

## 5.0kV<sub>RMS</sub> Opto-Compatible Single Channel Isolated Gate Driver

### GENERAL DESCRIPTION

The SiLM534xT isolated driver family is an opto-compatible, single channel, isolated MOSFET, IGBT gate driver with different drive current capability and UVLO voltage level. The peak output currents are from 1.0A to 4.0A. Key features and characteristics bring significant performance and reliability upgrades over standard opto-coupler based gate drivers while maintaining pin-to-pin compatibility in both schematic and layout design. Performance highlights include high common mode transient immunity (CMTI), low propagation delay, and small pulse width distortion.

The input stage is an emulated diode which means long term reliability and excellent aging characteristics compared to traditional LEDs. It is offered in a SOP6W-T package with  $\geq 8.0\text{mm}$  creepage and clearance. A mold compound from material group II which has a comparative tracking index (CTI)  $>400\text{V}$ . High performance and reliability of the SiLM534xT makes it ideal for use in all types of motor drives, solar inverters, industrial power supplies, and appliances.

### APPLICATION

- AC and brushless DC motor drives
- Renewable energy inverters
- Industrial power supplies

### FEATURES

- 1.0A to 4.0A peak output current
- 120ns (Max.) propagation delay
- 25ns (Max.) part-to-part delay matching
- 40ns (Max.) pulse width distortion
- 150kV/us (Min.) common mode transient immunity (CMTI)
- Wide gate drive supply voltage
  - 10 V to 40 V for SiLM5345/6T
  - 14 V to 40 V for SiLM5340/1/3T
- 30V reverse polarity voltage handling capability on input stage
- Pin to pin compatible to opto-coupler isolated gate drivers
- SOP6W-T package with  $\geq 8.0\text{mm}$  creepage and clearance
- Junction temperature,  $T_J$ :  $-40^\circ\text{C}$  to  $+150^\circ\text{C}$
- Safety certifications
  - 5kV<sub>RMS</sub> isolation for 1 minute per UL 1577
  - CQC certification per GB4943.1-2022
  - DIN VDE 0884-17: 2021-10

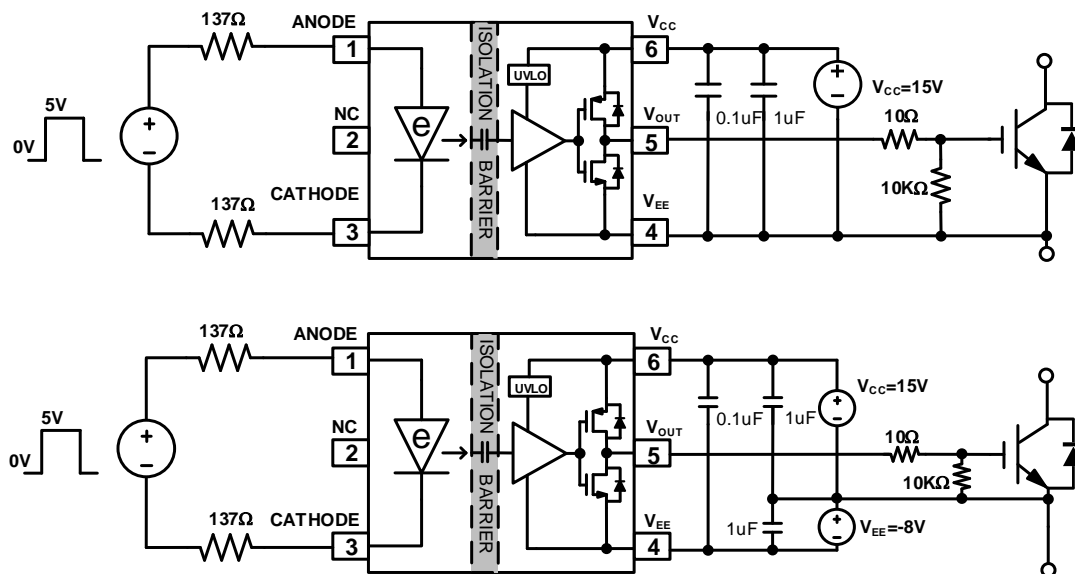


Figure 1. SiLM534xT Single and Bipolar Power Supplies Application Circuit to Drive IGBT

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**PIN CONFIGURATION**

Package	Pin Configuration (Top View)
SOP6W-T	

**PIN DESCRIPTION**

No.	Pin	Description
1	ANODE	Anode
2	NC	No Connection
3	CATHODE	Cathode
4	$V_{EE}$	Negative Power Supply Rail
5	$V_{OUT}$	Gate Drive Output
6	$V_{CC}$	Positive Power Supply Rail

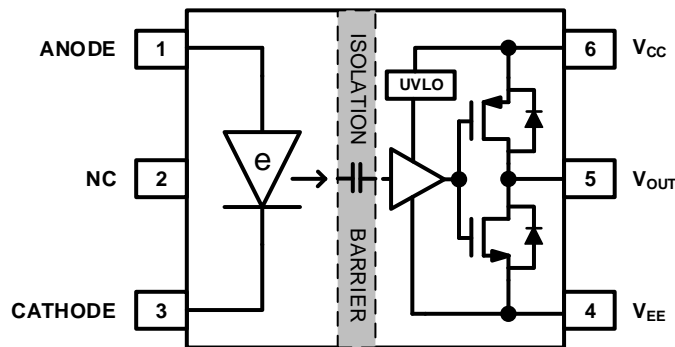
**FUNCTIONAL BLOCK DIAGRAM**


Figure 2. SiLM534xT Functional Block Diagram

## ORDERING INFORMATION

Order Part No.	Package	QTY
SiLM5340TCR-DG	SOP6W-T, Pb-Free	1000/Reel
SiLM5341TCR-DG	SOP6W-T, Pb-Free	1000/Reel
SiLM5343TCR-DG	SOP6W-T, Pb-Free	1000/Reel
SiLM5345TCR-DG	SOP6W-T, Pb-Free	1000/Reel
SiLM5346TCR-DG	SOP6W-T, Pb-Free	1000/Reel

## FAMILY OVERVIEW

Part Number	Peak Output Current	UVLO	Isolation Rating
SiLM5340T	1.0 A	12.5V	5.0kVrms
SiLM5341T	3.0 A	12.5V	5.0kVrms
SiLM5343T	4.0 A	12.5V	5.0kVrms
SiLM5345T	1.0 A	8.5V	5.0kVrms
SiLM5346T	4.0 A	8.5V	5.0kVrms

**ABSOLUTE MAXIMUM RATINGS**

Symbol	Definition	Min	Max	Unit
$I_{F(AVG)}$	Average Input Current		25	mA
$V_R$	Reverse Input Voltage		30	V
$V_{CC} - V_{EE}$	Output supply voltage		45	V
$T_J$	Junction temperature	-40	150	°C
$T_S$	Storage temperature	-55	150	

**RECOMMENDED OPERATION CONDITIONS**

Symbol	Definition	Min	Max	Unit
$V_{CC} - V_{EE}$	Output Supply Voltage (SiLM5340T/SiLM5341T/ SiLM5343T)	14	40	V
	Output Supply Voltage (SiLM5345T/SiLM5346T)	10	40	V
$I_F(ON)$	Input Diode Forward Current (Diode "ON")	7	16	mA
$V_F(OFF)$	Anode Voltage - Cathode Voltage (Diode "OFF")	-30	0.9	V
$T_J$	Junction temperature	-40	150	°C
$T_A$	Ambient temperature	-40	125	°C

**ESD RATINGS**

Symbol	Definition	Value	Unit
$V_{ESD}$	HBM	±4000	V
	CDM	±2000	

**THERMAL INFORMATION**

Symbol	Definition	Value	Unit
$R_{\theta JA}$	Junction to ambient thermal resistance	125	°C/W
$R_{\theta JC}$	Junction to case (top) thermal resistance	66	°C/W
$\Psi_{JT}$	Junction to top characterization parameter	30	°C/W

**PACKAGE SPECIFICATIONS**

Symbol	Definition	Min	Typ	Max	Units
R <sub>IO</sub>	Resistance (Input Side to Output Side)		10 <sup>12</sup>		Ω
C <sub>IO</sub>	Capacitance (Input Side to Output Side)		0.8		pF
C <sub>IN</sub>	Input Capacitance		30		pF

**INSULATION SPECIFICATIONS**

Symbol	Definition	Test Condition	Value	Units
CLR	External clearance	Shortest terminal to terminal distance through air	≥8	mm
CPG	External creepage	Shortest terminal to terminal distance across the package surface	≥8	mm
DTI	Distance through the insulation	Minimum internal gap	>16	um
CTI	Comparative tracking index	DIN EN 60112 (VDE 0303-11), IEC 60112	>400	V
	Material Group		II	
	Overvoltage category	Rated mains voltages ≤150Vrms	IV	
		Rated mains voltages ≤300Vrms	IV	
		Rated mains voltages ≤600Vrms	III	
		Rated mains voltages ≤1000Vrms	II	
<b>DIN V VDE 0884-11<sup>(1)</sup></b>				
V <sub>IORM</sub>	Maximum repetitive peak isolation voltage		1414	V <sub>PK</sub>
V <sub>IOWM</sub>	Maximum isolation working voltage		1000	V <sub>RMS</sub>
V <sub>IOTM</sub>	Maximum transient isolation voltage	60s	7000	V <sub>PK</sub>
V <sub>IOSM</sub>	Maximum surge isolation voltage	Test method per IEC62368, 1.2/50us waveform, V <sub>TEST</sub> =1.6 x V <sub>IOSM</sub>	6250	V <sub>PK</sub>
q <sub>pd</sub>	Apparent charge	Method b2: V <sub>pd(m)</sub> =1.875 x V <sub>IORM</sub> , t <sub>m</sub> =1 s	≤5	pC
	Climatic Category		40/125/21	
	Pollution Degree		2	
<b>UL1577</b>				
V <sub>ISO</sub>	Withstand Isolation Voltage	V <sub>TEST</sub> =V <sub>ISO</sub> , t=60s (qualification), V <sub>TEST</sub> =1.2 x V <sub>ISO</sub> , t=1s (100% production)	5000	V <sub>RMS</sub>

1.Certification pending

**SAFETY RELATED CERTIFICATIONS**

VDE	UL	CQC
DIN VDE 0884-17: 2021-10	UL 1577 component recognition program	Certified according to GB4943.1-2022
Reinforced Insulation $V_{IORM} = 1414 V_{PK}$ $V_{IOTM} = 7000 V_{PK}$ $V_{IOSM} = 6250 V_{PK}$	Single protection, 5000 $V_{RMS}$	Reinforced insulation, Altitude $\leq$ 5000m, Tropical climate, 400 $V_{RMS}$ maximum working voltage
Pending	File number: E521801	File number: CQC23001379623

**SAFETY LIMITING VALUES**

Symbol	Parameter	Condition	Value	Unit
$I_s$	Safety input, output, or supply current	$R_{\theta JA}=125^{\circ}C/W, V_{CC}-V_{EE} = 15V, T_J = 150^{\circ}C, T_A = 25^{\circ}C$	50	mA
		$R_{\theta JA}=125^{\circ}C/W, V_{CC}-V_{EE} = 30V, T_J = 150^{\circ}C, T_A = 25^{\circ}C$	25	mA
$P_s$	Safety input, output, or total power	$R_{\theta JA}=125^{\circ}C/W, T_J = 150^{\circ}C, T_A = 25^{\circ}C$	750	mW
$T_s$	Maximum safety temperature		150	$^{\circ}C$

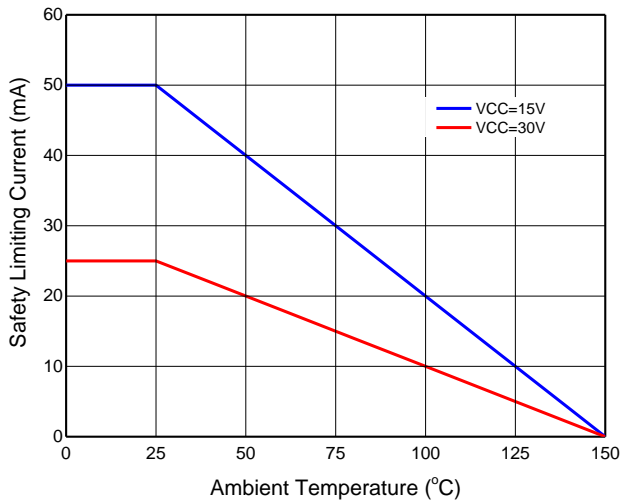


Figure 3. Thermal Derating Curve for Limiting Current per VDE

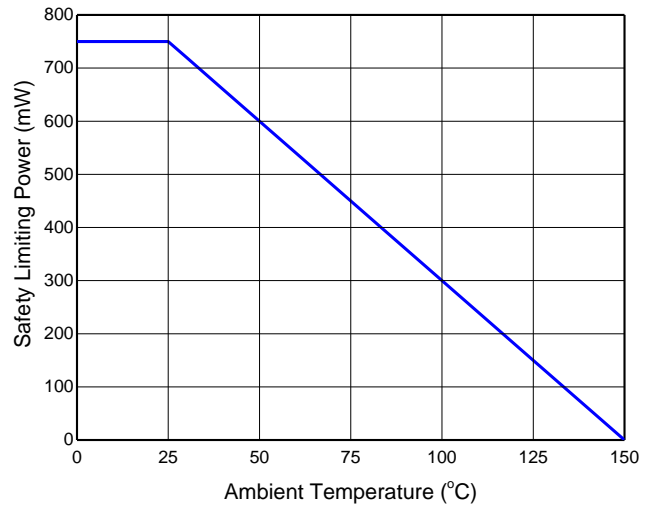


Figure 4. Thermal Derating Curve for Limiting Power per VDE

**ELECTRIAL CHARACTERISTICS (DC)**

$V_{CC}-V_{EE} = 15V$ ,  $V_{EE} = GND$  and  $T_A = 25^{\circ}C$  unless otherwise specified. All min and max specifications are at  $T_A = -40^{\circ}C$  to  $125^{\circ}C$

Symbol	Parameter	Condition	Min	Typ	Max	Unit
<b>INPUT</b>						
$I_{FLH}$	Input Forward Threshold Current Low to High		1.8	2.1	3	mA
$V_F$	Input Forward Voltage	$I_F=10mA$	2.1	2.25	2.5	V
$\Delta V_F/\Delta T$	Temp Coefficient of Input Forward Voltage	$I_F=10mA$		0.5		mV/ $^{\circ}C$
$V_R$	Input Reverse Breakdown Voltage	$I_R=10\mu A$	30			V
<b>OUTPUT(SiLM5340T/SiLM5345T)</b>						
$I_{OH}$	High Level Peak Output Current	$V_{CC}=15V, I_F=10mA, C_{VDD}=10\mu F, C_{LOAD}=220nF$		1.0		A
$I_{OL}$	Low Level Peak Output Current	$V_{CC}=15V, V_F=0V, C_{VDD}=10\mu F, C_{LOAD}=220nF$		1.5		A
$V_{OH}$	High Level Output Voltage	$I_F=10mA, I_O=-20mA$ "With respect to $V_{CC}$ "		105		mV
$V_{OL}$	Low Level Output Voltage	$V_F=0V, I_O=20mA$		50		mV
<b>OUTPUT(SiLM5341T)</b>						
$I_{OH}$	High Level Peak Output Current	$V_{CC}=15V, I_F=10mA, C_{VDD}=10\mu F, C_{LOAD}=220nF$		3.0		A
$I_{OL}$	Low Level Peak Output Current	$V_{CC}=15V, V_F=0V, C_{VDD}=10\mu F, C_{LOAD}=220nF$		4.5		A
$V_{OH}$	High Level Output Voltage	$I_F=10mA, I_O=-20mA$ "With respect to $V_{CC}$ "		33		mV
$V_{OL}$	Low Level Output Voltage	$V_F=0V, I_O=20mA$		16		mV
<b>OUTPUT(SiLM5343T/SiLM5346T)</b>						
$I_{OH}$	High Level Peak Output Current	$V_{CC}=15V, I_F=10mA, C_{VDD}=10\mu F, C_{LOAD}=220nF$		4.0		A
$I_{OL}$	Low Level Peak Output Current	$V_{CC}=15V, V_F=0V, C_{VDD}=10\mu F, C_{LOAD}=220nF$		6.0		A
$V_{OH}$	High Level Output Voltage	$I_F=10mA, I_O=-20mA$ "With respect to $V_{CC}$ "		26		mV
$V_{OL}$	Low Level Output Voltage	$V_F=0V, I_O=20mA$		13		mV



Symbol	Parameter	Condition	Min	Typ	Max	Unit
<b>UNDER VOLTAGE LOCKOUT(SiLM5340T/SiLM5341T/SiLM5343T)</b>						
UVLOR	Under Voltage Lockout $V_{CC}$ rising	$I_F=10mA$	11.5	12.5	13.5	V
UVLOF	Under Voltage Lockout $V_{CC}$ falling	$I_F=10mA$	10.5	11.5	12.5	V
UVLOHYS	Under Voltage Lockout Hysteresis			1.0		V
<b>UNDER VOLTAGE LOCKOUT (SiLM5345T/SiLM5346T)</b>						
UVLOR	Under Voltage Lockout $V_{CC}$ rising	$I_F=10mA$	8	8.5	9	V
UVLOF	Under Voltage Lockout $V_{CC}$ falling	$I_F=10mA$	7	7.5	8	V
UVLOHYS	Under Voltage Lockout Hysteresis			1.0		V

## SWITCHING CHARACTERISTICS (AC)

$V_{CC}-V_{EE} = 15V$ ,  $V_{EE} = GND$  and  $T_A = 25^\circ C$  unless otherwise specified. All min and max specifications are at  $T_A = -40^\circ C$  to  $125^\circ C$

Symbol	Parameter	Condition	Min	Typ	Max	Unit
$t_{PLH}$	Propagation delay, Low to High	$C_{LOAD} = 1nF$ , $f_{sw}=20kHz$ , (50% Duty Cycle), $V_{CC}=15V$		90	120	ns
$t_{PHL}$	Propagation delay, High to Low			90	120	ns
$t_r$	Turn on rise time				25	ns
$t_f$	Turn off fall time				15	ns
$t_{PWD}$	Pulse Width Distortion				40	ns
$t_{PDD}$	Propagation Delay Difference Between Any Two Parts				25	ns
$t_{UVLO\_REC}$	UVLO Recovery Delay	$V_{CC}$ Rising from 0V to 15V		22	30	us
$CMTI_H$	Output High Level Common Mode Transient Immunity	$I_F=10mA$ , $V_{CM}=1000V$ , $V_{CC}=15V$ , $T_A=25^\circ C$	150	200		kV/us
$CMTI_L$	Output Low Level Common Mode Transient Immunity	$V_F=0V$ , $V_{CM}=1000V$ , $V_{CC}=15V$ , $T_A=25^\circ C$	150	200		kV/us

**PARAMETER MEASUREMENT INFORMATION**

**Propagation Delay, Rise Time and Fall Time**

Figure 5 shows the propagation delay from the input forward current  $I_F$  to  $V_{OUT}$ . This figure also shows the circuit used to measure the rise ( $t_r$ ) and fall ( $t_f$ ) times and the propagation delays  $t_{PDHL}$  and  $t_{PDLH}$ .

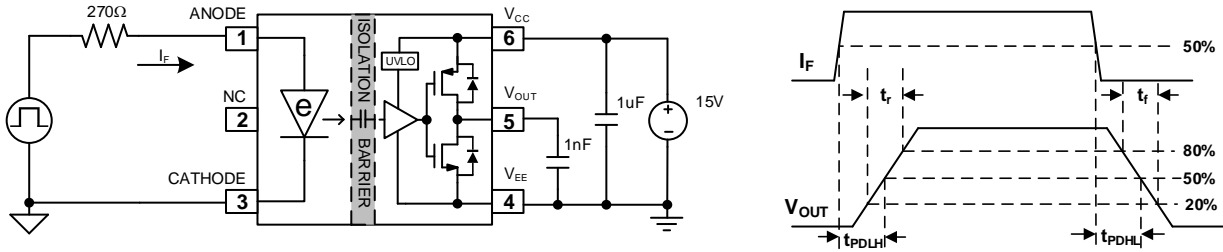


Figure 5. Propagation Delay, Rise Time and Fall Time

**IOH and IOL Testing**

Figure 6 shows the circuit used to measure the output drive current  $I_{OH}$  and  $I_{OL}$ . A load capacitance of 220nF is used at the output. The peak  $dv/dt$  of the capacitor voltage is measured in order to determine the peak source and sink currents of the gate driver.

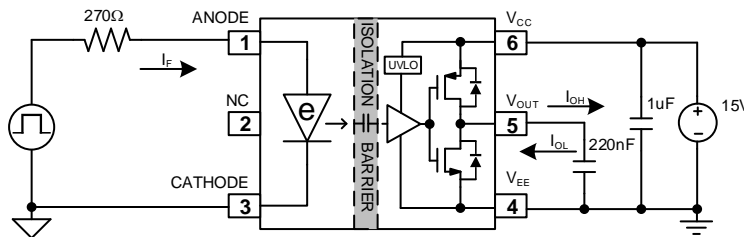


Figure 6.  $I_{OH}$  and  $I_{OL}$

**CMTI Testing**

Figure 7 is the simplified diagram of the CMTI testing. Common mode voltage is set to 1000V. The test is performed with  $I_F=10mA$  ( $V_{OUT}= High$ ) and  $V_F=0V$  ( $V_{OUT}= Low$ ).

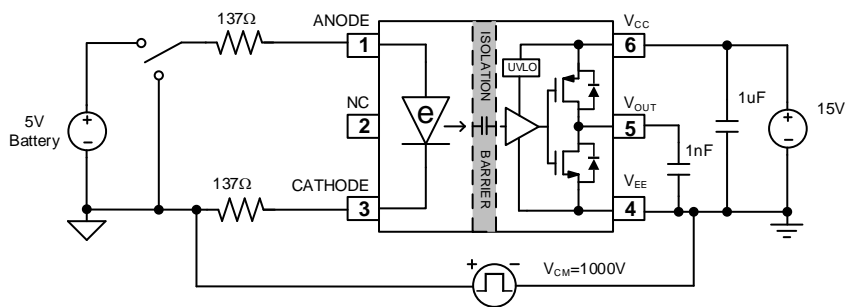


Figure 7. CMTI Test Circuit

## FEATURE DESCRIPTION

SiLM534xT is a single channel isolated gate driver, with an opto-compatible input stage, that can drive IGBTs and MOSFETs. It has 1.0 A to 4.0A peak output current capability with maximum output driver supply voltage of 40V. The inputs and the outputs are galvanically isolated. SiLM534xT is offered in SOP6W-T package with >8.5mm creepage and clearance. The reinforced isolation rating is 5kV<sub>RMS</sub> for 60 seconds. It is pin-to-pin compatible with standard opto-coupler isolated gate drivers. While standard opto-coupler isolated gate drivers use an LED as the input stage, SiLM534xT uses an emulated diode as the input stage which does not use light emission to transmit signals across the isolation barrier. The input stage is isolated from the driver stage by dual, series HV SiO<sub>2</sub> capacitors in full differential configuration that not only provides reinforced isolation but also offers great performance of common mode transient immunity >150kV/us. The e-diode input stage along with capacitive isolation technology gives SiLM534xT several performance advantages over standard opto-coupler isolated gate drivers.

- Since the emulated diode does not use light emission for its operation, the reliability and aging characteristics of SiLM534xT are naturally superior to those of standard opto-coupler isolated gate drivers.
- Higher ambient operating temperature range of 125°C, compared to only 105°C for most opto-coupler isolated gate drivers
- The e-diode forward voltage drop has less part-to-part variation and smaller variation across temperature. Hence, the operating point of the input stage is more stable and predictable across different parts and operating temperature
- Higher common mode transient immunity than opto-coupler isolated gate drivers
- Smaller propagation delay than opto-coupler isolated gate drivers
- Due to superior process controls achievable in capacitive isolation compared to opto-coupler isolation, there is less part-to-part skew in the propagation delay, making the system design simpler and more robust
- Smaller pulse width distortion than opto-coupler isolated gate drivers

### Input Stage

The input stage of SiLM534xT is an emulated diode. When the emulated diode is forward biased by applying a positive voltage to the Anode with respect to the Cathode, a forward current,  $I_F$ , flows into the e-diode. The forward voltage drop across the e-diode is 2.25V (typ). An external resistor should be used to limit the forward current. The recommended range for the forward current is 7mA to 16mA. When  $I_F$  exceeds the input forward threshold current  $I_{FLH}$  (2.1mA typ), the  $V_{OUT}$  is driver high. If the  $I_F$  is lower than  $I_{FLH}$ , or the voltage between Anode and Cathode is reverse biased, the  $V_{OUT}$  is driven low.

The reverse breakdown voltage of the e-diode is up to 30V. The large reverse breakdown voltage of the e-diode enables SiLM534xT to be operated in interlock architecture as shown in Figure 8. The example shows two gate drivers driving a set of IGBTs. The inputs of the gate drivers are connected as shown in Figure 8 and driven by two buffers that are controlled by the MCU. Interlock architecture prevents both the e-diodes from being "ON" at the same time, preventing shoot through in the IGBTs as shown in Figure 9. It also ensures that if both PWM signals are erroneously stuck high (or low) simultaneously, both gate driver outputs will be driven low.

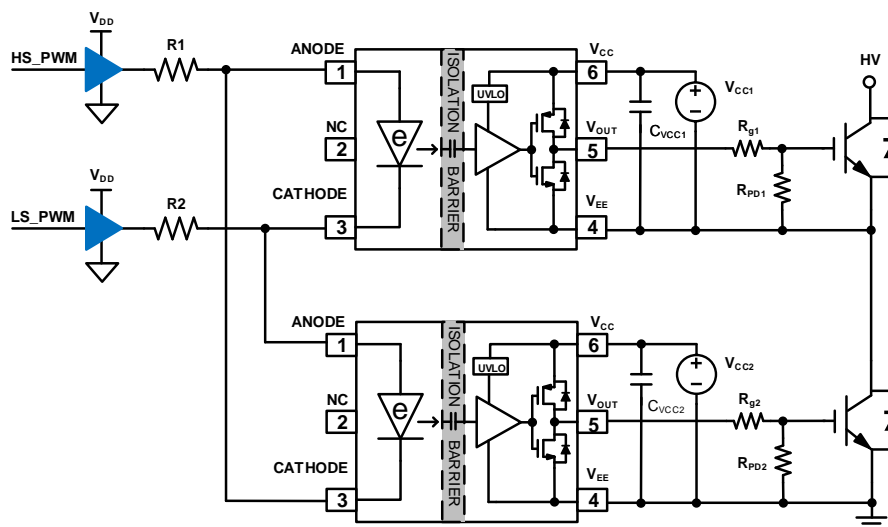
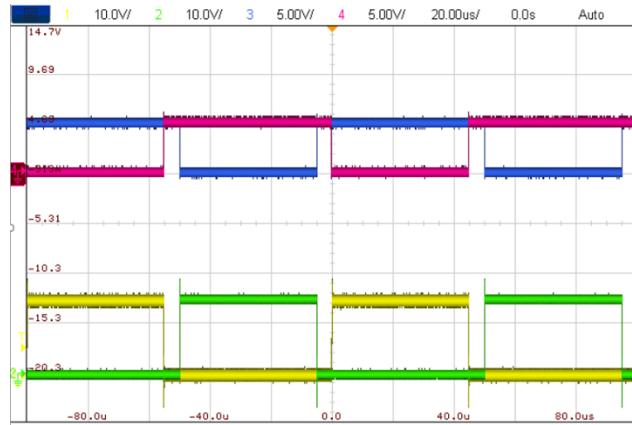


Figure 8. Interlock Architecture



CH1: HS\_OUT, CH2: LS\_OUT, CH3: HS\_PWM, CH4: LS\_PWM

Figure 9. Interlock PWM input and output waveform

**Under Voltage Lockout (UVLO)**

The SiLM534xT integrates the UVLO protection on the  $V_{CC}$  to prevent an under driven condition on IGBTs and MOSFETs. When  $V_{CC}$  is lower than  $UVLO_R$  during start up or lower than  $UVLO_F$  after start up, the UVLO feature holds the  $V_{OUT}$  low, regardless of the input forward current. A hysteresis on the UVLO feature prevents glitch when there is noise from the power supply. When  $V_{CC}$  drops below  $UVLO_F$ , a recovery delay ( $t_{UVLO\_REC}$ ) occurs on the output when the supply voltage rises above  $UVLO_R$  again.

**Typical Input Configuration Circuit**

The circuit in Figure 10 and Figure 11 show two typical input configuration circuits for SiLM534xT to driver IGBT.

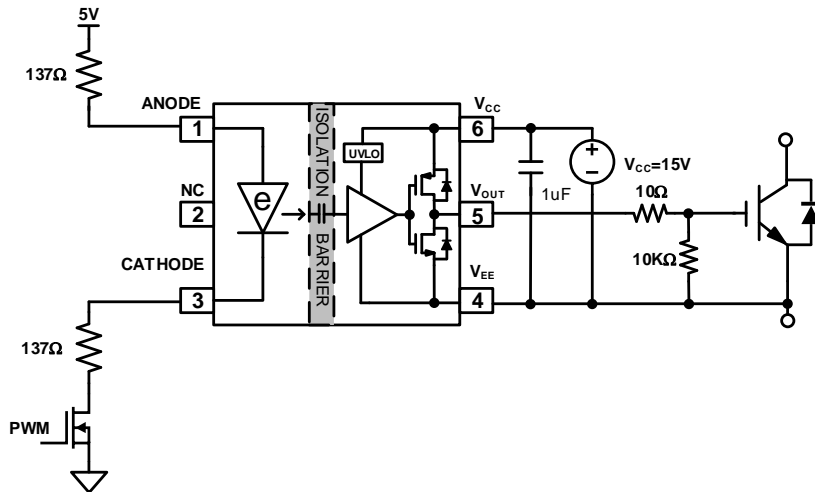


Figure 10. Single MOSFET Circuit as Input Drive of SiLM534xT to Drive IGBT

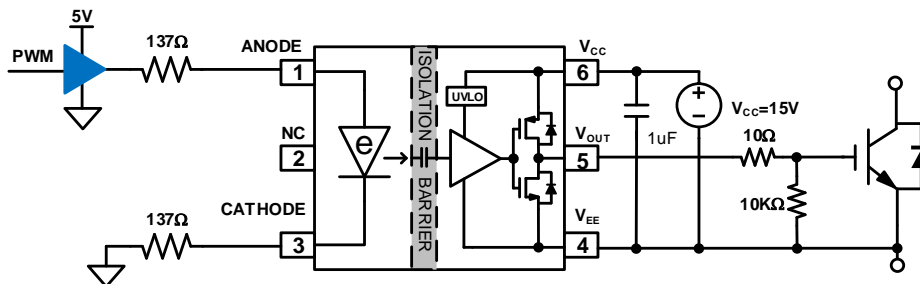


Figure 11. Buffer Circuit as Input Drive of SiLM534xT to Drive IGBT

**Layout**

In order to achieve optimum performance for the SiLM534xT, some suggestions on PCB layout.

Component placement:

- Low ESR and low ESL capacitors must be connected close to the device between the  $V_{CC}$  and  $V_{EE}$  pins to bypass noise and to support high peak currents when turning on the external power transistor.
- To avoid large negative transients on the VEE pins connected to the switch node, the parasitic inductances between the source of the top transistor and the source of the bottom transistor must be minimized.

Grounding considerations:

- Limiting the high peak currents that charge and discharge the transistor gates to a minimal physical area is essential. This limitation decreases the loop inductance and minimizes noise on the gate terminals of the transistors. The gate driver must be placed as close as possible to the transistors.

High-voltage considerations:

- To ensure isolation performance between the primary and secondary side, avoid placing any PCB traces or copper below the driver device. A PCB cutout or groove is recommended in order to prevent contamination that may compromise the isolation performance.

**PACKAGE CASE OUTLINES**

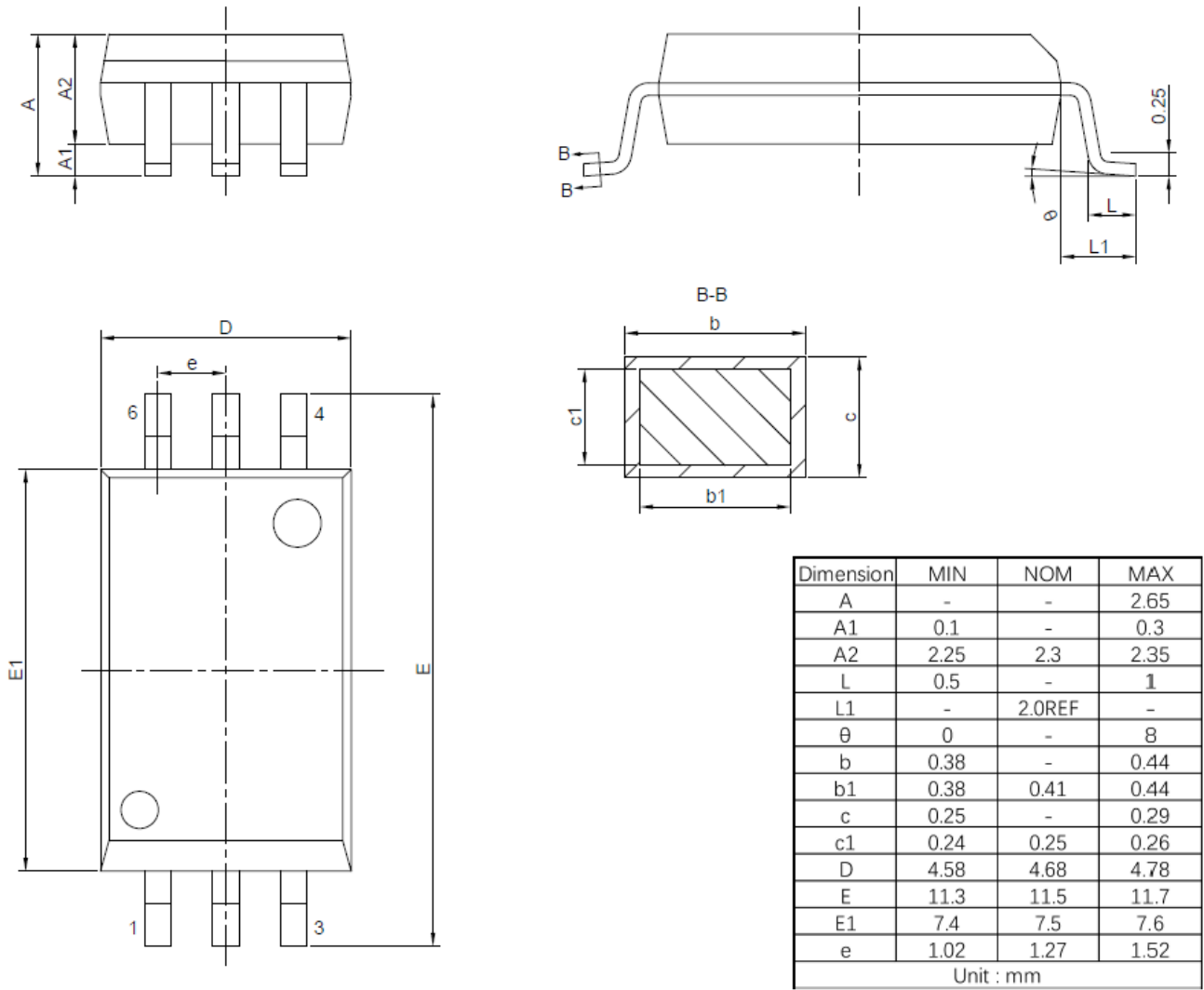
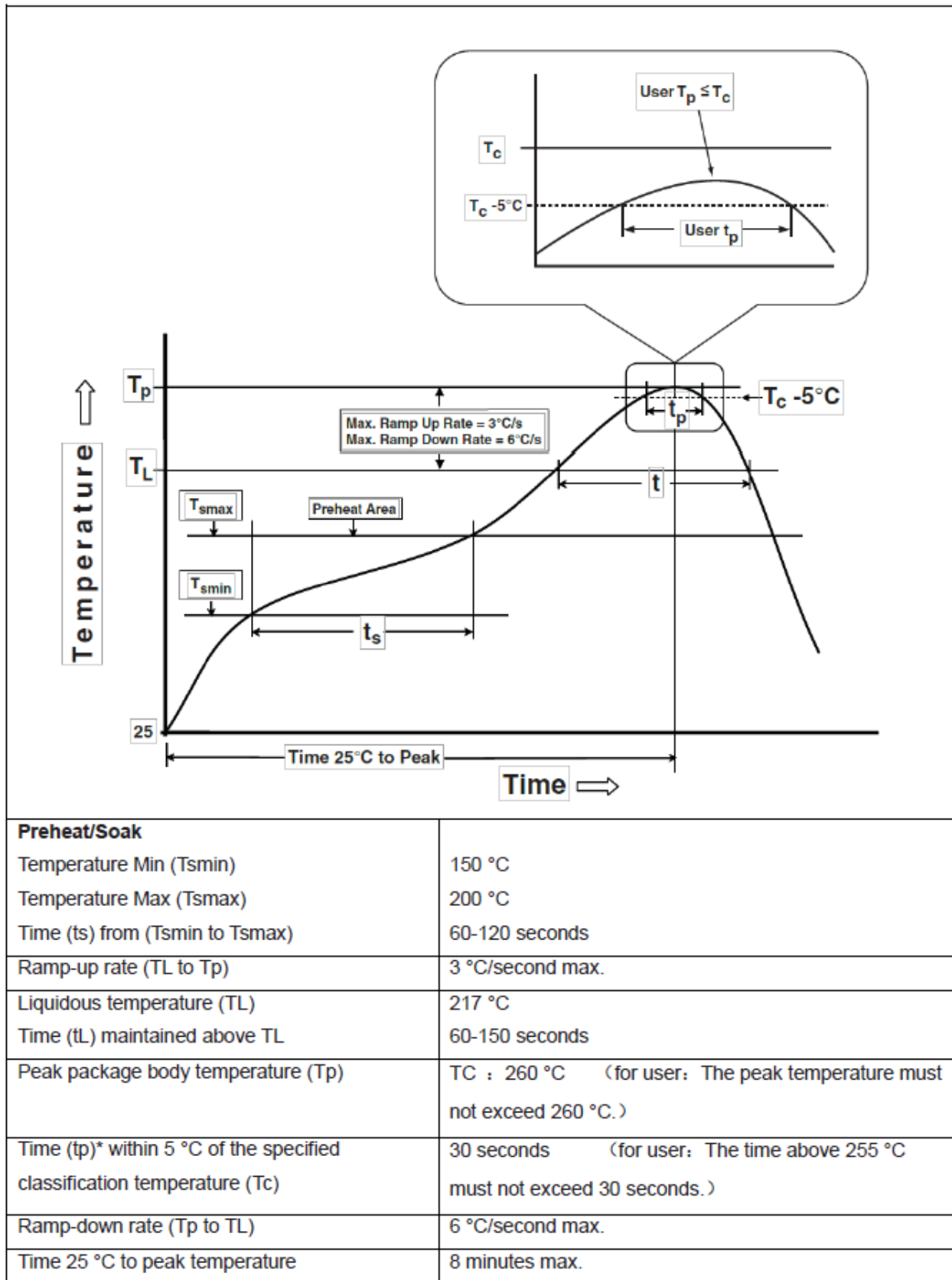


Figure 12. SOP6W-T Package Outline Dimensions

**REFLOW PROFILE GUIDANCE**


**REVISION HISTORY**

Note: page numbers for previous revisions may differ from page numbers in current version

Page or Item	Subjects (major changes since previous revision)
<b>Rev 1.0 datasheet: 2023-05-08</b>	
Whole document	Initial datasheet release