

# Switched Mode Controller for DC Motor Drive

## FEATURES

- Single or Dual Supply Operation
- $\pm 2.5V$  to  $\pm 20V$  Input Supply Range
- $\pm 5\%$  Initial Oscillator Accuracy;  $\pm 10\%$  Over Temperature
- Pulse-by-Pulse Current Limiting
- Under-Voltage Lockout
- Shutdown Input with Temperature Compensated 2.5V Threshold
- Uncommitted PWM Comparators for Design Flexibility
- Dual 100mA, Source/Sink Output Drivers

## DESCRIPTION

The UC1637 is a pulse width modulator circuit intended to be used for a variety of PWM motor drive and amplifier applications requiring either uni-directional or bi-directional drive circuits. When used to replace conventional drivers, this circuit can increase efficiency and reduce component costs for many applications. All necessary circuitry is included to generate an analog error signal and modulate two bi-directional pulse train outputs in proportion to the error signal magnitude and polarity.

This monolithic device contains a sawtooth oscillator, error amplifier, and two PWM comparators with  $\pm 100mA$  output stages as standard features. Protection circuitry includes under-voltage lockout, pulse-by-pulse current limiting, and a shutdown port with a 2.5V temperature compensated threshold.

The UC1637 is characterized for operation over the full military temperature range of  $-55^{\circ}C$  to  $+125^{\circ}C$ , while the UC2637 and UC3637 are characterized for  $-25^{\circ}C$  to  $+85^{\circ}C$  and  $0^{\circ}C$  to  $+70^{\circ}C$ , respectively.

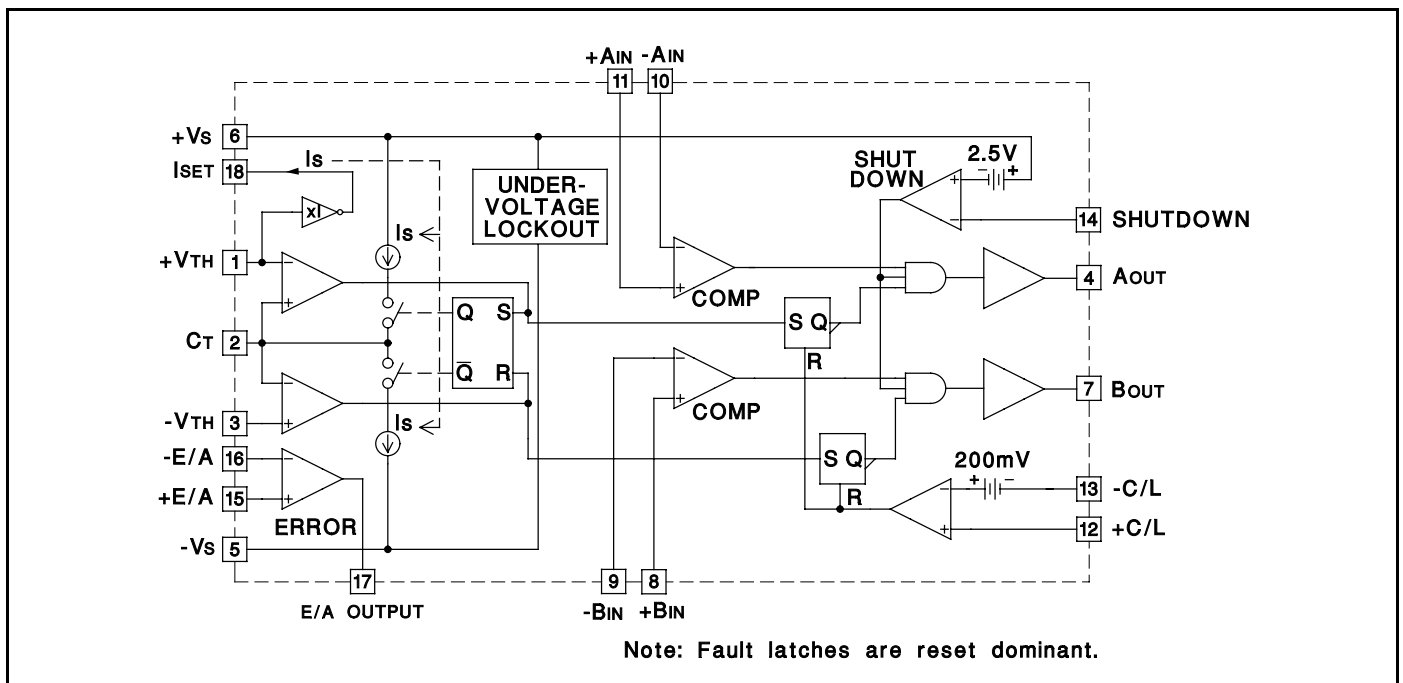
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage ( $\pm V_s$ )	.....	$\pm 20V$
Output Current, Source/Sink (Pins 4, 7)	.....	500mA
Analog Inputs (Pins 1, 2, 3, 8, 9, 10, 11, 12, 13, 14, 15, 16)	.....	$\pm V_s$
Error Amplifier Output Current (Pin 17)	.....	$\pm 20mA$
Oscillator Charging Current (Pin 18)	.....	-2mA
Power Dissipation at $T_A = 25^{\circ}C$ (Note 2)	.....	1000mW
Power Dissipation at $T_C = 25^{\circ}C$ (Note 2)	.....	2000mW
Storage Temperature Range	.....	$-65^{\circ}C$ to $+150^{\circ}C$
Lead Temperature (Soldering, 10 Seconds)	.....	$+300^{\circ}C$

Note 1: Currents are positive into, negative out of the specified terminal.

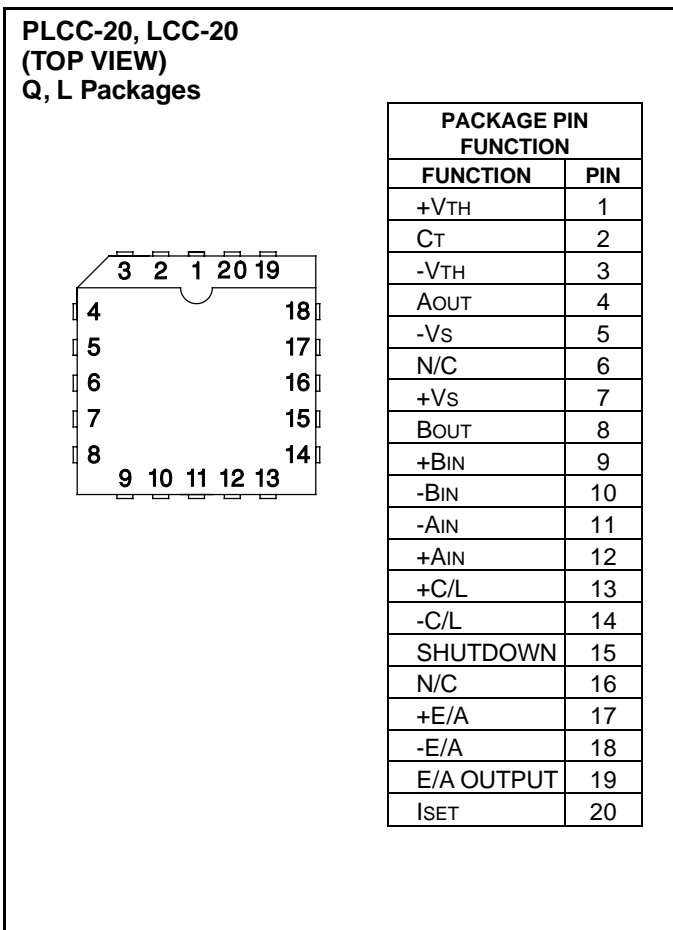
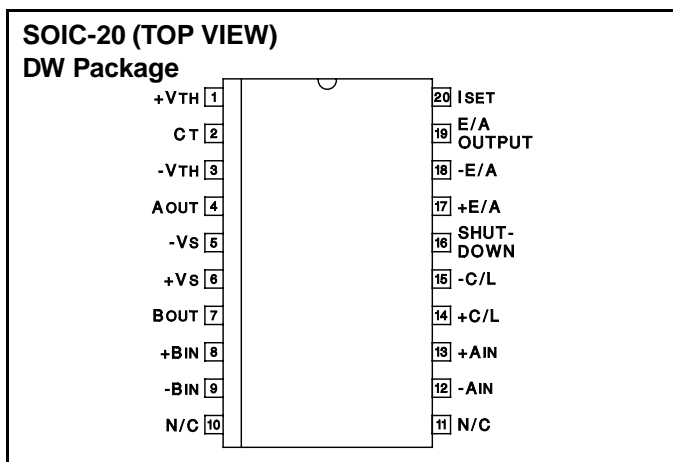
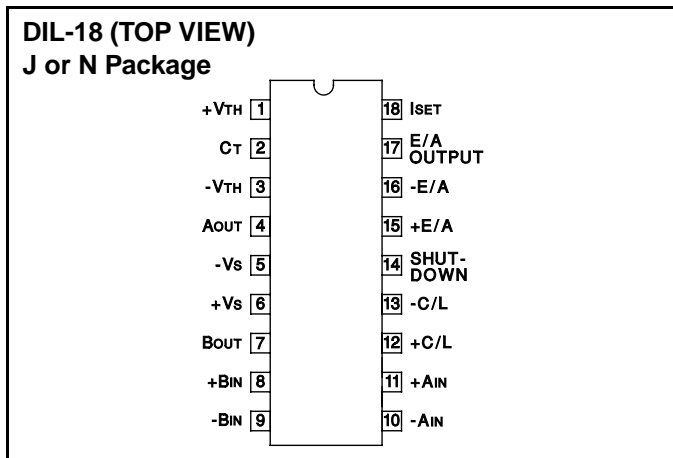
Note 2: Consult Packaging Section of Databook for thermal limitations and considerations of package.

## BLOCK DIAGRAM



Note: Fault latches are reset dominant.

CONNECTION DIAGRAM



**ELECTRICAL CHARACTERISTICS:** Unless otherwise stated, these specifications apply for  $T_A = -55^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$  for the UC1637;  $-25^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  for the UC2637; and  $0^{\circ}\text{C}$  to  $+70^{\circ}\text{C}$  for the UC3637;  $+V_S = +15\text{V}$ ,  $-V_S = -15\text{V}$ ,  $+V_{TH} = 5\text{V}$ ,  $-V_{TH} = -5\text{V}$ ,  $R_T = 16.7\text{k}\Omega$ ,  $C_T = 1500\text{pF}$ ,  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	UC1637/UC2637			UC3637			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
<b>Oscillator</b>								
Initial Accuracy	$T_J = 25^{\circ}\text{C}$ (Note 6)	9.4	10	10.6	9	10	11	kHz
Voltage Stability	$V_S = \pm 5\text{V}$ to $\pm 20\text{V}$ , $V_{PIN 1} = 3\text{V}$ , $V_{PIN 3} = -3\text{V}$		5	7		5	7	%
Temperature Stability	Over Operating Range (Note 3)		0.5	2		0.5	2	%
+VTH Input Bias Current	$V_{PIN 2} = 6\text{V}$	-10	0.1	10	-10	0.1	10	$\mu\text{A}$
-VTH Input Bias Current	$V_{PIN 2} = 0\text{V}$	-10	-0.5		-10	-0.5		$\mu\text{A}$
+VTH, -VTH Input Range		$+V_S - 2$		$-V_S + 2$	$+V_S - 2$		$-V_S + 2$	V
<b>Error Amplifier</b>								
Input Offset Voltage	$V_{CM} = 0\text{V}$		1.5	5		1.5	10	mV
Input Bias Current	$V_{CM} = 0\text{V}$		0.5	5		0.5	5	$\mu\text{A}$
Input Offset Current	$V_{CM} = 0\text{V}$		0.1	1		0.1	1	$\mu\text{A}$
Common Mode Range	$V_S = \pm 2.5$ to $20\text{V}$	$-V_S + 2$		$+V_S$	$-V_S + 2$		$+V_S$	V
Open Loop Voltage Gain	$R_L = 10\text{k}$	75	100		80	100		dB
Slew Rate			15			15		$\text{V}/\mu\text{s}$
Unity Gain Bandwidth			2			2		MHz
CMRR	Over Common Mode Range	75	100		75	100		dB
PSRR	$V_S = \pm 2.5$ to $\pm 20\text{V}$	75	110		75	110		dB

**ELECTRICAL CHARACTERISTICS:** Unless otherwise stated, these specifications apply for  $T_A = -55^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$  for the UC1637;  $-25^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  for the UC2637; and  $0^{\circ}\text{C}$  to  $+70^{\circ}\text{C}$  for the UC3637:  $V_S = +15\text{V}$ ,  $-V_S = -15\text{V}$ ,  $+V_{TH} = 5\text{V}$ ,  $-V_{TH} = -5\text{V}$ ,  $R_T = 16.7\text{k}\Omega$ ,  $C_T = 1500\text{pF}$ ,  $T_A = T_J$ .

PARAMETERS	TEST CONDITIONS	UC1637/UC2637			UC3637			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
<b>Error Amplifier (Continued)</b>								
Output Sink Current	$V_{PIN\ 17} = 0\text{V}$		-50	-20		-50	-20	mA
Output Source Current	$V_{PIN\ 17} = 0\text{V}$	5	11		5	11		mA
High Level Output Voltage		13	13.6		13	13.6		V
Low Level Output Voltage			-14.8	-13		-14.8	-13	V
<b>PWM Comparators</b>								
Input Offset Voltage	$V_{CM} = 0\text{V}$		20			20		mV
Input Bias Current	$V_{CM} = 0\text{V}$		2	10		2	10	$\mu\text{A}$
Input Hysteresis	$V_{CM} = 0\text{V}$		10			10		mV
Common Mode range	$V_S = \pm 5\text{V}$ to $\pm 20\text{V}$	$-V_S + 1$		$+V_S - 2$	$-V_S + 1$		$+V_S - 2$	V
<b>Current Limit</b>								
Input Offset Voltage	$V_{CM} = 0\text{V}$ , $T_J = 25^{\circ}\text{C}$	190	200	210	180	200	220	mV
Input Offset Voltage T.C.			-0.2			-0.2		$\text{mV}/^{\circ}\text{C}$
Input Bias Current		-10	-1.5		-10	-1.5		$\mu\text{A}$
Common Mode Range	$V_S = \pm 2.5\text{V}$ to $\pm 20\text{V}$	$-V_S$		$+V_S - 3$	$-V_S$		$+V_S - 3$	V
<b>Shutdown</b>								
Shutdown Threshold	(Note 4)	-2.3	-2.5	-2.7	-2.3	-2.5	-2.7	V
Hysteresis			40			40		mV
Input Bias Current	$V_{PIN\ 14} = +V_S$ to $-V_S$	-10	-0.5		-10	-0.5		$\mu\text{A}$
<b>Under-Voltage Lockout</b>								
Start Threshold	(Note 5)		4.15	5.0		4.15	5.0	V
Hysteresis			0.25			0.25		mV
<b>Total Standby Current</b>								
Supply Current			8.5	15		8.5	15	mA
<b>Output Section</b>								
Output Low Level	$I_{SINK} = 20\text{mA}$		-14.9	-13		-14.9	-13	V
	$I_{SINK} = 100\text{mA}$		-14.5	-13		-14.5	-13	
Output High Level	$I_{SOURCE} = 20\text{mA}$	13	13.5		13	13.5		V
	$I_{SOURCE} = 100\text{mA}$	12	13.5		12	13.5		
Rise Time	(Note 3) $C_L = \text{Inf}$ , $T_J = 25^{\circ}\text{C}$		100	600		100	600	ns
Fall Time	(Note 3) $C_L = \text{Inf}$ , $T_J = 25^{\circ}\text{C}$		100	300		100	300	ns

Note 3: These parameters, although guaranteed over the recommended operating conditions, are not 100% tested in production.

Note 4: Parameter measured with respect to  $+V_S$  (Pin 6).

Note 5: Parameter measured at  $+V_S$  (Pin 6) with respect to  $-V_S$  (Pin 5).

Note 6:  $R_T$  and  $C_T$  referenced to Ground.

## FUNCTIONAL DESCRIPTION

Following is a description of each of the functional blocks shown in the Block Diagram.

### Oscillator

The oscillator consists of two comparators, a charging and discharging current source, a current source set terminal, ISET and a flip-flop. The upper and lower threshold of the oscillator waveform is set externally by applying a voltage at pins  $+V_{TH}$  and  $-V_{TH}$  respectively. The  $+V_{TH}$  ter-

minal voltage is buffered internally and also applied to the ISET terminal to develop the capacitor charging current through  $R_T$ . If  $R_T$  is referenced to  $-V_S$  as shown in Figure 1, both the threshold voltage and charging current will vary proportionally to the supply differential, and the oscillator frequency will remain constant. The triangle waveform oscillators frequency and voltage amplitude is determined by the external components using the formulas given in Figure 1.

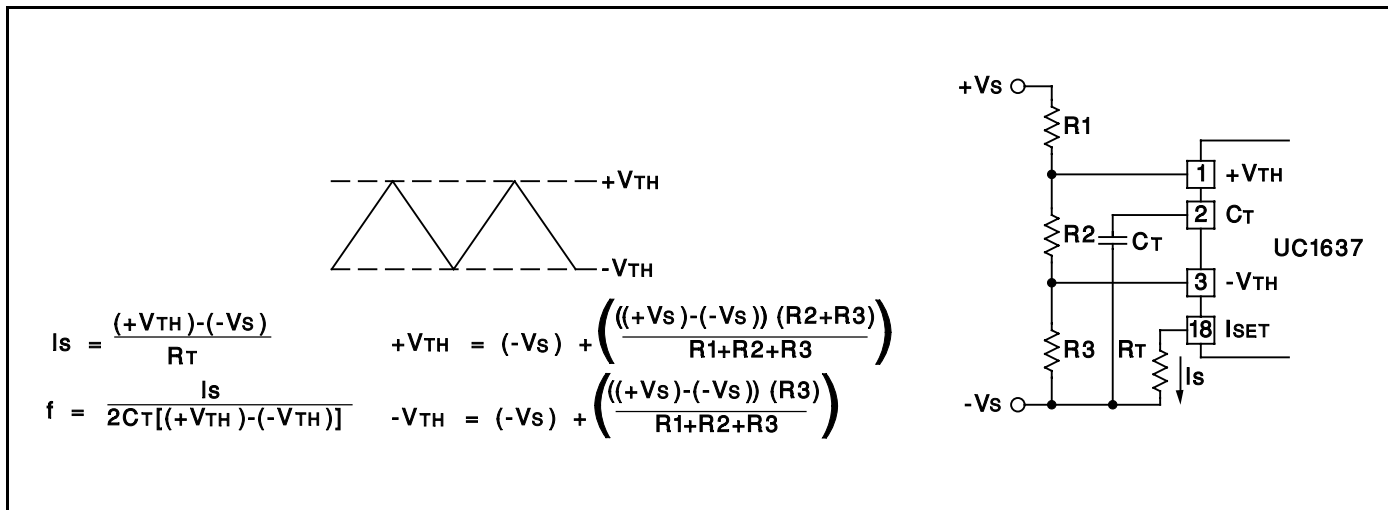


Figure 1. Oscillator Setup

### PWM Comparators

Two comparators are provided to perform pulse width modulation for each of the output drivers. Inputs are uncommitted to allow maximum flexibility. The pulse width of the outputs A and B is a function of the sign and amplitude of the error signal. A negative signal at Pin 10 and 8 will lengthen the high state of output A and shorten the high state of output B. Likewise, a positive error signal reverses the procedure. Typically, the oscillator waveform is compared against the summation of the error signal and the level set on Pin 9 and 11.

### MODULATION SCHEMES

#### Case A Zero Deadtime (Equal voltage on Pin 9 and Pin 11)

In this configuration, maximum holding torque or stiffness and position accuracy is achieved. However, the power input into the motor is increased. Figure 3A shows this configuration.

#### Case B Small Deadtime (Voltage on Pin 9 > Pin 11)

A small differential voltage between Pin 9 and 11 provides the necessary time delay to reduce the chances of momentary short circuit in the output stage during transitions, especially where power-amplifiers are used. Refer to Figure 3B.

#### Case C Increased Deadtime and Deadband Mode

(Voltage on Pin 9 > Pin 11)

With the reduction of stiffness and position accuracy, the power input into the motor around the null point of the servo loop can be reduced or eliminated by widening the window of the comparator circuit to a degree of acceptance. Where position accuracy and mechanical stiffness is unimportant, deadband operation can be used. This is shown in Figure 3C.

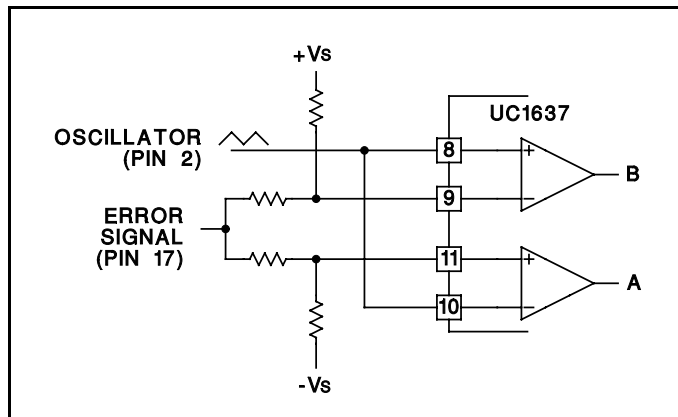


Figure 2. Comparator Biasing

### Output Drivers

Each output driver is capable of both sourcing and sinking 100mA steady state and up to 500mA on a pulsed basis for rapid switching of either POWERFET or bipolar transistors. Output levels are typically  $-V_s + 0.2V$  @50mA low level and  $+V_s - 2.0V$  @50mA high level.

### Error Amplifier

The error amplifier consists of a high slew rate ( $15V/\mu s$ ) op-amp with a typical 1MHz bandwidth and low output impedance. Depending on the  $\pm V_s$  supply voltage, the common mode input range and the voltage output swing is within 2V of the  $V_s$  supply.

### Under-Voltage Lockout

An under-voltage lockout circuit holds the outputs in the low state until a minimum of 4V is reached. At this point, all internal circuitry is functional and the output drivers are enabled. If external circuitry requires a higher starting voltage, an over-riding voltage can be programmed through the shutdown terminal as shown in Figure 4.

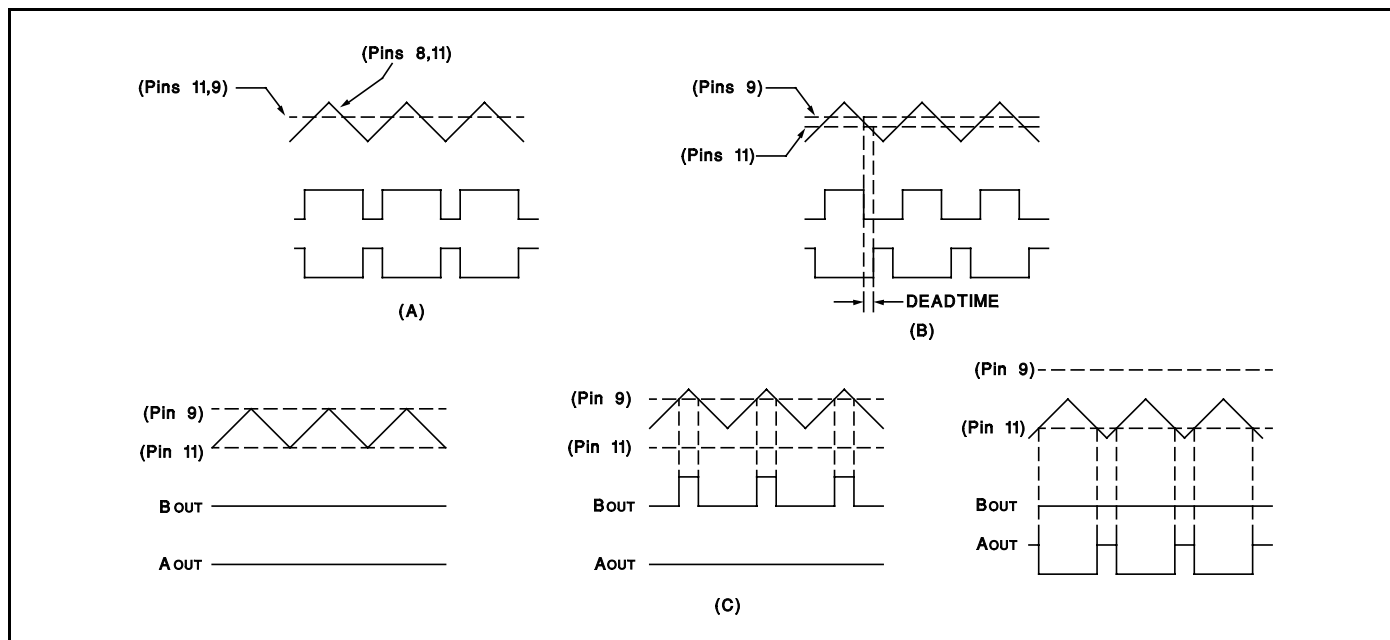


Figure 3. Modulation Schemes Showing (A) Zero Deadtime (B) Deadtime and (C) Deadband Configurations

### Shutdown Comparator

The shutdown terminal may be used for implementing various shutdown and protection schemes. By pulling the terminal more than 2.5V below  $V_{IN}$ , the output drivers will be enabled. This can be realized using an open collector gate or NPN transistor biased to either ground or the negative supply. Since the threshold is temperature stabilized, the comparator can be used as an accurate low voltage lockout (Figure 4) and/or delayed start as in Figure 5. In the shutdown mode the outputs are held in the low state.

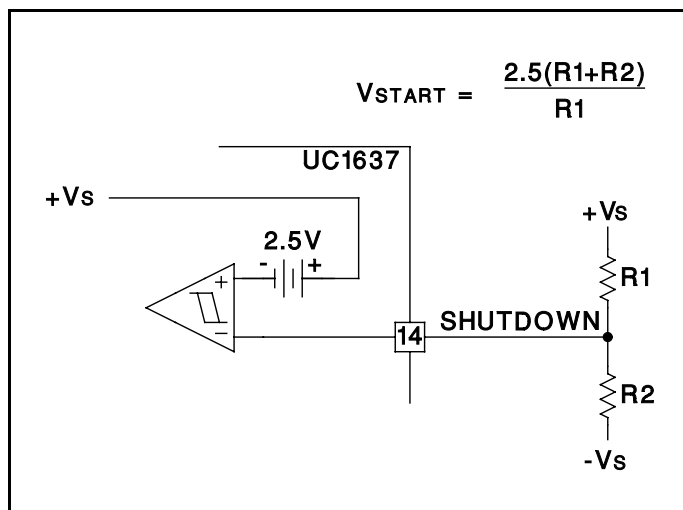


Figure 4. External Under-Voltage Lockout

### Current Limit

A latched current limit amplifier with an internal 200mV offset is provided to allow pulse-by-pulse current limiting. Differential inputs will accept common mode signals from

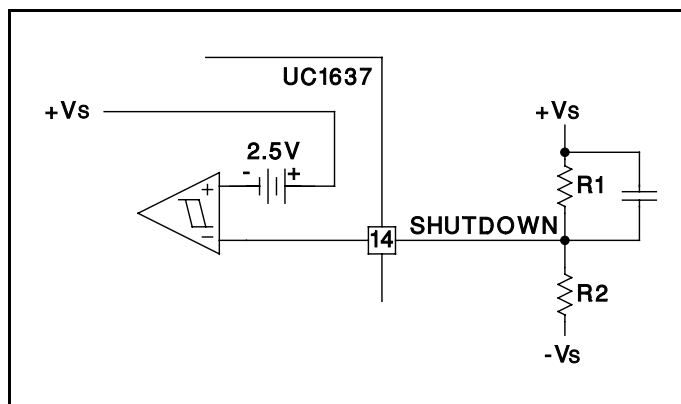


Figure 5. Delayed Start-Up

$-V_s$  to within 3V of the  $+V_s$  supply while providing excellent noise rejection. Figure 6 shows a typical current sense circuit.

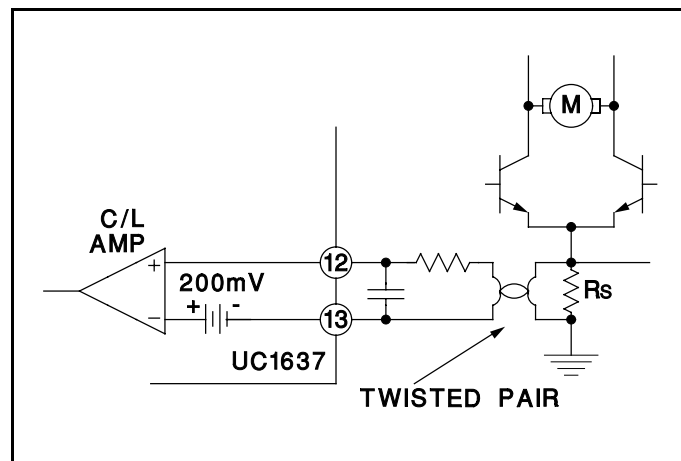


Figure 6. Current Limit Sensing

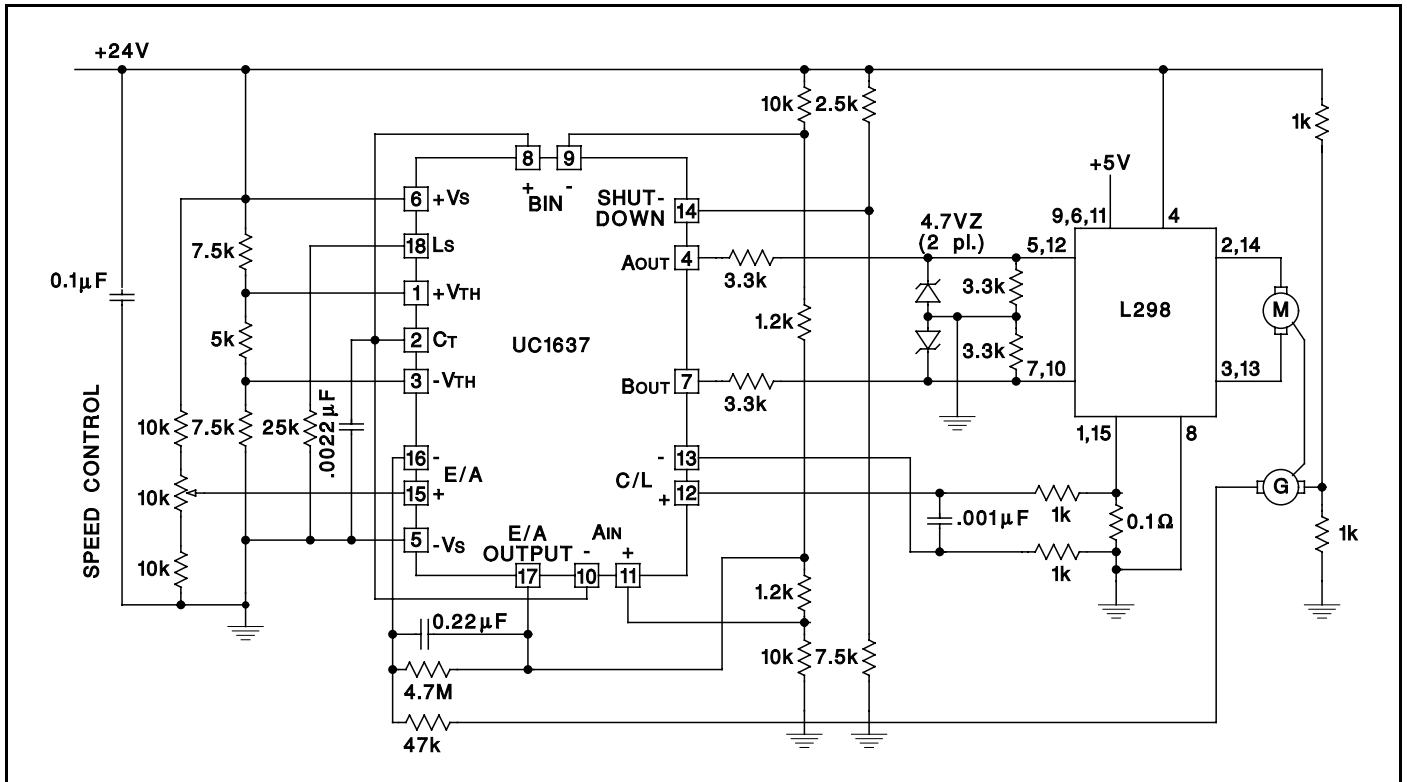


Figure 7. Bi-Directional Motor Drive with Speed Control Power-Amplifier

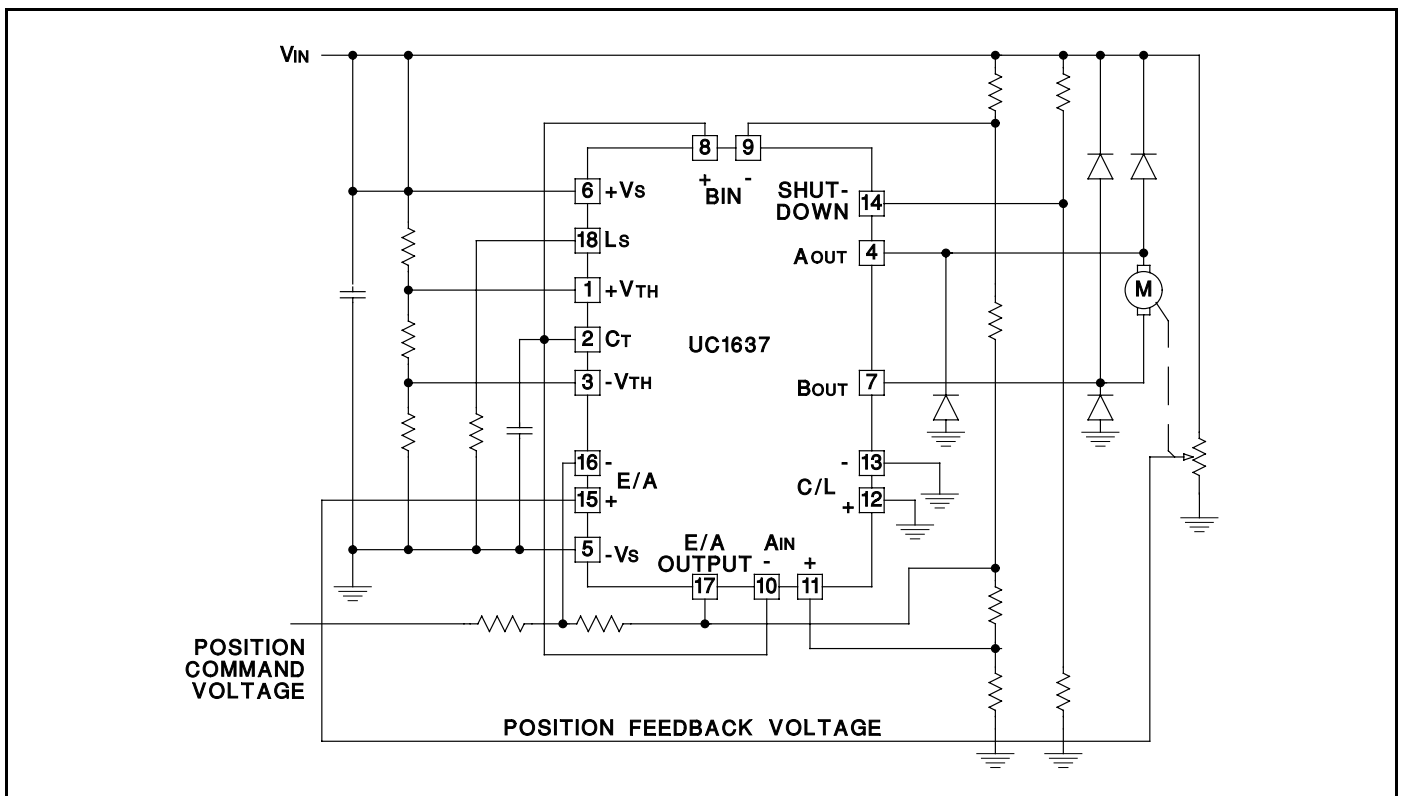


Figure 8. Single Supply Position Servo Motor Drive

**PACKAGING INFORMATION**

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
5962-89957012A	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	5962- 89957012A UC1637L/ 883B	<a href="#">Samples</a>
5962-8995701VA	ACTIVE	CDIP	J	18	1	TBD	A42	N / A for Pkg Type	-55 to 125	5962-8995701VA UC1637J/883B	<a href="#">Samples</a>
UC1637J	ACTIVE	CDIP	J	18	1	TBD	A42	N / A for Pkg Type	-55 to 125	UC1637J	<a href="#">Samples</a>
UC1637J883B	ACTIVE	CDIP	J	18	1	TBD	A42	N / A for Pkg Type	-55 to 125	5962-8995701VA UC1637J/883B	<a href="#">Samples</a>
UC1637L	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	UC1637L	<a href="#">Samples</a>
UC1637L883B	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	5962- 89957012A UC1637L/ 883B	<a href="#">Samples</a>
UC2637DW	ACTIVE	SOIC	DW	20	25	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-25 to 85	UC2637DW	<a href="#">Samples</a>
UC2637DWG4	ACTIVE	SOIC	DW	20	25	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-25 to 85	UC2637DW	<a href="#">Samples</a>
UC2637DWTR	ACTIVE	SOIC	DW	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-25 to 85	UC2637DW	<a href="#">Samples</a>
UC2637DWTRG4	ACTIVE	SOIC	DW	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-25 to 85	UC2637DW	<a href="#">Samples</a>
UC2637J	ACTIVE	CDIP	J	18	1	TBD	A42	N / A for Pkg Type	0 to 0	UC2637J	<a href="#">Samples</a>
UC2637N	ACTIVE	PDIP	N	18	20	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type	-25 to 85	UC2637N	<a href="#">Samples</a>
UC2637NG4	ACTIVE	PDIP	N	18	20	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type	-25 to 85	UC2637N	<a href="#">Samples</a>
UC2637Q	LIFEBUY	PLCC	FN	20	46	Green (RoHS & no Sb/Br)	CU SN	Level-2-260C-1 YEAR	0 to 0	UC2637Q	
UC2637QTR	LIFEBUY	PLCC	FN	20	1000	Green (RoHS & no Sb/Br)	CU SN	Level-2-260C-1 YEAR	0 to 0	UC2637Q	
UC3637DW	ACTIVE	SOIC	DW	20	25	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	0 to 70	UC3637DW	<a href="#">Samples</a>

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
UC3637DWTR	ACTIVE	SOIC	DW	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	0 to 70	UC3637DW	<a href="#">Samples</a>
UC3637J	ACTIVE	CDIP	J	18	1	TBD	A42	N / A for Pkg Type	0 to 70	UC3637J	<a href="#">Samples</a>
UC3637N	ACTIVE	PDIP	N	18	20	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type	0 to 70	UC3637N	<a href="#">Samples</a>
UC3637NG4	ACTIVE	PDIP	N	18	20	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type	0 to 70	UC3637N	<a href="#">Samples</a>
UC3637Q	LIFEBUY	PLCC	FN	20	46	Green (RoHS & no Sb/Br)	CU SN	Level-2-260C-1 YEAR	0 to 70	UC3637Q	
UC3637QG3	LIFEBUY	PLCC	FN	20	46	Green (RoHS & no Sb/Br)	CU SN	Level-2-260C-1 YEAR	0 to 70	UC3637Q	

(1) 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.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.



**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.

**OTHER QUALIFIED VERSIONS OF UC1637, UC3637, UC3637M :**

- Catalog: [UC3637](#), [UC3637M](#), [UC3637](#)
  
- Military: [UC1637](#), [UC1637](#)
  
- Space: [UC1637-SP](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product
  
- Military - QML certified for Military and Defense Applications
  
- Space - Radiation tolerant, ceramic packaging and qualified for use in Space-based application

**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
UC2637DWTR	SOIC	DW	20	2000	330.0	24.4	10.8	13.3	2.7	12.0	24.0	Q1
UC3637DWTR	SOIC	DW	20	2000	330.0	24.4	10.8	13.3	2.7	12.0	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)
UC2637DWTR	SOIC	DW	20	2000	367.0	367.0	45.0
UC3637DWTR	SOIC	DW	20	2000	367.0	367.0	45.0

## IMPORTANT NOTICE

Texas Instruments Incorporated (TI) reserves the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete.

TI's published terms of sale for semiconductor products (<http://www.ti.com/sc/docs/stdterms.htm>) apply to the sale of packaged integrated circuit products that TI has qualified and released to market. Additional terms may apply to the use or sale of other types of TI products and services.

Reproduction of significant portions of TI information in TI data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such reproduced 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.

Buyers and others who are developing systems that incorporate TI products (collectively, "Designers") understand and agree that Designers remain responsible for using their independent analysis, evaluation and judgment in designing their applications and that Designers have full and exclusive responsibility to assure the safety of Designers' applications and compliance of their applications (and of all TI products used in or for Designers' applications) with all applicable regulations, laws and other applicable requirements. Designer represents that, with respect to their applications, Designer has all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. Designer agrees that prior to using or distributing any applications that include TI products, Designer will thoroughly test such applications and the functionality of such TI products as used in such applications.

TI's provision of technical, application or other design advice, quality characterization, reliability data or other services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, "TI Resources") are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using TI Resources in any way, Designer (individually or, if Designer is acting on behalf of a company, Designer's company) agrees to use any particular TI Resource solely for this purpose and subject to the terms of this Notice.

TI's provision of TI Resources does not expand or otherwise alter TI's applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

Designer is authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources 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.

TI RESOURCES ARE PROVIDED "AS IS" AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS. TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY DESIGNER AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

Unless TI has explicitly designated an individual product as meeting the requirements of a particular industry standard (e.g., ISO/TS 16949 and ISO 26262), TI is not responsible for any failure to meet such industry standard requirements.

Where TI specifically promotes products as facilitating functional safety or as compliant with industry functional safety standards, such products are intended to help enable customers to design and create their own applications that meet applicable functional safety standards and requirements. Using products in an application does not by itself establish any safety features in the application. Designers must ensure compliance with safety-related requirements and standards applicable to their applications. Designer may not use any TI products in life-critical medical equipment unless authorized officers of the parties have executed a special contract specifically governing such use. Life-critical medical equipment is medical equipment where failure of such equipment would cause serious bodily injury or death (e.g., life support, pacemakers, defibrillators, heart pumps, neurostimulators, and implantables). Such equipment includes, without limitation, all medical devices identified by the U.S. Food and Drug Administration as Class III devices and equivalent classifications outside the U.S.

TI may expressly designate certain products as completing a particular qualification (e.g., Q100, Military Grade, or Enhanced Product). Designers agree that it has the necessary expertise to select the product with the appropriate qualification designation for their applications and that proper product selection is at Designers' own risk. Designers are solely responsible for compliance with all legal and regulatory requirements in connection with such selection.

Designer will fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of Designer's non-compliance with the terms and provisions of this Notice.