KTS1900

Ideal Diode and Load Switch Controller with Reverse Input Protection

Features

- 4.2V to 60V Wide Input Operating Range
- Reverse Voltage Protection to –60V Requirements with a Suitable TVS Diode
- ESD Ratings
  - HBM: ±2kV
  - CDM: ±750V
- Internal Charge Pump for External High-Side N-Channel MOSFET Driving
- Controller and MOSFET Driver Suitable for:
  - Single MOSFET for Reverse Protection
  - Two Back-to-Back MOSFETs, one for Reverse Protection and the other for Load Switching and Inrush Control
- 1.5A/30µA Sink/Source Current Capability of MOSFET Gate Driver
- EN Pin to Enable/Disable the Controller
- 1µA Shutdown Current
- 110µA Operating Quiescent Current
- 500ns Reverse Protection Response Time

Small 6 Pin SOT23 Package (2.9mm x 1.6mm)

Applications

- Reverse Power Supply Protection
- Telecom/Server/Networking Systems
- Battery and System Protection
- Redundant Power Systems
- Industrial and Medical Systems

Brief Description

The KTS1900 is an ideal diode and load switch controller with reverse input protection. It has an internal charge pump to enable the use of an N-channel MOSFET with low on-resistance to replace a Schottky diode or a P-channel MOSFET based solution. It also can be used with two Back-to-Back MOSFETs for Load switching and Inrush Control. With low on-resistance N-Channel MOSFET, the lower forward voltage drops, less power dissipation, and heat dissipation can be achieved.

The KTS1900 operates over a wide input voltage range from 4.2V to 60V to support a variety of telecom and server applications. It withstands a negative voltage down to -65V, which simplifies the system design.

The KTS1900 monitors the load current by sensing the forward voltage drop of the MOSFET. The forward voltage drop is regulated to avoid oscillation at light loads and minimize the power dissipation at high current conditions.

The KTS1900 turns off the MOSFET fast to prevent reverse current in case of failure of input voltage source. The EN pin is available to turn off the controller and minimize the current drawn by the controller down to 3µA.

The KTS1900 is available in a small fully green compliant 6-Pin SOT-23 Package (2.9mm x 1.6mm).

Typical Application

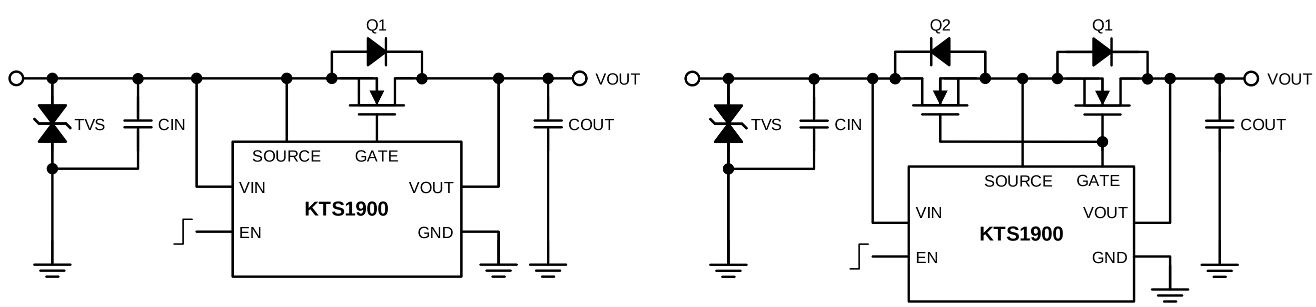


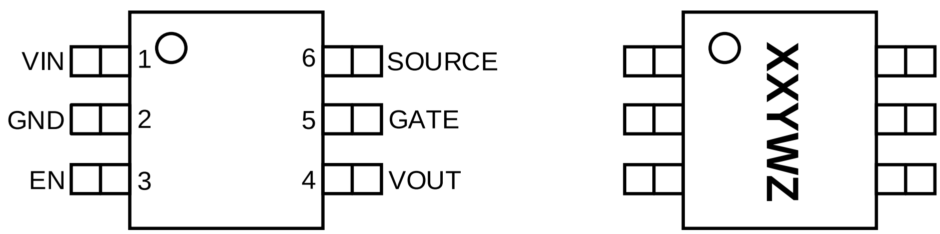
Figure 1. (a) Ideal Diode Controller Application (b) Load Switch Controller Application

Ordering Information

Part Number	Marking[1]	Operating Temperature	Package
KTS1900GXAA-TA	SPYWZ	-40°C to +125°C	SOT23-6L

Pinout Diagram

SOT23-6



Top View
SOT23-6 2.9mm x 1.6mm x 1.45mm
SOT23 Package

Top Mark
XX = Device Code, YW = Date Code, Z = Serial Number

Pin Descriptions

Pin #	Name	Function
1	VIN	Supply voltage input. Connect to supply voltage. This VIN pin is also connected to SOURCE pin. See the typical application schematic for details.
2	GND	Device ground.
3	EN	Enable control pin. EN pin is used to enable and disable the controller. EN pin can be also connected to VIN directly to enable the controller.
4	VOUT	Output voltage sense pin. Connect to the drain of the external N-channel MOSFET (cathode of the ideal diode).
5	GATE	Gate drive. Connect to the gate of the external N-Channel MOSFET.
6	SOURCE	Source pin. Connect to the source of the external N-Channel MOSFET. Source pin is also connected to VIN pin.

1. XX = Device Code, YW = Date Code, Z = Serial Number.

Absolute Maximum Ratings

T_A = 25°C unless otherwise noted

Symbol	Description	Min.	Max.	Units
VIN	VIN, EN, SOURCE to GND	-65	65	V
VOUT	VOUT to GND	-0.3	65	V
VOUT	VOUT to VIN	-65	80	V
VI-S	VIN to SOURCE	-0.3	80	A
VO-S	VOUT to SOURCE	-0.3	80	V
VGS	GATE to SOURCE	-0.3	20	V
T_J	Operating Junction Temperature Range (TJ)	-40	150	°C
T_S	Storage Temperature Range (TS)	-55	150	°C
T_{LEAD}	Maximum Soldering Temperature (at leads, 10 sec) (TLEAD)	-	250	°C

ESD and Surge Rating

Symbol	Description	Value	Units
V(ESD) Electrostatic Discharge	Human body model (HBM), all pins	±2000	V
	Charged device model (CDM), all pins	±750	V

Thermal Capabilities[2]

Symbol	Description	Value	Units
Θ_{JA}	Thermal Resistance – Junction to Ambient	103.2	°C/W
P_D	Maximum Continuous Power Dissipation at 25°C (TJ = 125°C)	968	W
$\Delta P_D/\Delta T$	Derating Factor Above T_A = 25°C	-9.6	mW/°C

Recommended Operating Conditions[3]

Symbol	Description	Min.	Max.	Units
V_{IN}	VIN to GND	-60	60	V
V_{EN}	EN to GND	-60	60	V
V_{OUT}	VOUT to GND	-0.3	60	V
T_J	Operating Junction Temperature Range (TJ)	-40	125	°C

2. Junction to Ambient thermal resistance is highly dependent on PCB layout. Values are based on thermal properties of the device when soldered to an EV board.
3. The recommended Operating Conditions table defines the conditions for actual device operation. Recommended operating conditions are specified to ensure optimal performance to the datasheet specifications. Kinetic does not recommend exceeding them or designing to Absolute Maximum Rating.

Electrical Characteristics[4]

Typical values correspond to TA = 25°C. *Minimum* and *Maximum* specs are applied over the full operation junction temperature range of -40°C to 125°C, unless otherwise noted. SOURCE pin tied to VIN pin, VIN = 12V, V_{EN} = 12V unless otherwise noted.

SUPPLY AND ENABLE

Symbol	Description	Conditions	Min	Typ	Max	Units
V_{IN}	Operating Input Voltage Range		4.2		60	V
	VIN Undervoltage Threshold	VIN Rising		3.8	4.1	V
		VIN Falling	2.65	3		V
I_Q	Operating Quiescent Current	EN = 12V		110	180	µA
I_{SHDN}	Shutdown Supply Current	EN = 0V		1	4	µA
EN	EN Logic High Threshold	EN Rising		1.24	1.32	V
	EN Logic Low Threshold	EN Falling	0.7	1.14		V
I_{EN}	EN Pin Sink Current	EN = 12V		3	5	µA

GATE DRIVER

Symbol	Description	Conditions	Min	Typ	Max	Units
V_{GATE}	Gate Drive Voltage (GATE to SOURCE)	Full Conduction Mode, V_{SOURCE} - V_{VOUT} = 100mV	10	12	15	V
I_{GATE}	Gate Peak Source Current			15		µA
	Gate Peak Sink Current			1.5		A
t_{don}	Gate Turn-On Delay Time			60	100	µs
t_{doff}	Gate Turn-Off Delay Time			230		ns
Trec-F	Recovery Delay from Forward Detection to Gate Turn ON			5		µs

SOURCE TO DRAIN VOLTAGE

Symbol	Description	Conditions	Min	Typ	Max	Units
V_{SDREG}	Regulated Source to Drain Voltage (VOUT-SOURCE)		25	40	65	mV
V_{SDREV}	Source to Drain Voltage Threshold for Reverse Current Blocking		-24	-15	-2	mV

VOUT AND SOURCE PIN CURRENT

Symbol	Description	Conditions	Min	Typ	Max	Units
I_{VOUT}	VOUT Pin Sink Current	Vsource = 12V		1.5	2	µA
I_{SOURCE}	SOURCE Pin Sink Current	Vsource = 12V		5	10	µA

4. Device is guaranteed to meet performance specifications over the -40°C to +85°C operating temperature range by design, characterization and correlation with statistical process controls.

Timing Diagrams

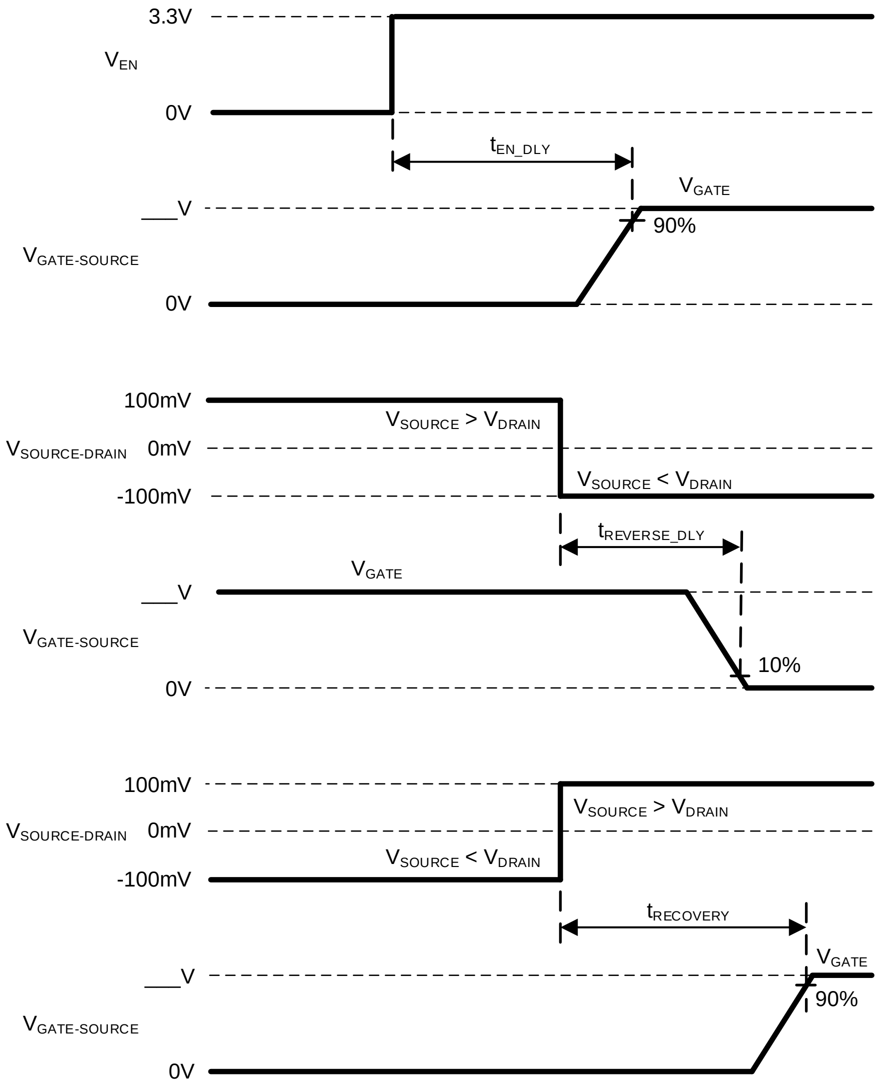
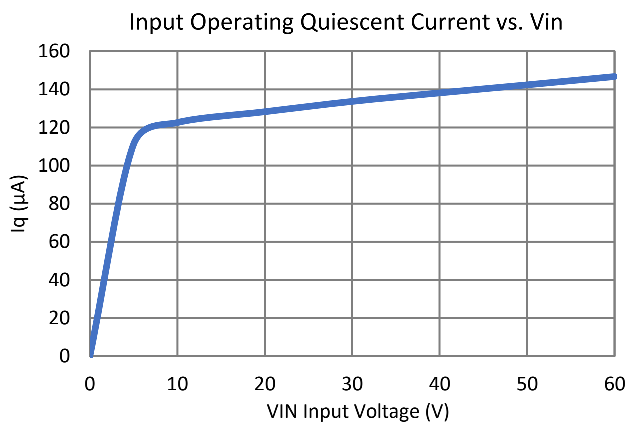
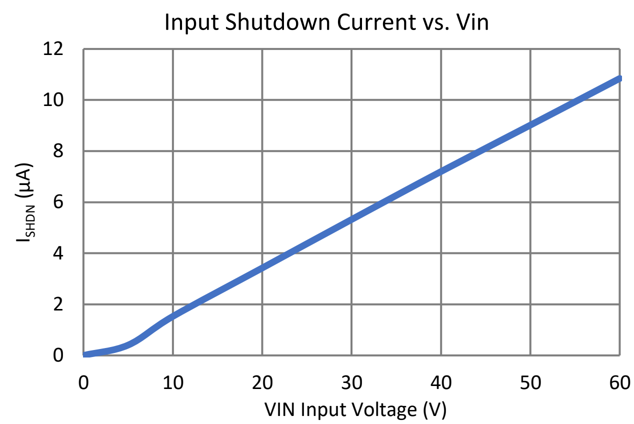


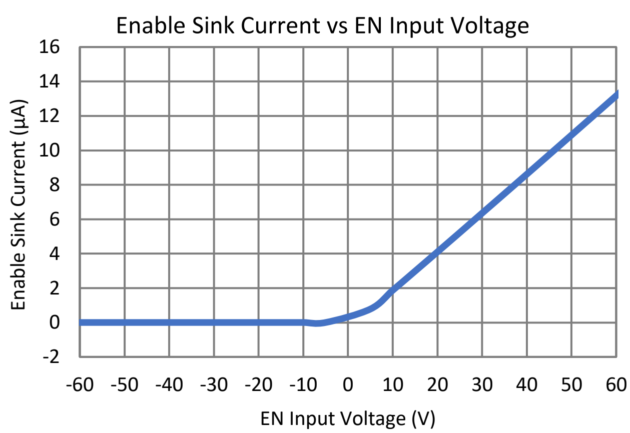
Figure 2. Timing Definition

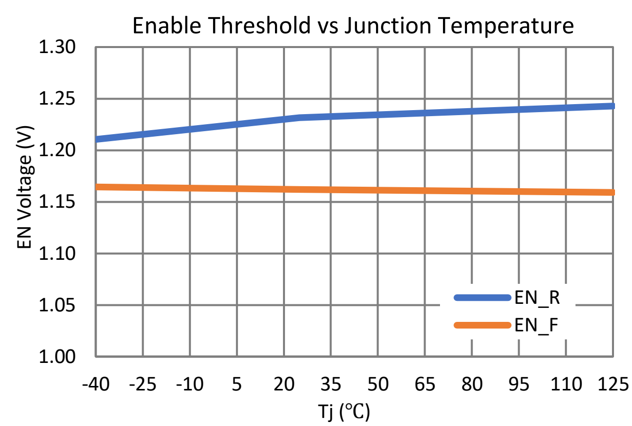
Typical Characteristics

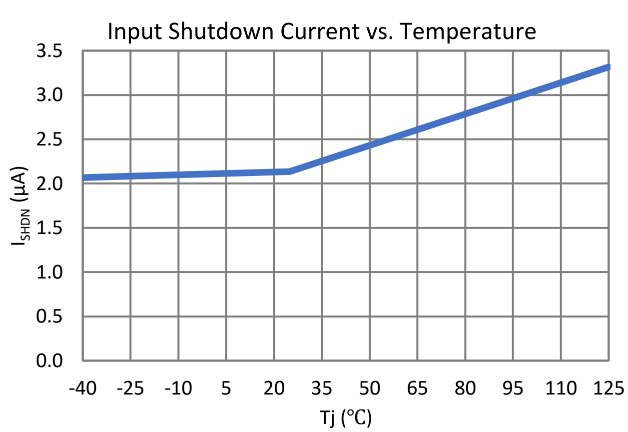
V_{IN} = 12V, T_A = 25°C, unless otherwise specified.

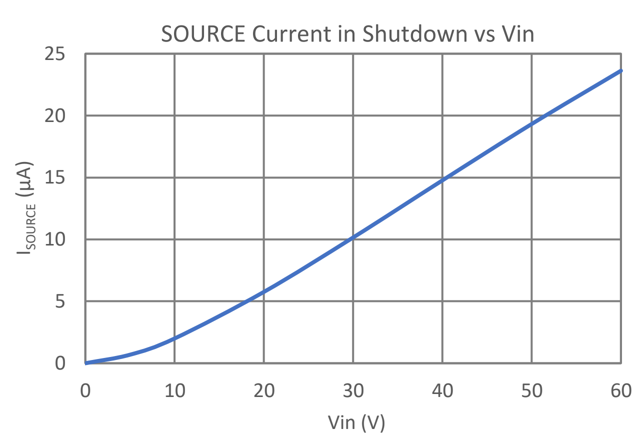






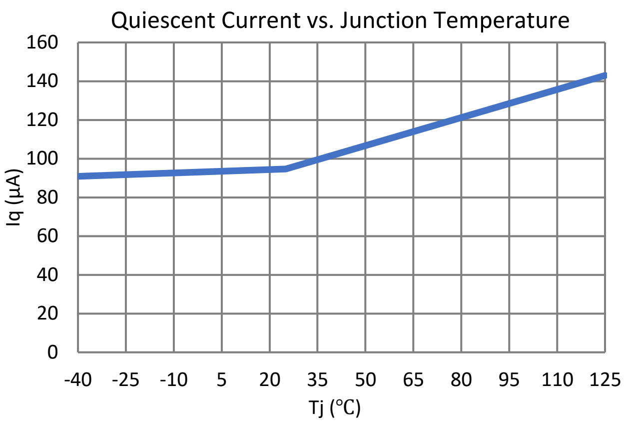


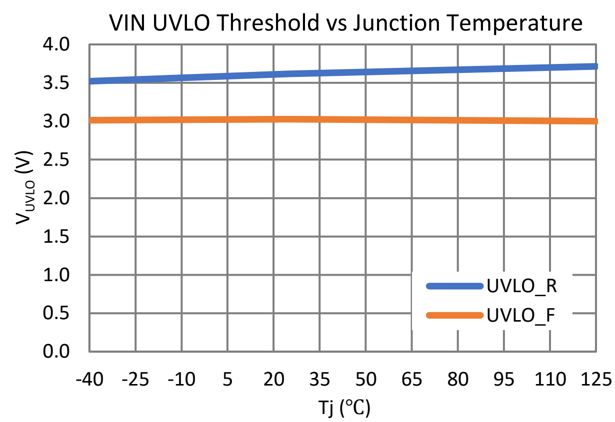


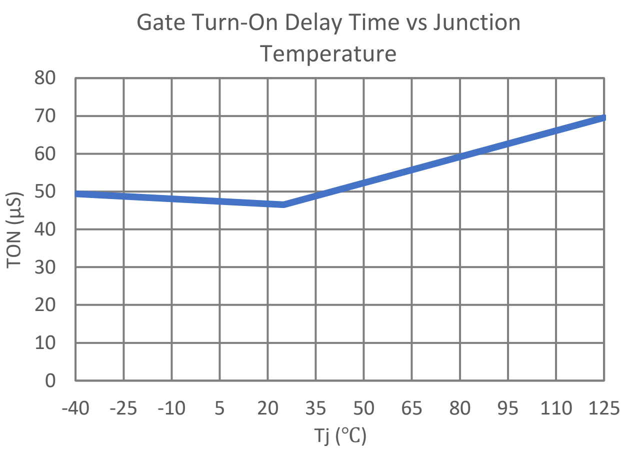


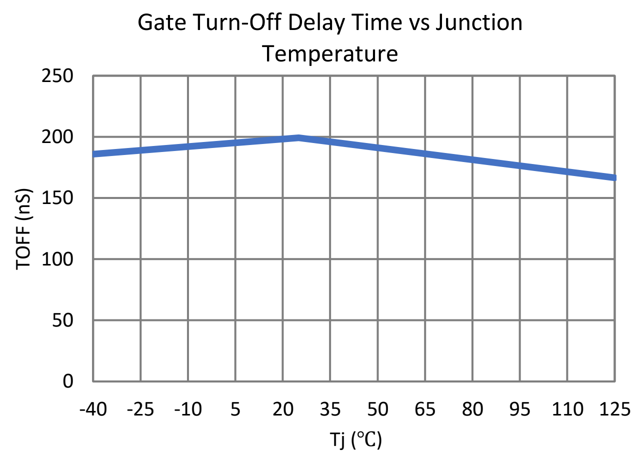
Typical Characteristics

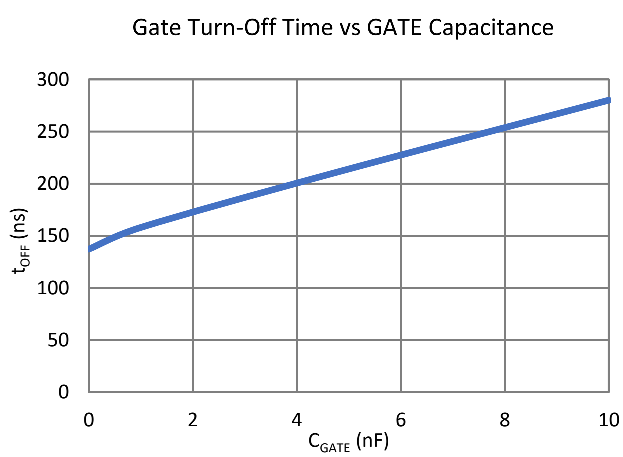
V_{IN} = 12V, T_A = 25°C, unless otherwise specified.

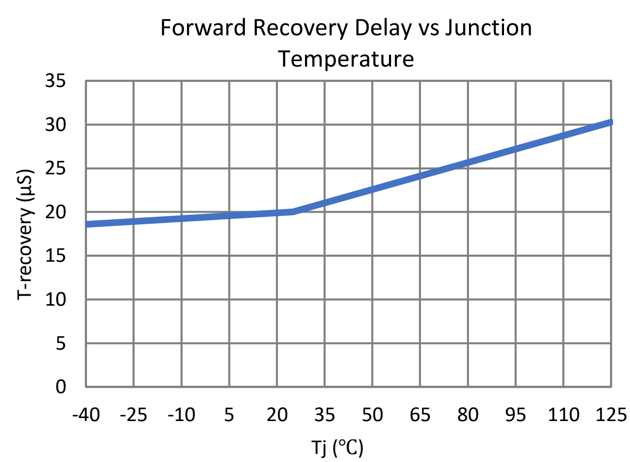












Functional Block Diagram

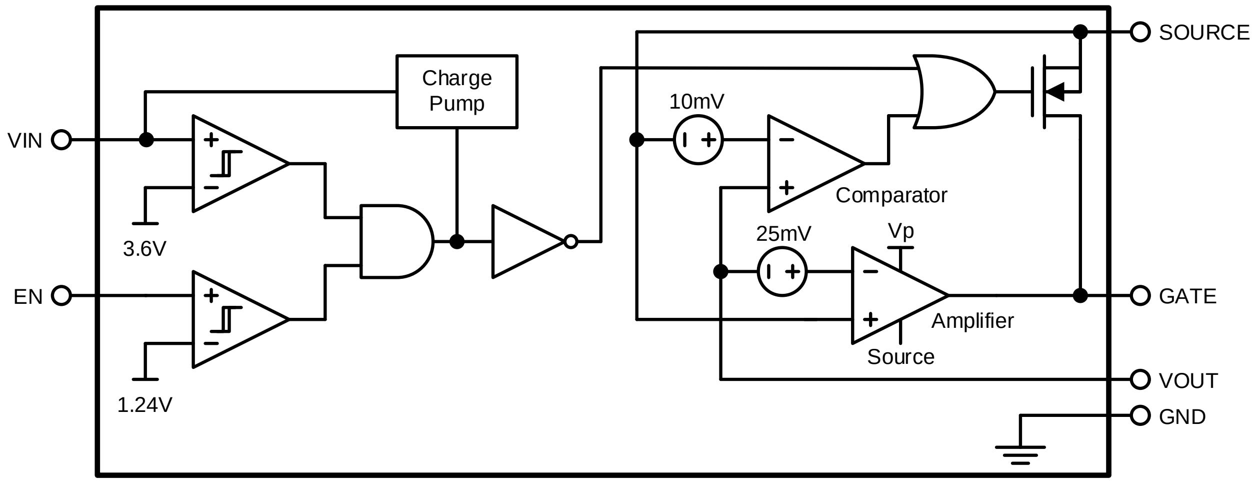


Figure 3. Functional Block Diagram

Application Information

Overview

To achieve ideal diode function KTS1900 controls an external N-MOSFET. This ideal diode controller integrates fast input reverse protection circuit, which protect the back-end components from damage when reverse polarity at input. An internal charge pump is used to supply NMOSFET GATE driver voltage. KTS1900 sense the source to drain voltage drop of the NMOSFET and regulate the forward voltage drop 40mV to keep the power loss across the NMOSFET minimum. This make the KTS1900 ideal diode solution for efficiency compared to traditional a Schottky diode. The KTS1900 monitors the load current by sensing the forward voltage drop of the MOSFET. The forward voltage drop is regulated to avoid oscillation at light loads and minimize the power dissipation at high current conditions. The KTS1900 turns off the MOSFET fast to prevent reverse current in case of failure of input voltage source. The EN pin is available to turn off the controller and minimize the current drawn by the controller down to 1µA.

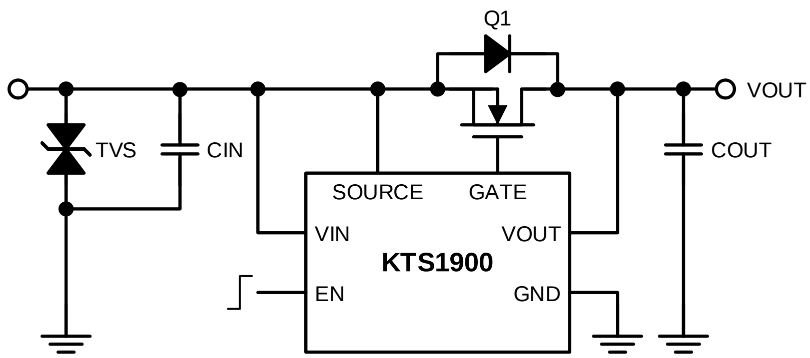


Figure 4. Typical Application

Linear Regulation Control

KTS1900 monitors the source drain voltage drop, keeps it 40mV. As output current increases, GATE voltage increases to keep the external NMOSFET regulated. This results the lower RDSON and power loss across the NMOSFET as listed in Table 1.

IOUT (A)	VGS (V)	RON (mΩ)	PLOSS (mW)
0.1	2.195	476.00	4.8
1	2.611	48.70	48.7
2	2.854	24.80	99.2
3	3.073	16.87	151.8
4	3.310	12.90	206.4
5	3.603	10.52	263.0
6	3.998	8.98	323.4
7	4.583	7.90	387.1
8	5.480	7.15	457.6
9	6.832	6.61	535.5
10	8.790	6.27	627.0
11	11.260	6.08	735.9
12	13.870	6.05	871.2
13	13.890	6.2	1047.8

Table 1. Linear Regulation Control as Output Current Increases

Operational Waveform

The normal working waveform for ideal diode configuration with 12V input voltage is shown in Figure 5 and Figure 6.

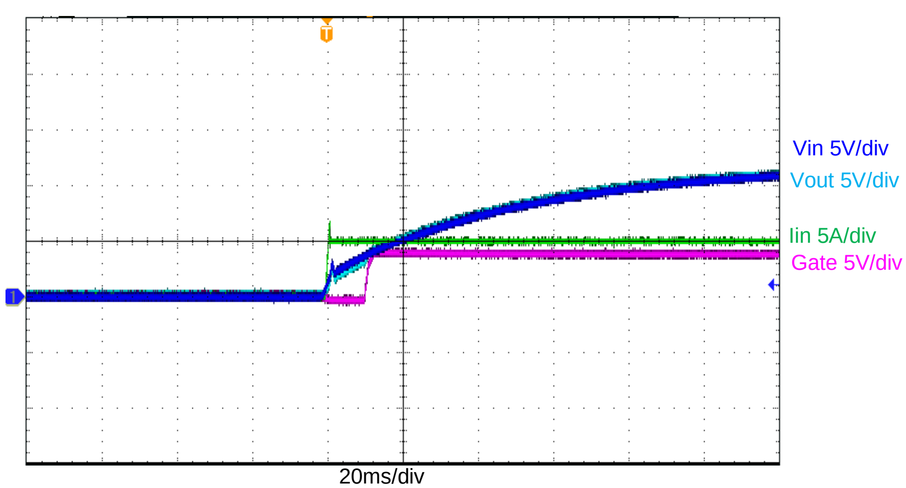


Figure 5. Start up at 12Vin, and 5A Load

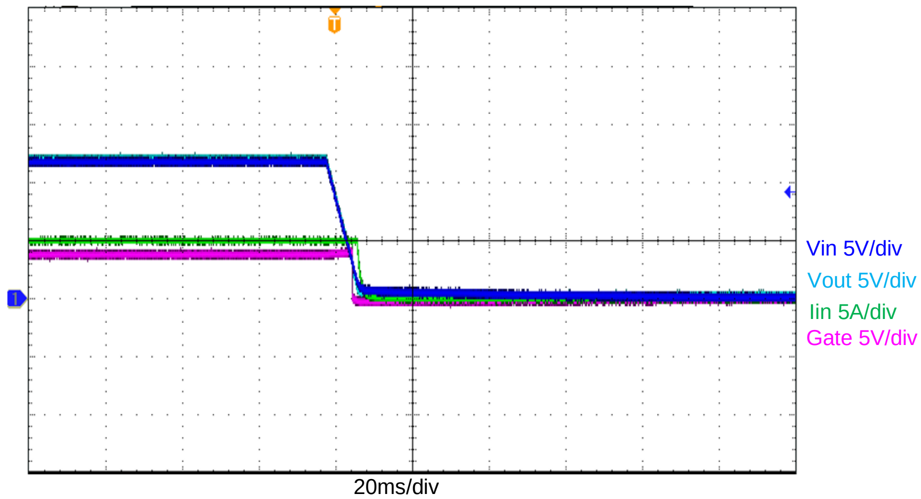


Figure 6. Turn off at 12Vin, and 5A Load

Reverse Blocking

During input supply failure or micro-short conditions, huge reverse current can flow into the input, discharging the load capacitors used for holdup. KTS1900 features a very fast reverse comparator and strong gate drive to pull down the gate to source voltage to turn OFF the MOSFET. The internal reverse comparator monitors the voltage across source and drain and if it exceeds the reverse current threshold, GATE is shorted to source with fast transient response. Reverse comparator delay and gate pulldown current determine how fast the MOSFET can be turned off. Figure 7 shows KTS1900 fast reverse blocking when an input short happens. This prevents hold capacitors at the output from discharged into the shorted battery input line, keeps the power supply of the back-end circuits stable.

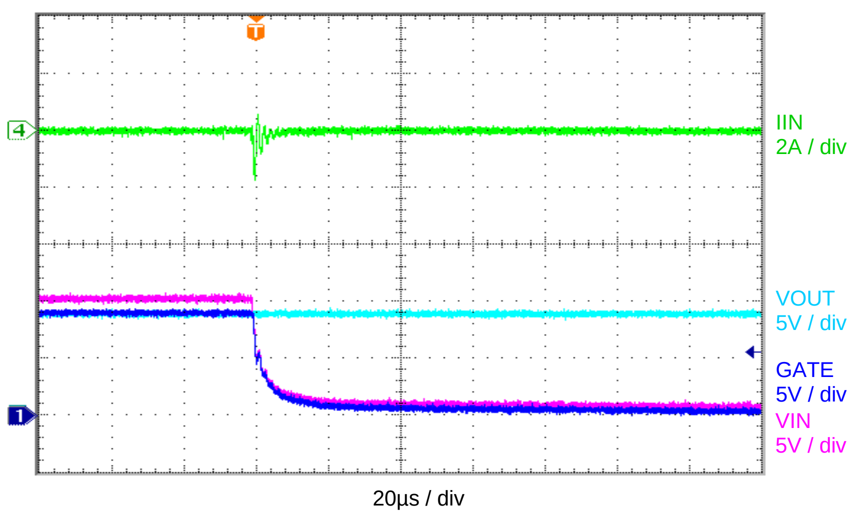


Figure 7. Reverse Blocking During Input Short

Reverse Polarity Protection

During maintenance of the battery or jump start of the vehicle, the battery can be connected in reverse polarity during reinstallation. When connected battery with reversed polarity, the KTS1900 remains turned off to protect the downstream circuits and components from damage. Figure 8 and Figure 9 show output voltage keeps stable when a reverse battery connection of -12V or -24V is applied at its input.

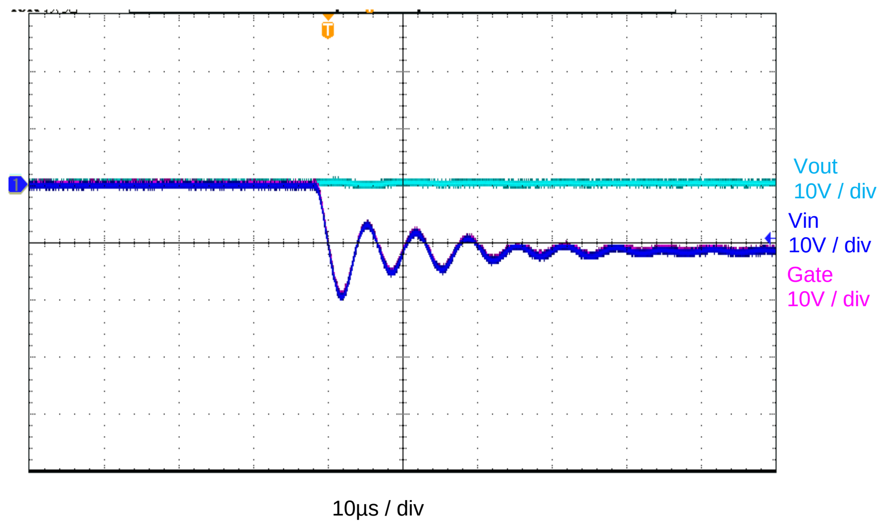


Figure 8. VIN Switch 0 to -12V

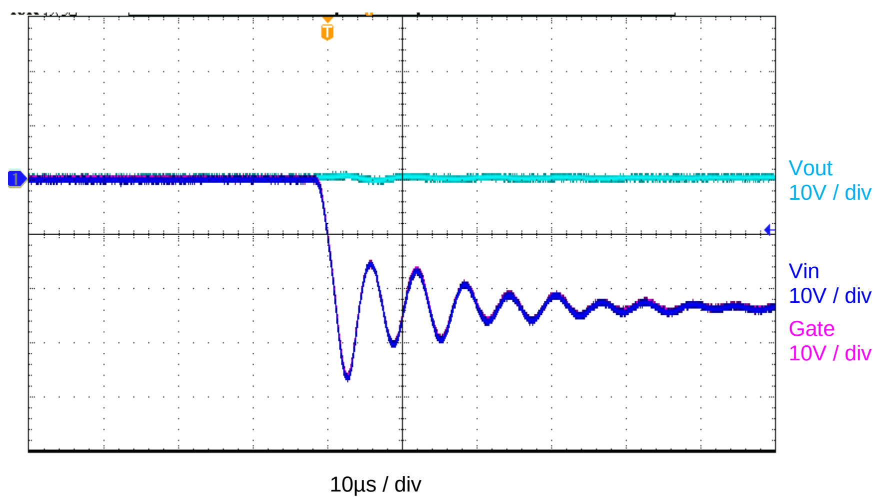


Figure 9. VIN Switch 0 to -24V

OR-ing Power Supplies Application

In OR-ing power supplies application, two or more power supplies is needed to increase system redundancy or increase power capacity in N+1 configuration. Typically, more than one power supply source is paralleled in a N+1 redundant configuration. Minimum 'N' supplies are required to power the load and additional supply is provided for redundancy in case of one of the power supply’s fail. Power supply with higher voltage provides most or all the power required by the load. To share loads almost equally among the power supplies, power supply DC set point is adjusted to match other units closely.

With external N-Channel MOSFETs, KTS1900 can be used in OR-ing Solution as Figure 10 shows. The source drain voltage drop is regulated to 40mV as the external N-Channel MOSFET is turned ON during normal operation. When input supply failure happens, KTS1900 quickly detects the reverse current and quickly pulls down the MOSFET gate, leaving the body diode of the MOSFET to block the reverse current flow.

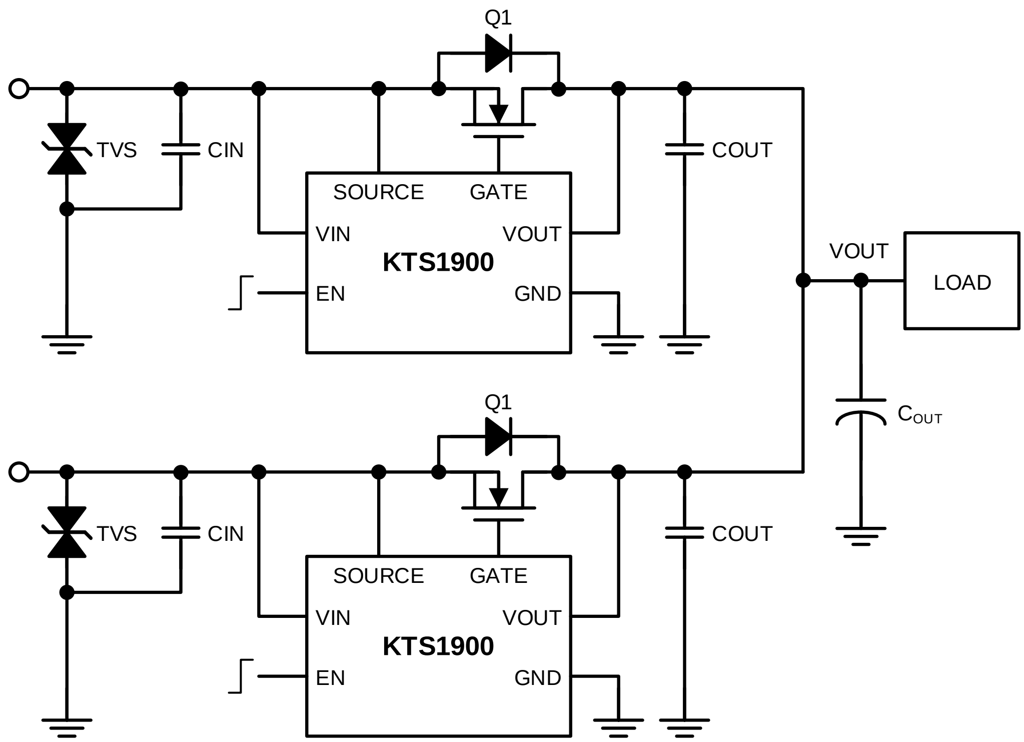


Figure 10. Typical OR-ing Application (Redundant Power Supplies)

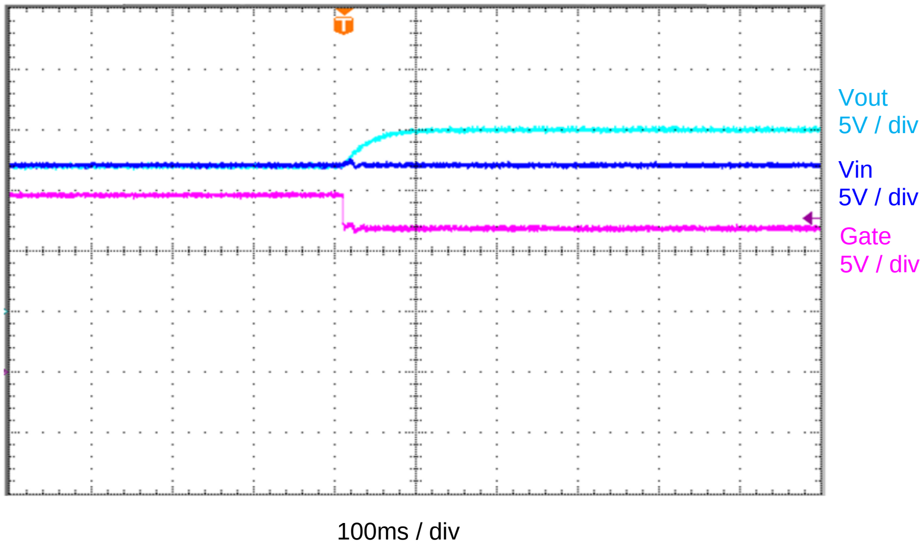


Figure 11. OR-Ing Performance VINB = 15V Cut in When VINA = 12V

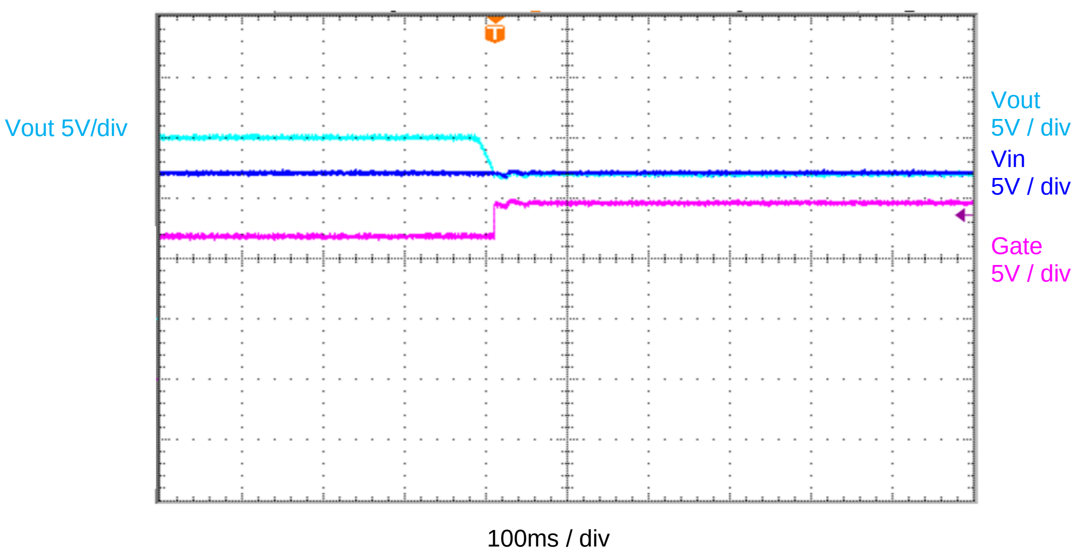


Figure 12. OR-Ing Performance VINB = 15V Cut out When VINA = 12V

Load Switch Configuration

In load switch configuration, additional MOSFET can be used in KTS1900 circuit to protect the system from reverse direction. In this case, Q1 acts as the ideal diode, while Q2 acts as a switch to control forward power flow as shown in Figure 13. In addition, the body diodes of two MOSFETs prohibit current flow when the MOSFETs are off. Additional R and C can be added to the Gate circuit to control the turning ON and OFF speed that results in inrush control.

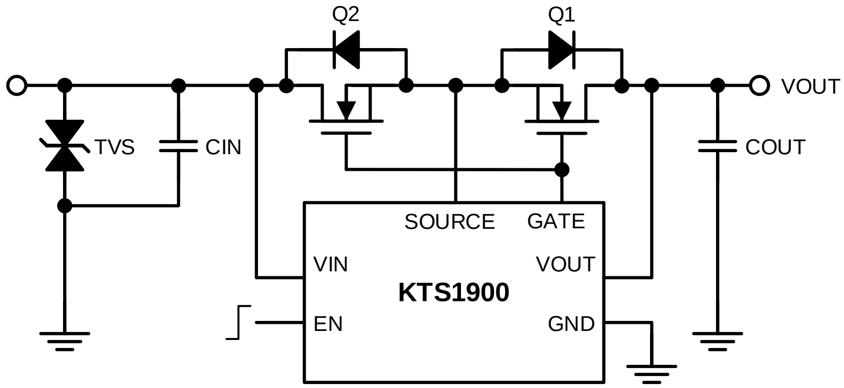


Figure 13. Load Switch Circuit Configuration with two Switch

Operational Waveform

The normal working waveform for load switch configuration is shown in Figure 14 and Figure 15.

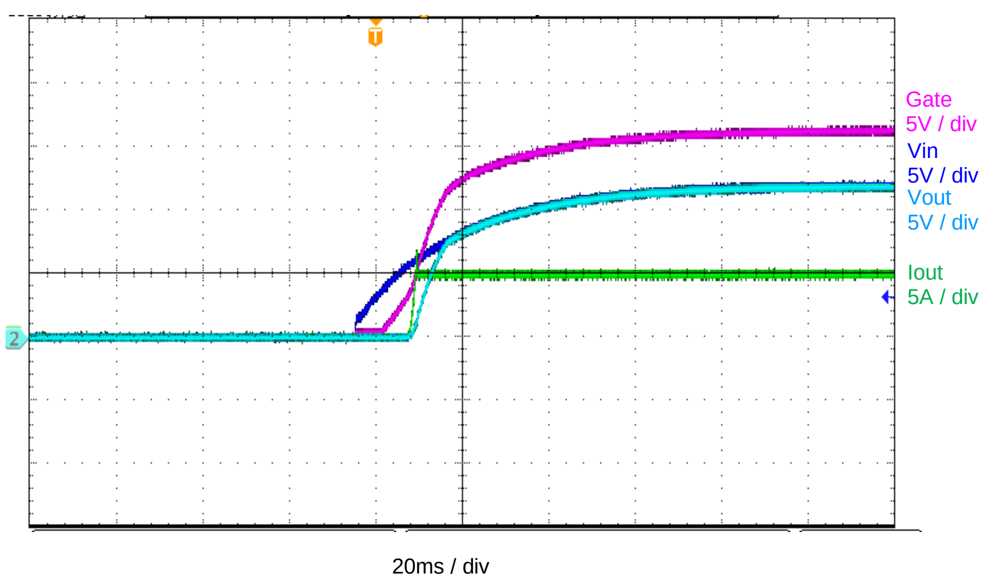


Figure 14. Start up at 12Vin, and 5A Load

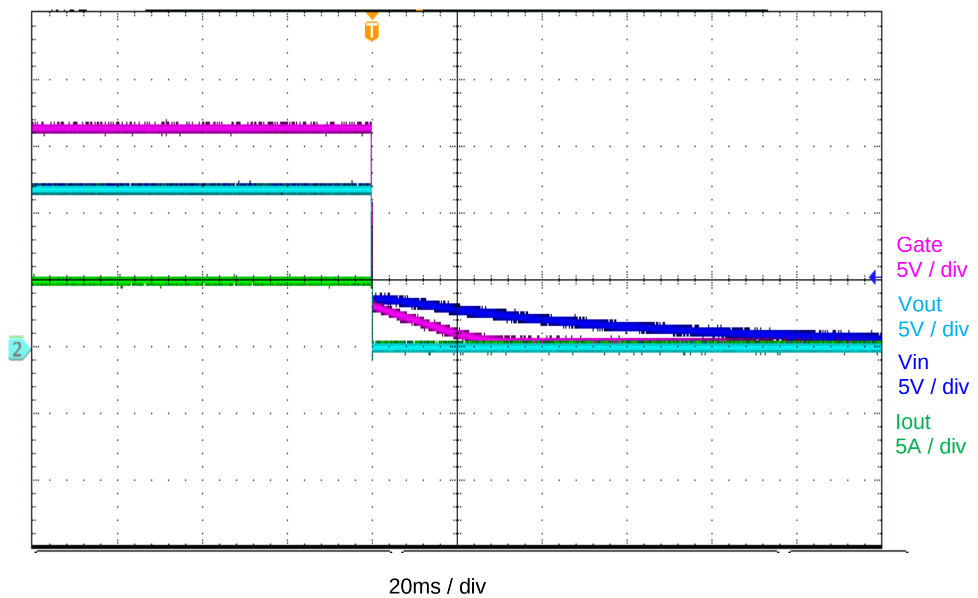


Figure 15. Turn off at 12Vin, and 5A Load

Reverse Polarity Protection

In load switch configuration and for dynamic input reverse protection a –12V or -24V source is connected to the Vin input of the KTS1900. Figure 16 and figure 17 show that the output voltage remains at a constant 0 V in this situation. This test shows that the KTS1900 can protect the load from negative input voltage.

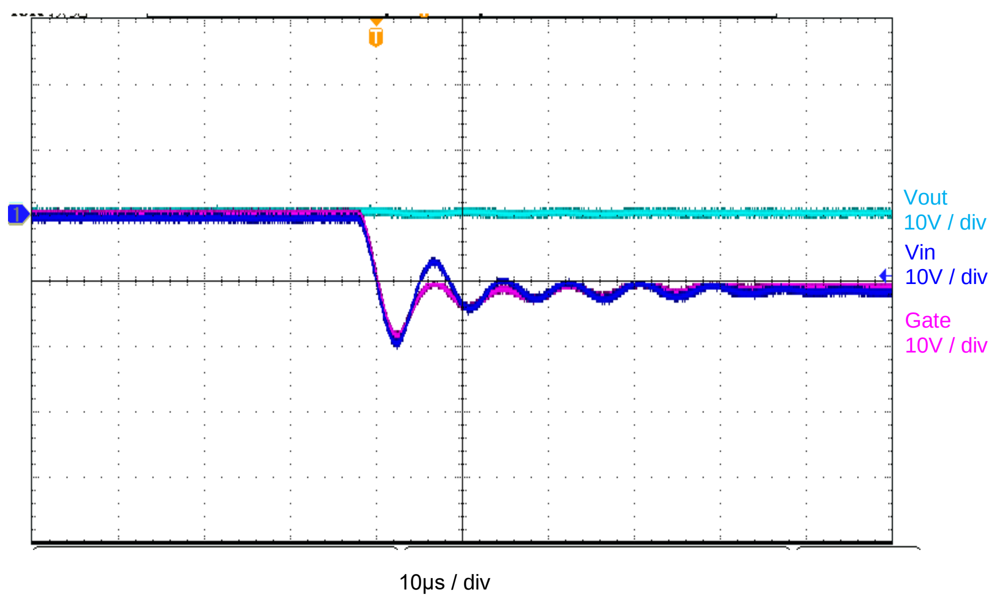


Figure 16. VIN Switch 0 to -12V Reverse Protection

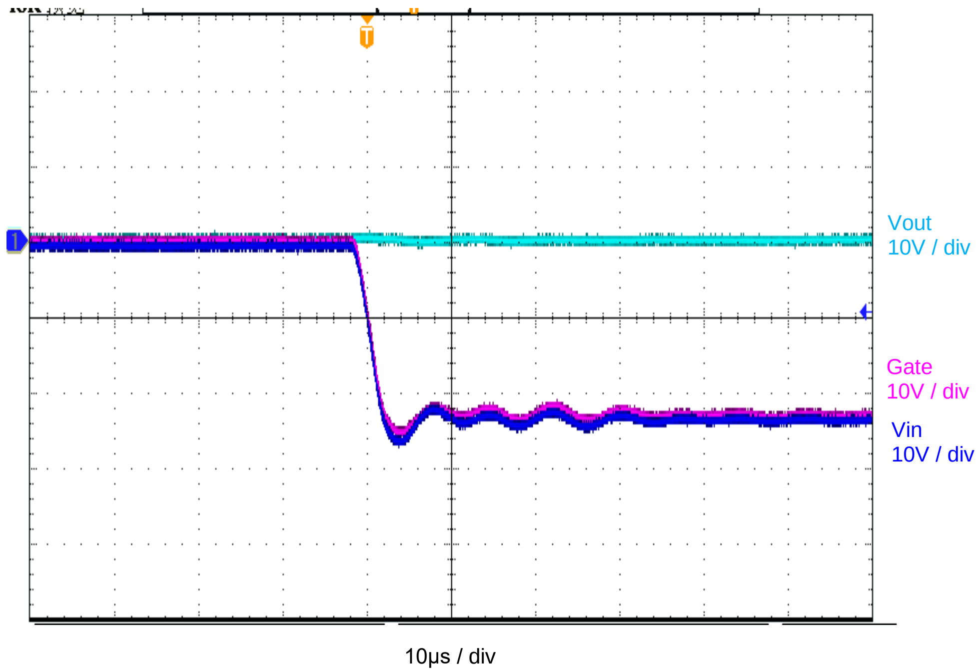


Figure 17. VIN Switch 0 to -24V Reverse Protection

Input Voltage Short Protection

For input voltage short protection, VIN switch 12V to 0V, and VOUT keeps stable, with low reverse current as shown in Figure 18.

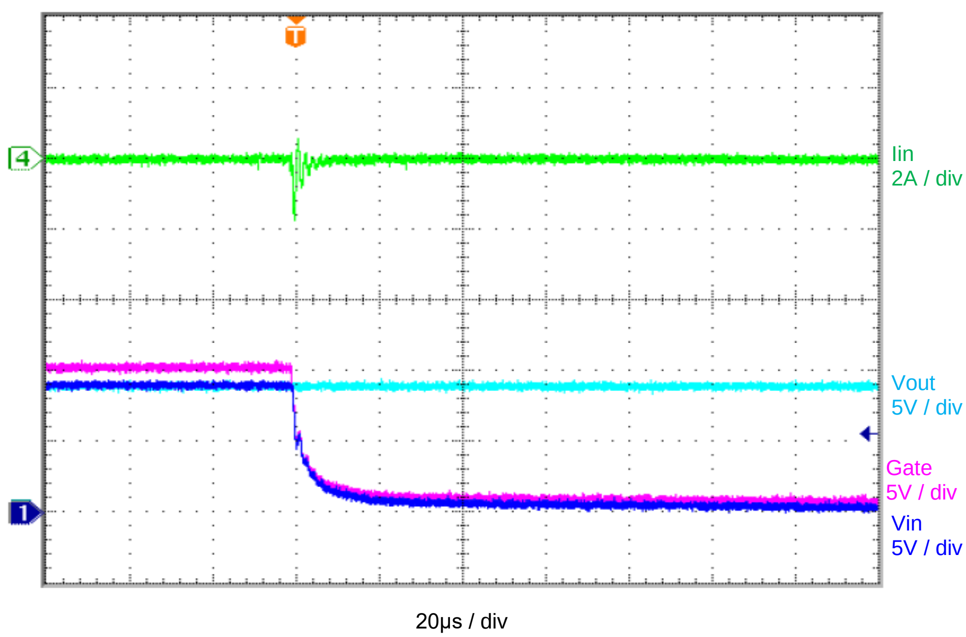


Figure 18. VIN Switch 12V to 0V Short Protection

ISO7637-2 Pulse Test

To ensure the compatibility of KTS1900 to conducted electrical transients of equipment installed in automotive applications; ISO7637-2 Pulse test is used as the reference with 12 V or 24 V electrical systems. This test is a simulation of transients due to supply disconnection from inductive loads and to guarantee it remains connected directly in parallel with an inductive load. The test waveform details, and the related parameters are shown in Figure 19 and Table 2. Respectively.

During dynamic reverse polarity conditions specified in ISO 7637-2 Pulse 1, negative transient voltage as low as -150V is applied at the 12V battery supply line with 10Ω generator impedance for 2ms and -600V at the 24-V battery supply line with 50Ω generator impedance for 1ms. When the ISO 7637-2 test pulse 1 is applied at the battery input, the load current starts to reverse quickly and tries to pull the output voltage negative. KTS1900 detects the reverse current and turns OFF the MOSFET to block reverse current and prevents the output from going negative. Downstream bulk holdup capacitors provide energy to rest of the module during such transients. With a bi-direction TVS, input voltage is clamped from exceeding the absolute maximum ratings of KTS1900 and N-MOSFET.

Figure 20 shows the result of KTS1900 for -600V transient pulse test that can be used as the reference for 24V system.

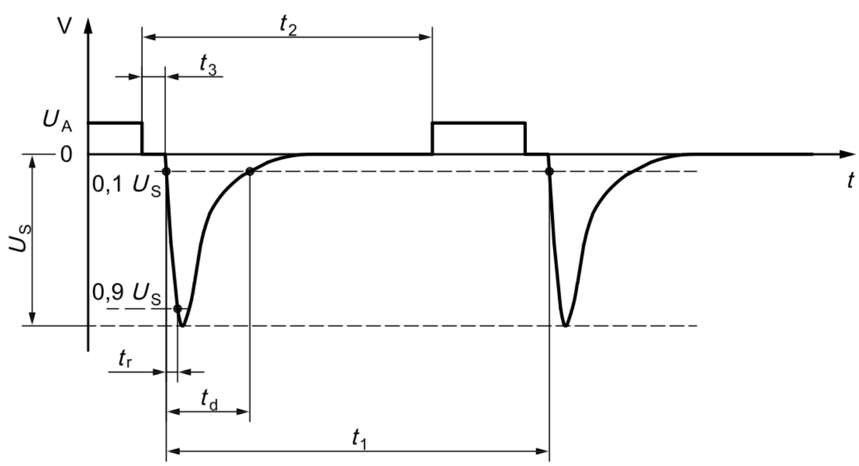


Figure 19. Test Pulse 1 Reference Waveform Details in ISO7637-2 Pulse Test Standard

Parameters	Nominal 12V System	Nominal 24V System
U_s	-75V to -150V	-300V to -600V
t_d	2ms	1ms
t_r	~1µs	~3µs
t_1	≥0.5s	
t_2	200ns	
t_3	<100µs	
t_1 shall be chosen such that it is the minimum time for the DUT to be correctly initialized before the application of the next pulse. t_3 Is the smallest possible time necessary between the disconnection of the supply source and the application of the pulse.		

Table 2. Parameters for Test Pulse 1 in ISO7637-2 Standard

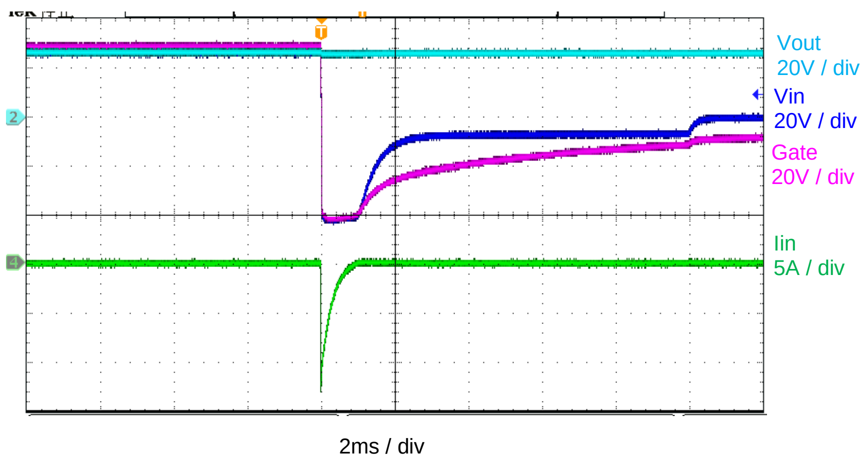


Figure 20. -600V Transient Results Based on ISO7367-2 Pulse Test

Typical Application Circuits

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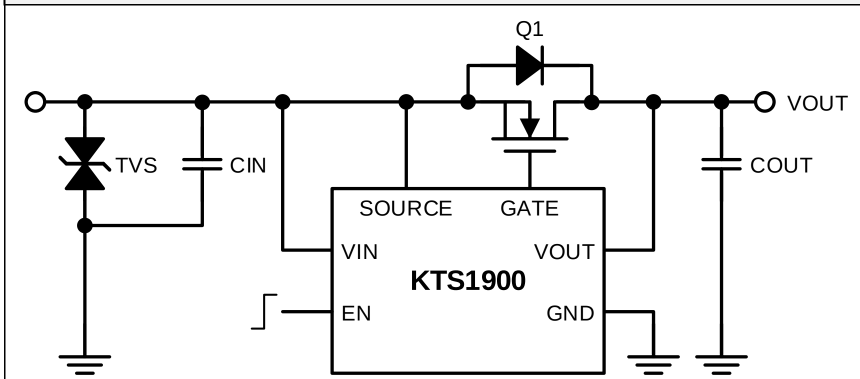
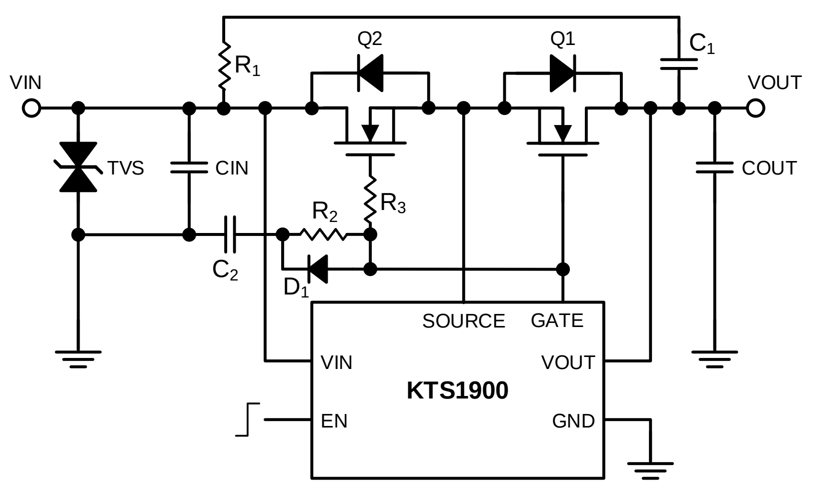
<tr><th>Ideal Diode Schematic</th><th>BOM</th></tr>
<tr><td>
</td><td>TVS = SMBJ33CA-13-F
DIODE, TVS, Bi, 33V, SMB
Q1 = DMT6007LFG-13
MOSFET, N-CH, 60V, 15A
CIN = 2.2µF, 10 V, +/- 10%, X7R, 1210
COUT = 2.2µF, 100V, +/- 10%, X7R, 1210</td></tr>
<tr><th>Load Switch Schematic</th><th>BOM</th></tr>
<tr><td>
</td><td>TVS = SMBJ33CA-13-F
DIODE, TVS, Bi, 33V, SMB
D1 = BAS521-7
DIODE, SWITCHING, 250mA 300V, SOD-523, OPTIONAL
Q1 and Q2 = IPB027N10N3GATMA1
MOSFET, N-CH,100V 120A
CIN = 2.2µF, 100V, ±10%, X7R, 1210
COUT = 2.2µF, 100V, ±10%, X7R, 1210
C1 = 10nF, 500V, ±20%, X7R, 1206
C2 =10nF, 100V, ±20%, X7R, 0805
R1 = 100Ω, 1/2W, 5%, 1210
R2 =10kΩ, 1/8W, 5%, 0805
R310Ω, 1/8W, 5%, 0805</td></tr>
</table>

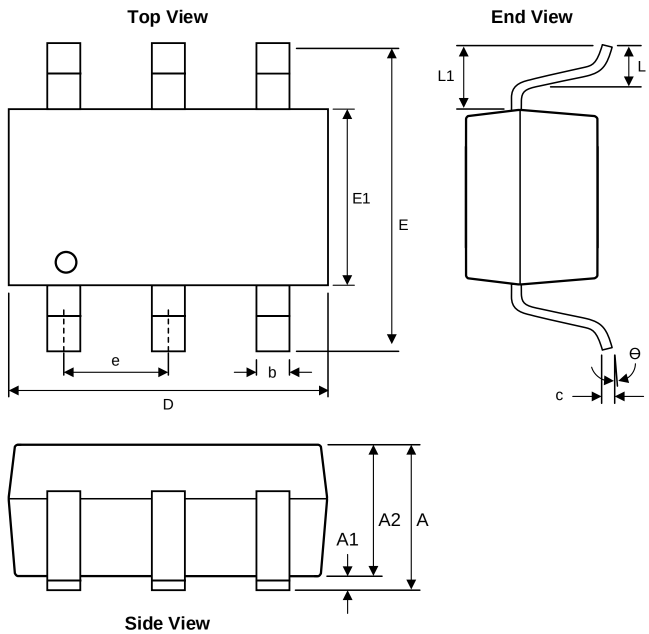
Recommended PCB Layout

KTS1900 PCB layout is optimized for low EMI, and good performance and follows the below PCB layout recommendations.

1. Connect the input capacitor CIN as close as possible to the VIN and GND pins using wide metal traces.
2. Connect the VIN, SOURCE and VOUT pins as close as possible to the MOSFET source and drain pins. With short and wide traces to minimize resistive losses.
3. Place surge suppressors and transient protection components as close as possible to the input of KTS1900 with short lead lengths.
4. Connect the ground terminals of output capacitors COUT as close as possible to the ground terminal of CIN and the PGND pins using top-side metal.
5. Check the clearance details and guidelines to determine and increase the effective pins spacing between high voltage and ground pins.

Packaging Information

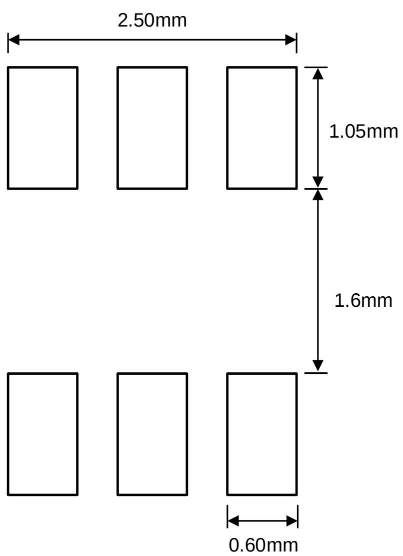
SOT23-6 (2.90mm x 1.60mm x 1.45mm)



Dimension	mm		
	Min.	Typ.	Max.
A	–	–	1.45
A1	0	–	0.15
A2	0.90	1.15	1.30
b	0.30	–	0.50
c	0.08	–	0.22
D	2.90 BSC		
E	2.80 BSC		
E1	1.60BSC		
e	0.95 BSC		
L	0.30	0.45	0.60
L1	0.60 BSC		
ϴ°	0	4	8

Recommended Footprint

(NSMD) Pad Type



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