              | Data capture record                           |
| DM               | Data manual                                   |
| DSP              | Digital signal processor                      |
| DVFS             | Dynamic voltage and frequency scaling         |
| ESD              | Electrostatic discharge                       |
| ESR              | Equivalent series resistance                  |
| FET              | Field effect transistor                       |
| FS               | Full speed                                    |
| FSR              | Full-scale range                              |
| GND              | Ground  |
| GP               | General-purpose                               |
| GPIO             | General-purpose input/output                  |
| hiZ              | High impedance                                |
| HS               | High speed or high security                   |
| HW               | Hardware                                      |
| I <sup>2</sup> C | Inter-integrated circuit                      |
| I2S              | Inter IC sound                                |
| IC               | Integrated circuit                            |
| ICN              | Idle channel noise                            |
| ID               | Identification                                |
| IDDQ             | Direct drain quiescent current                |
| IF               | Interface                                     |
| IO or I/O        | Input/output                                  |
| JTAG             | Joint Test Action Group, IEEE 1149.1 standard |
| LDO              | Low-dropout regulator                         |
| LED              | Light-emitting diode                          |
| LJF              | Left-justified format                         |
| LS               | Low speed                                     |
| MADC             | Monitoring analog-to-digital converter        |

|              |   |
|--------------|---|
| MMC          | Multimedia card                             |
| NA, N/A      | Not applicable                              |
| NRZI         | Nonreturn to zero inverted                  |
| OCP          | Open-core protocol                          |
| OTG          | On-the-Go                                   |
| PBGA         | Plastic ball grid array                     |
| PCB          | Printed circuit board                       |
| PD           | Pulldown                                    |
| PDM          | Pulse density modulated                     |
| PFM          | Pulse frequency modulation                  |
| PLL          | Phase-locked loop                           |
| POL          | Polarity                                    |
| POR          | Power-on reset                              |
| PSR          | Power-supply rejection                      |
| PSRR         | Power-supply rejection ratio                |
| PU           | Pullup                                      |
| PWL          | Pulse-width length                          |
| PWM          | Pulse-width modulation                      |
| PWT          | Pulse-width time                            |
| RJF          | Right-justified format                      |
| RTC          | Real-time clock                             |
| RX           | Receive                                     |
| SDI          | Serial display interface                    |
| SMPS         | Switch-mode power supplies                  |
| SNR          | Signal-to-noise ratio                       |
| SW           | Software                                    |
| SYNC/SYNCHRO | Synchronization                             |
| SYS          | System                                      |
| TBD          | To be defined                               |
| THRU         | Feed through                                |
| TRM          | Technical reference manual                  |
| TX           | Transmit                                    |
| UART         | Universal asynchronous receiver/transmitter |
| ULPI         | UTMI+ low pin Interface                     |
| UPR          | Uninterrupted power rail                    |
| USB          | Universal serial bus                        |
| UTMI         | USB transceiver macrocell Interface         |

**PACKAGING INFORMATION**

| Orderable Device | Status <sup>(1)</sup> | Package Type | Package Drawing | Pins | Package Qty | Eco Plan <sup>(2)</sup>    | Lead/<br>Ball Finish | MSL Peak Temp <sup>(3)</sup> | Samples<br>(Requires Login) |
|------------------|-----------------------|--------------|-----------------|------|-------------|----------------------------|----------------------|------------------------------|-----------------------------|
| TPS65920A2ZCH    | ACTIVE                | NFBGA        | ZCH             | 139  | 184         | Green (RoHS<br>& no Sb/Br) | SNAGCU               | Level-3-260C-168 HR          |                             |
| TPS65920A2ZCHR   | ACTIVE                | NFBGA        | ZCH             | 139  | 1000        | Green (RoHS<br>& no Sb/Br) | SNAGCU               | Level-3-260C-168 HR          |                             |
| TPS65920BZCH     | NRND                  | NFBGA        | ZCH             | 139  | 184         | Green (RoHS<br>& no Sb/Br) | SNAGCU               | Level-3-260C-168 HR          |                             |
| TPS65920BZCHR    | NRND                  | NFBGA        | ZCH             | 139  | 1000        | Green (RoHS<br>& no Sb/Br) | SNAGCU               | Level-3-260C-168 HR          |                             |
| TPS65930A2ZCH    | ACTIVE                | NFBGA        | ZCH             | 139  | 184         | Green (RoHS<br>& no Sb/Br) | SNAGCU               | Level-3-260C-168 HR          |                             |
| TPS65930A2ZCHR   | ACTIVE                | NFBGA        | ZCH             | 139  | 1000        | Green (RoHS<br>& no Sb/Br) | SNAGCU               | Level-3-260C-168 HR          |                             |
| TPS65930BZCH     | NRND                  | NFBGA        | ZCH             | 139  | 184         | Green (RoHS<br>& no Sb/Br) | SNAGCU               | Level-3-260C-168 HR          |                             |
| TPS65930BZCHR    | NRND                  | NFBGA        | ZCH             | 139  | 1000        | Green (RoHS<br>& no Sb/Br) | SNAGCU               | Level-3-260C-168 HR          |                             |

<sup>(1)</sup> The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

<sup>(2)</sup> Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

<sup>(3)</sup> MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.



**Important Information and Disclaimer:** The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

**TAPE AND REEL INFORMATION**

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**


\*All dimensions are nominal

| Device         | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TPS65920A2ZCHR | NFBGA        | ZCH             | 139  | 1000 | 330.0              | 24.4               | 10.4    | 10.4    | 2.3     | 16.0    | 24.0   | Q1            |
| TPS65930A2ZCHR | NFBGA        | ZCH             | 139  | 1000 | 330.0              | 24.4               | 10.4    | 10.4    | 2.3     | 16.0    | 24.0   | Q1            |

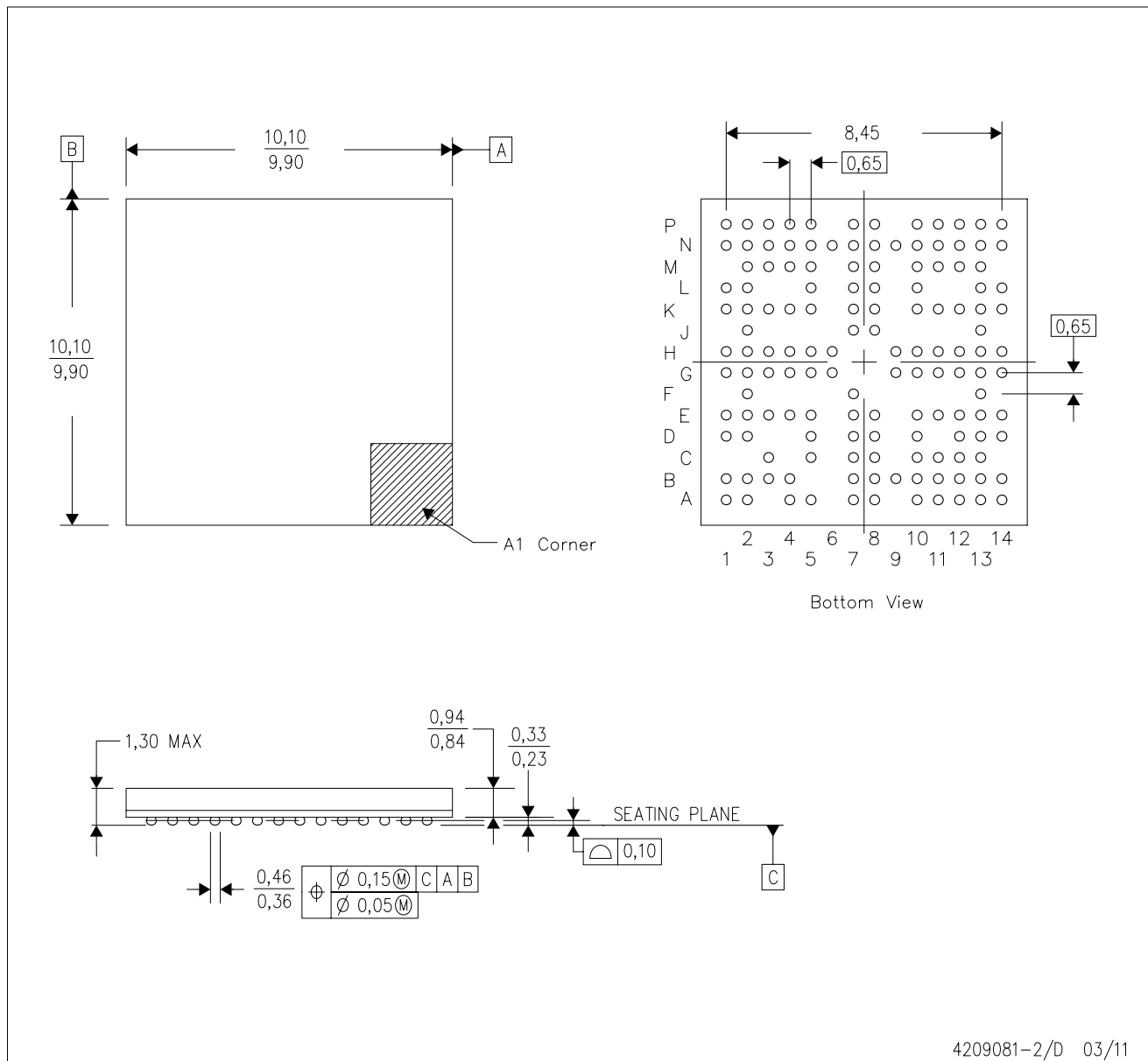
**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

| Device         | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TPS65920A2ZCHR | NFBGA        | ZCH             | 139  | 1000 | 333.2       | 345.9      | 41.3        |
| TPS65930A2ZCHR | NFBGA        | ZCH             | 139  | 1000 | 333.2       | 345.9      | 41.3        |

ZCH (S-PBGA-N139)

PLASTIC BALL GRID ARRAY



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. nFBGA configuration
  - D. This is a Pb-free solder ball design.

## IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

### Products

|                             |  |
|-----------------------------|--|
| Audio                       | <a href="http://www.ti.com/audio">www.ti.com/audio</a>             |
| Amplifiers                  | <a href="http://amplifier.ti.com">amplifier.ti.com</a>             |
| Data Converters             | <a href="http://dataconverter.ti.com">dataconverter.ti.com</a>     |
| DLP® Products               | <a href="http://www.dlp.com">www.dlp.com</a>                       |
| DSP                         | <a href="http://dsp.ti.com">dsp.ti.com</a>                         |
| Clocks and Timers           | <a href="http://www.ti.com/clocks">www.ti.com/clocks</a>           |
| Interface                   | <a href="http://interface.ti.com">interface.ti.com</a>             |
| Logic                       | <a href="http://logic.ti.com">logic.ti.com</a>                     |
| Power Mgmt                  | <a href="http://power.ti.com">power.ti.com</a>                     |
| Microcontrollers            | <a href="http://microcontroller.ti.com">microcontroller.ti.com</a> |
| RFID                        | <a href="http://www.ti-rfid.com">www.ti-rfid.com</a>               |
| RF/IF and ZigBee® Solutions | <a href="http://www.ti.com/lprf">www.ti.com/lprf</a>               |

### Applications

|                               |  |
|-------------------------------|--|
| Communications and Telecom    | <a href="http://www.ti.com/communications">www.ti.com/communications</a>                 |
| Computers and Peripherals     | <a href="http://www.ti.com/computers">www.ti.com/computers</a>                           |
| Consumer Electronics          | <a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>                   |
| Energy and Lighting           | <a href="http://www.ti.com/energy">www.ti.com/energy</a>                                 |
| Industrial                    | <a href="http://www.ti.com/industrial">www.ti.com/industrial</a>                         |
| Medical                       | <a href="http://www.ti.com/medical">www.ti.com/medical</a>                               |
| Security                      | <a href="http://www.ti.com/security">www.ti.com/security</a>                             |
| Space, Avionics and Defense   | <a href="http://www.ti.com/space-avionics-defense">www.ti.com/space-avionics-defense</a> |
| Transportation and Automotive | <a href="http://www.ti.com/automotive">www.ti.com/automotive</a>                         |
| Video and Imaging             | <a href="http://www.ti.com/video">www.ti.com/video</a>                                   |
| Wireless                      | <a href="http://www.ti.com/wireless-apps">www.ti.com/wireless-apps</a>                   |

TI E2E Community Home Page

[e2e.ti.com](http://e2e.ti.com)

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2011, Texas Instruments Incorporated