KTS1900Q

Ideal Diode and Load Switch Controller with Reverse Input Protection

Features

- 4V to 60V Wide Input Operating Range
- Reverse Voltage Protection to –60V Requirements with a Suitable TVS Diode
- AEC-Q100 Qualified Over -40°C to 125°C Ambient Operating Temp Range
- ESD Ratings
  - HBM, per AEC Q100-002: ±2kV
  - CDM, per AEC Q100-011: ±750V
- Meets Automotive ISO7637 Transient Requirements with a Suitable External TVS Diode
- 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/15µA Sink/Source Current Capability of MOSFET Gate Driver
- EN Pin to Enable/Disable the Controller
- 1µA Shutdown Current
- 110µA Operating Quiescent Current
- 230ns Reverse Protection Response Time
- Small 6 Pin SOT23 Package (2.9mm x 1.6mm)

Applications

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

Brief Description

The KTS1900Q is an AEC-Q100 qualified 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 KTS1900Q operates over a wide input voltage range from 4V to 60V to support a variety of automotive and telecom/server applications. It withstands ±65V voltage, which simplifies the system design to meet automotive ISO7637 transient requirements.

The KTS1900Q 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 KTS1900Q 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.

The KTS1900Q is available in a small fully green compliant 6-Pin SOT23-6L Package (2.9mm x 1.6mm).

Typical Application

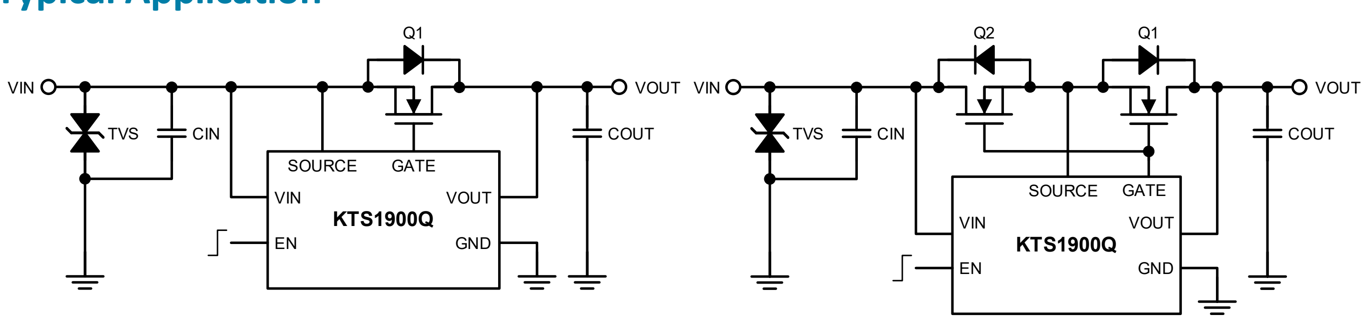


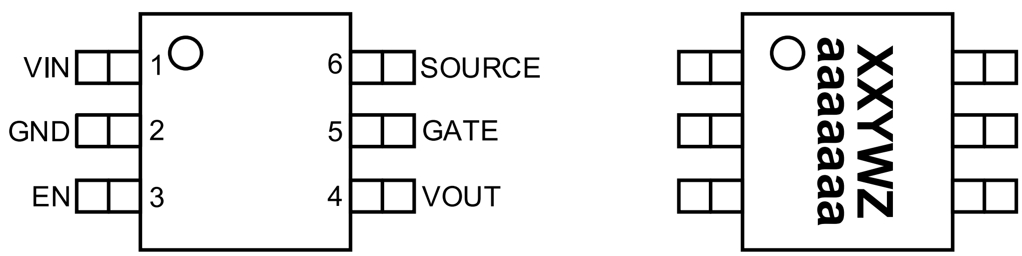
Figure 1. (a) Ideal Diode Controller Application (b) Load Switch Controller Application

Ordering Information

Part Number	Marking[1]	Operating Temperature	Package
KTS1900QGXAA-TA	ZMYWZ aaaaaaa	-40°C to +125°C	SOT23-6L

Pin Descriptions

SOT23-6L



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
aaaaaaa = Assembly Lot Tracking Number

Pin #	Name	Function
1	VIN	Supply voltage input. Connect pin to supply voltage VIN with a 2.2µF capacitor to ground. The VIN pin must be connected to the SOURCE pin in Ideal Diode mode. 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. Use 2.2µF from VOUT to ground
5	GATE	Gate drive. Connect to the gate of the external N-Channel MOSFETs.
6	SOURCE	Source pin. Connect to the source of the external N-Channel MOSFETs in Load Switch mode. SOURCE pin is also connected to VIN pin in single MOSFET application.

1. ZM = Device Code, YW = Date Code, Z = Serial Number, aaaaaaa = Assembly Lot Tracking Number

Absolute Maximum Ratings[2]

(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	V
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 Ratings[3]

Symbol	Description	Value	Units
V(ESD) Electrostatic discharge	Human body model (HBM), per AEC Q100-002, all pins	±2000	V
	Charged device model (CDM), per AEC Q100-011, all pins	±750	V

Thermal Capabilities[4]

Symbol	Description	Value	Units
Θ_{JA}	Thermal Resistance – Junction to Ambient	120	°C/W
P_D	Maximum Continuous Power Dissipation at 25°C (T_J = 125°C)	833	mW
$\Delta P_D/\Delta T$	Derating Factor Above T_A = 25°C	-8.3	mW/°C

Recommended Operating Conditions[5]

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	℃

2. Stresses above those listed in Absolute Maximum Ratings may cause permanent damage to the device. Functional operation at conditions other than the operating conditions specified is not implied. Only one Absolute Maximum rating should be applied at any one time.
3. ESD conform to JEDEC and IEC industry standards. Some pins may have higher performance.
4. 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.
5. 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[6]

Typical values correspond to T_A = 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		60	V
	VIN Undervoltage Threshold	VIN Rising		3.6	3.95	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[7]			1.5		A
T_{EN_DLY}	Gate Turn-On Delay Time			60	100	µs
$T_{REVERSE\_DLY}$	Gate Turn-Off Delay Time			230		ns
$T_{RECOVERY}$	Recovery Delay from Forward Detection to Gate Turn ON[7]			5		µs

Source to Drain Voltage

Symbol	Description	Conditions	Min.	Typ.	Max.	Units
V_{SDREG}	Regulated Source to Drain Voltage (SOURCE-VOUT)		25	45	70	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	V_{OUT} = 12V		1.5	2	µA
I_{SOURCE}	SOURCE Pin Sink Current[7]	V_{SOURCE} = 12V		5	10	µA

6. Device is guaranteed to meet performance specifications over the -40°C to +125°C operating temperature range by design, characterization and correlation with statistical process controls.
7. Guaranteed by design, characterization and statistical process control methods; not production tested.

Timing Diagrams

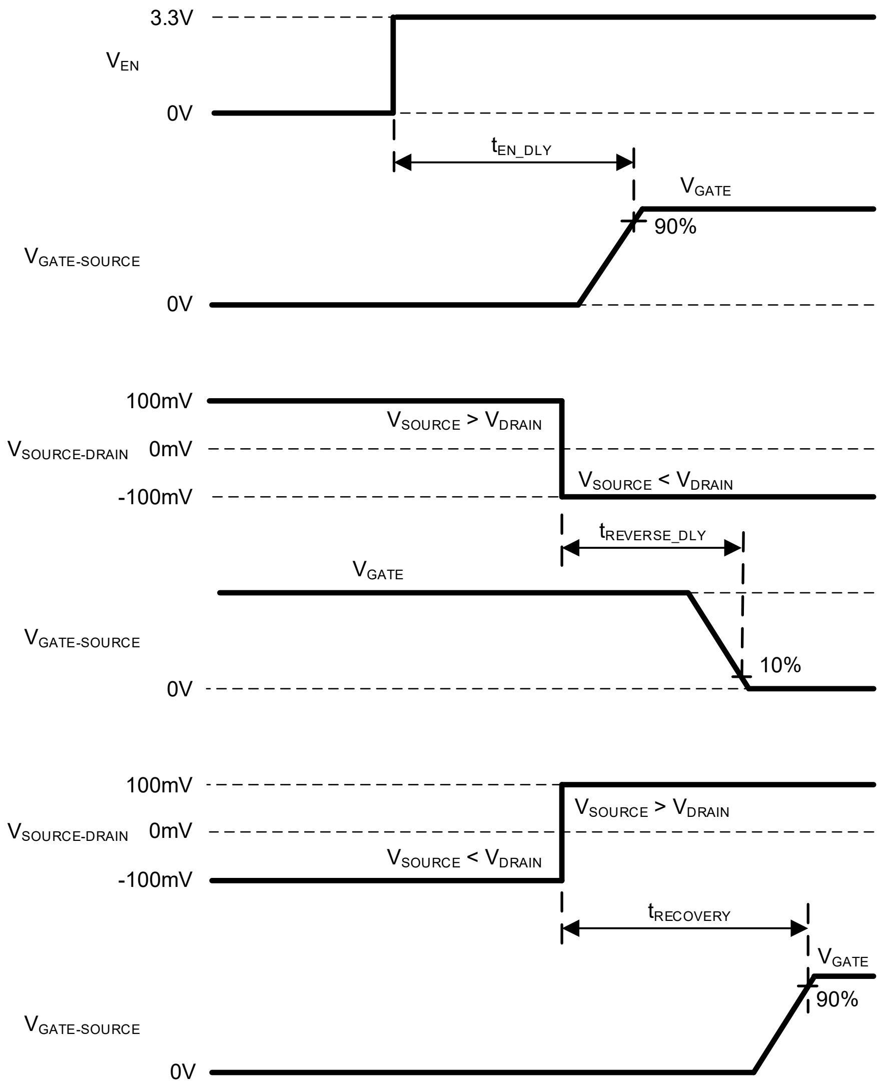
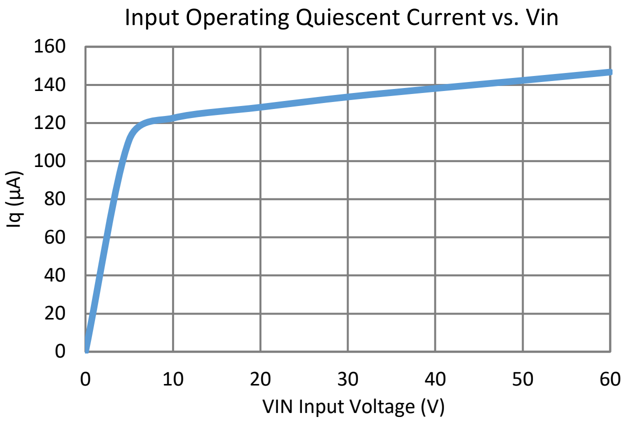
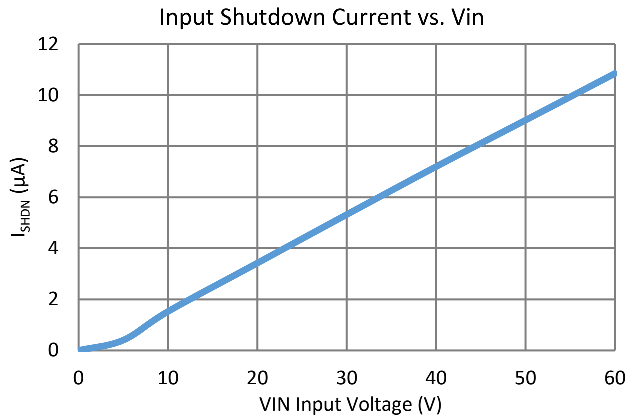


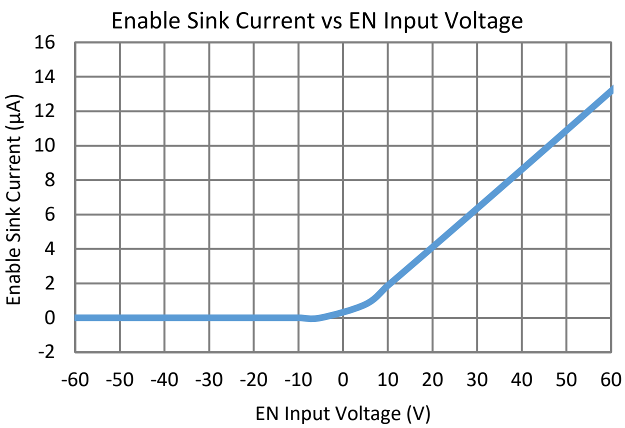
Figure 2. Timing Definition

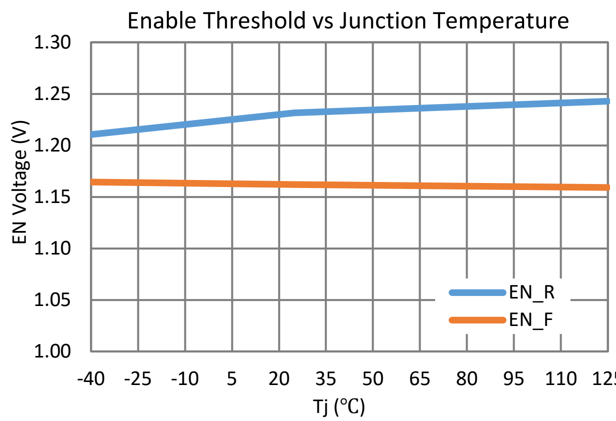
Typical Characteristics

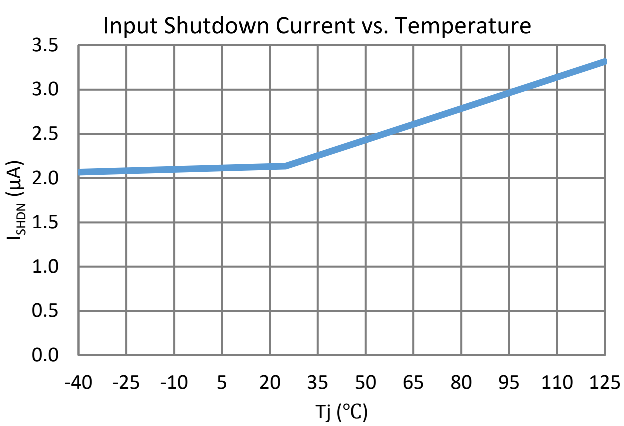
V_{IN} = 12V, T_A = 25°C, unless otherwise specified.

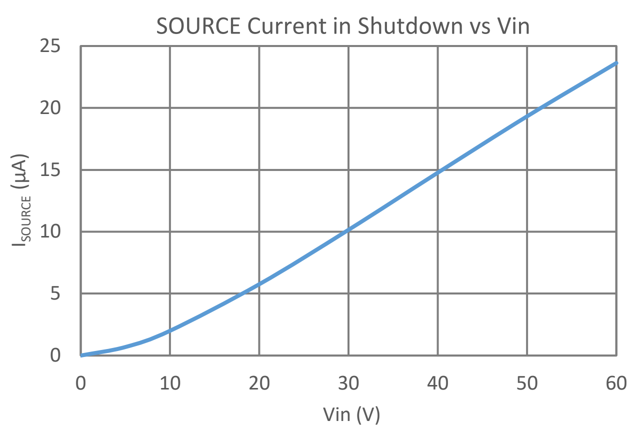






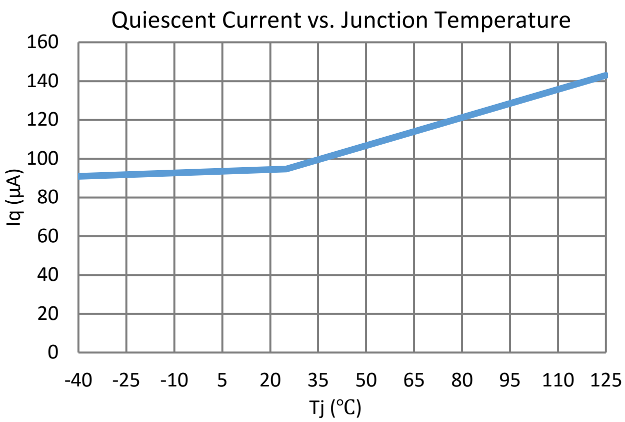


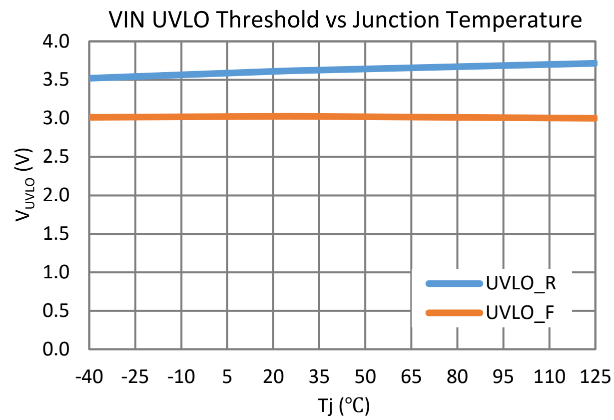


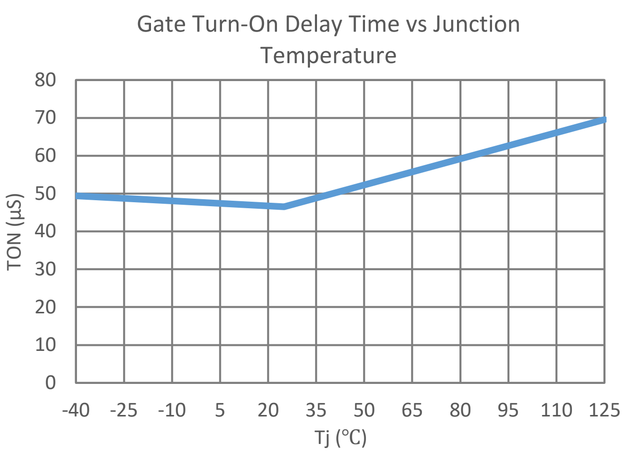


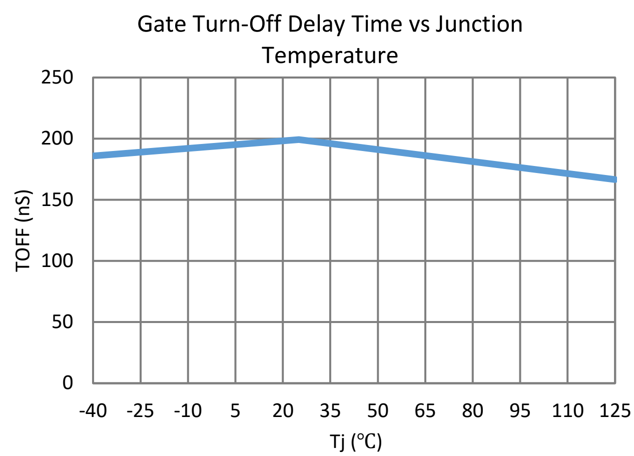
Typical Characteristics

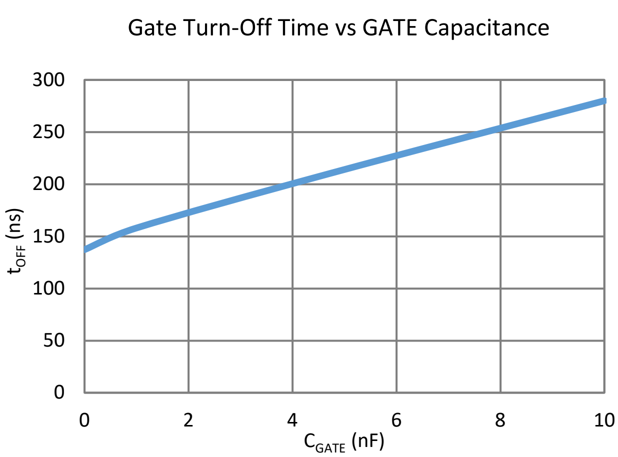
V_{IN} = 12V, T_A = 25°C, unless otherwise specified.

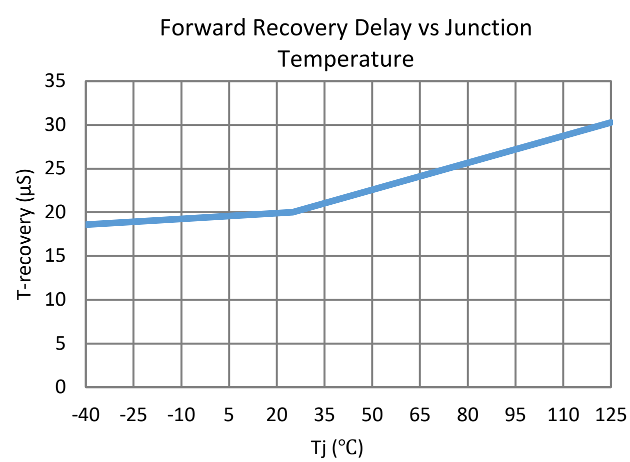












Functional Block Diagram

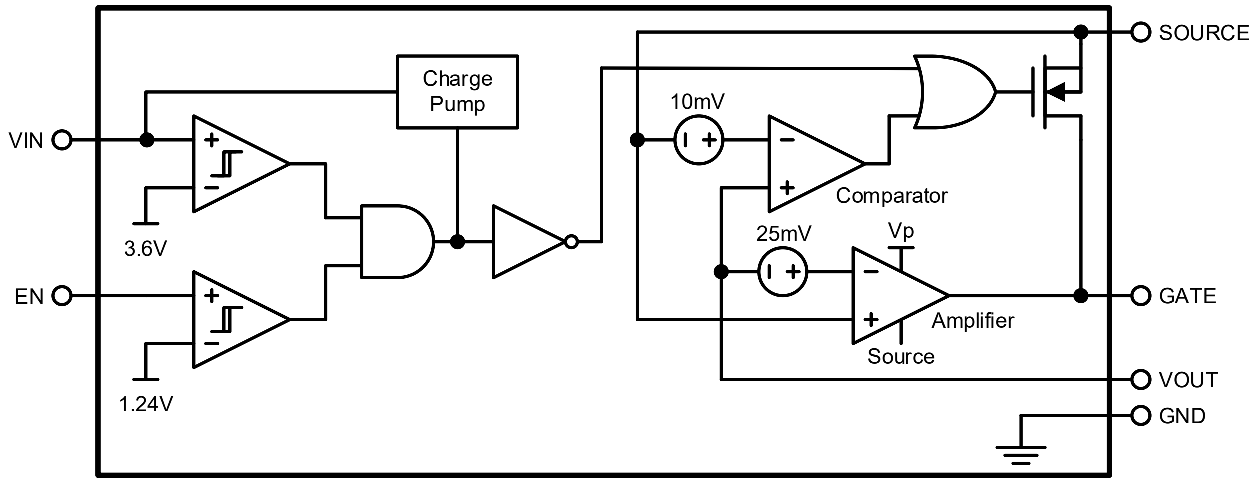


Figure 3. Functional Block Diagram

Application Information

Overview

To achieve an ideal diode function the KTS1900Q controls an external N-MOSFET. An internal charge pump is used to supply NMOSFET gate driver turn on voltage. This ideal diode controller integrates a fast reverse current protection circuit. This protects the system from reverse current when there is a short or reverse polarity at VIN. In forward mode the KTS1900Q also senses the source to drain voltage drop of the NMOSFET. The device linearly increases the GATE voltage to regulate the forward voltage drop to 40mV at light load. To keep the power loss at a minimum the GATE voltage increases with load current. This makes the KTS1900Q ideal diode solution more efficient compared to traditional a Schottky diode. The forward voltage drop is regulated to avoid oscillation at light loads and minimize the power dissipation at higher currents. The KTS1900Q also detects reverse current through the MOSFET. If the threshold is reached the MOSFET is turned off with a 1.5 Amp GATE pull down. The EN pin is also available to turn off the MOSFETs and minimize the current drawn by the controller down to 1µA.

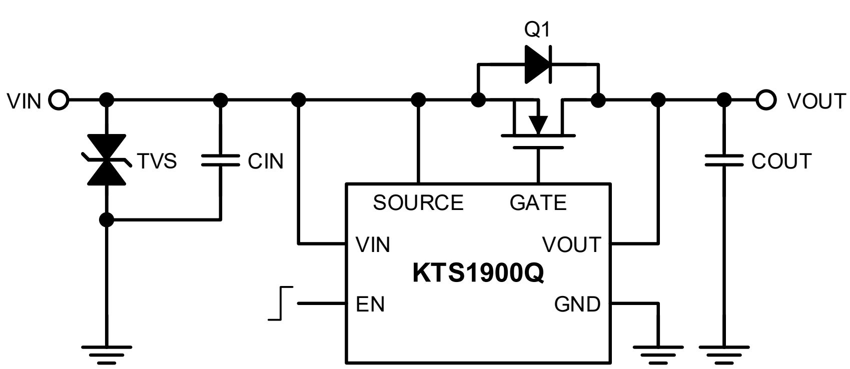


Figure 4. Typical Application

Linear Regulation Control

The table below shows that at light load the gate drive is reduced to regulate the source to drain voltage. At higher currents the MOSFET is driven to its lowest resistance. This results in a soft turn on and the lowest RON at higher currents as listed in Table 1.

Table 1. Linear Regulation Control as Output Current Increases

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

Notes: VGS is the MOSFET GATE to SOURCE voltage. PLOSS is the MOSFET power loss.

Operational Waveform

The normal startup and shut down waveforms for ideal diode configuration with 12V input are shown in Figure 5 and Figure 6.

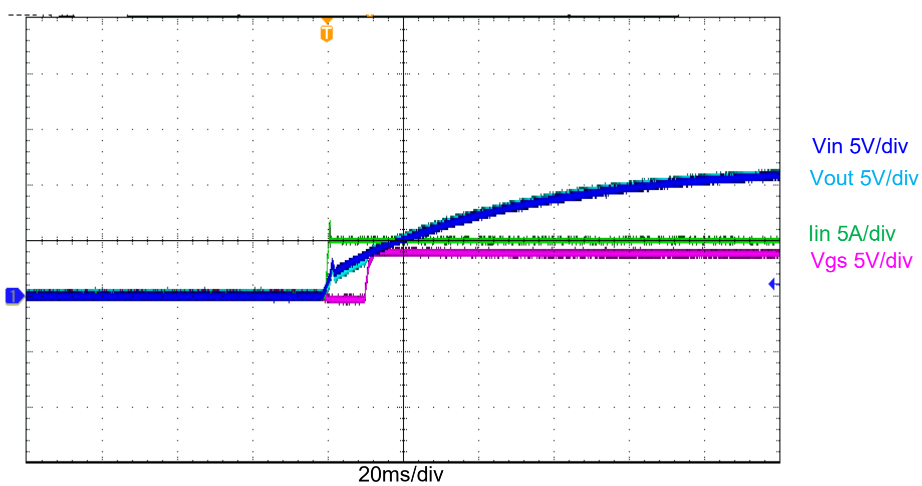


Figure 5. Start up at 12V Vin, and 5A Load

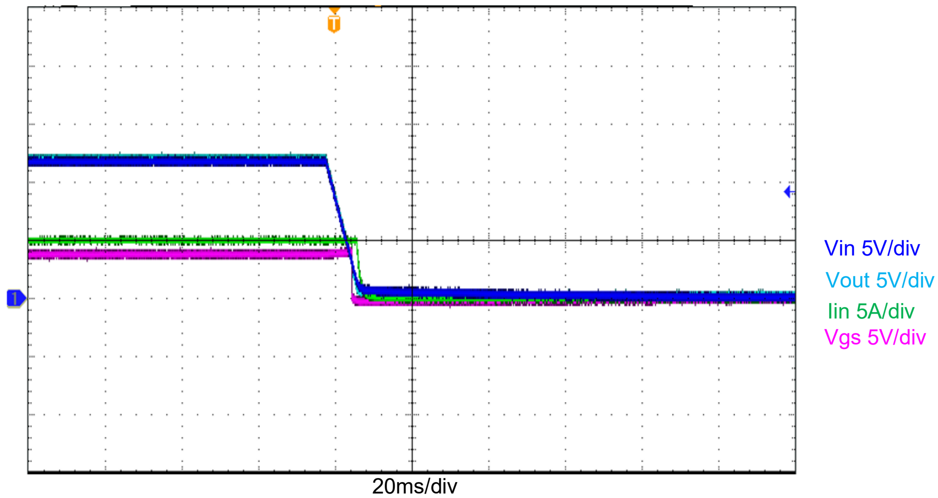


Figure 6. Turn off at 12V Vin, and 5A Load

Reverse Blocking

During input supply failure or micro-short conditions, huge reverse currents can flow in reverse, discharging the load capacitors used for VOUT holdup. KTS1900Q features a very fast reverse current comparator and a strong gate driver to pull down the gate and turn off the MOSFET. The internal reverse comparator monitors the voltage across source and drain and if it exceeds the reverse current threshold, the GATE is pulled down to source with a fast response. Reverse current comparator delay, gate pulldown current and total gate capacitance determine how fast the MOSFET can be turned off. Figure 7 shows the fast reverse blocking when an input short happens. Once the MOSFET drain to source voltage exceeds the 15mV threshold the device is turned off. With the MOSFET off the voltage on the body diode increases well beyond the 15mV latching the circuit off. This is shown in Figure 7. The circuit will remain off until the source to drain voltage is above 40mV on the body diode. This prevents the holdup capacitors on VOUT from discharging into the shorted input rail. The IIN trace in Figure 7 shows very little reverse let through current. This keeps the power supplies on the back-end circuits stable.

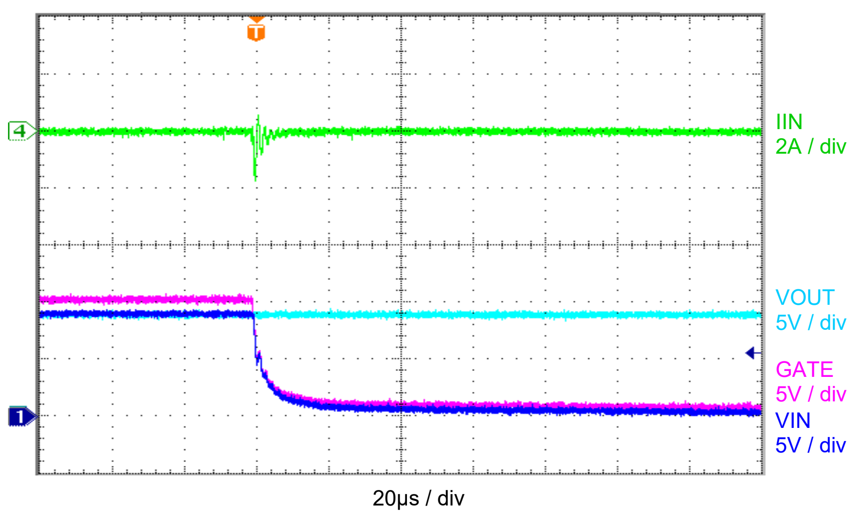


Figure 7. Reverse Blocking During Input Short

Reverse Polarity Protection

During maintenance of the battery or jump start of the vehicle, the battery can be connected in reverse polarity during reinstallation. If a battery is connected with a reversed polarity, the KTS1900Q is rapidly turned off to protect the downstream circuits and components from damage. Figure 8 and Figure 9 show the VOUT stability when a reverse battery connection of -12V or -24V is applied at its VIN.

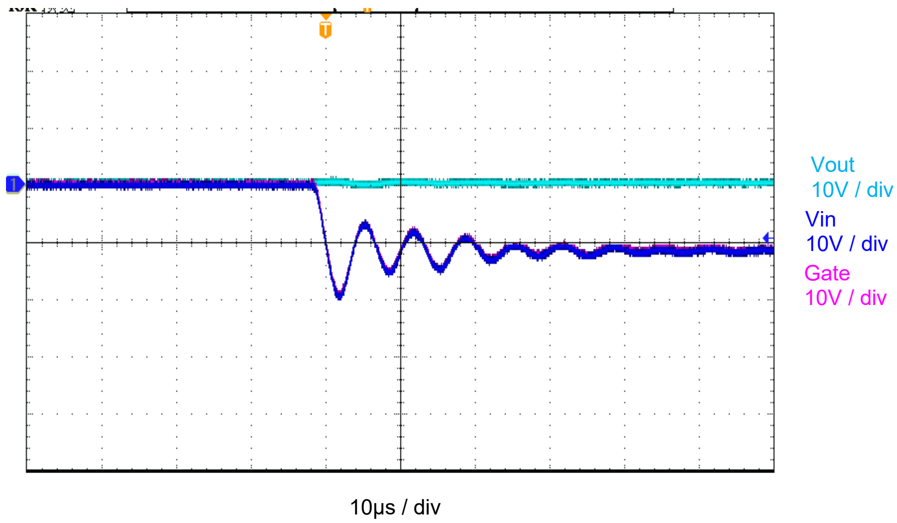


Figure 8. VIN Switch from 0V to -12V

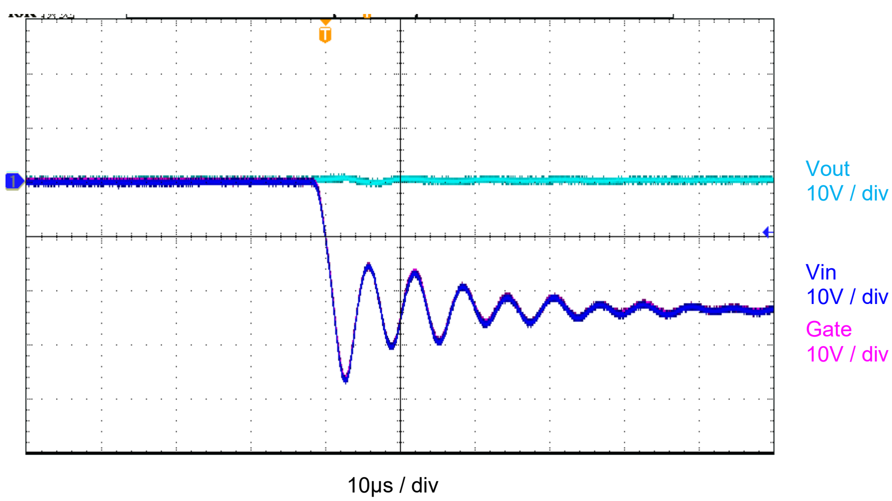


Figure 9. VIN Switch from 0V to -24V

OR-ing Power Supplies Application

In OR-ing power supplies application, two or more power supplies are needed to increase system redundancy or increase power capacity or both. Typically, in the N+1 configuration, more than one power supply source is paralleled with ideal diodes. A minimum 'N' supplies are required to power the load and additional supplies are added for redundancy in case of failed power supplies. The power supply with higher voltage provides most or all the current required by the load. To share loads equally, the power supplies DC set point is adjusted to match other units closely.

With external N-Channel MOSFETs, KTS1900Q can be used in an OR-ing solution as Figure 10 shows. When an input supply failure happens, the KTS1900Q 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. Redundant power supplies can then service the load.

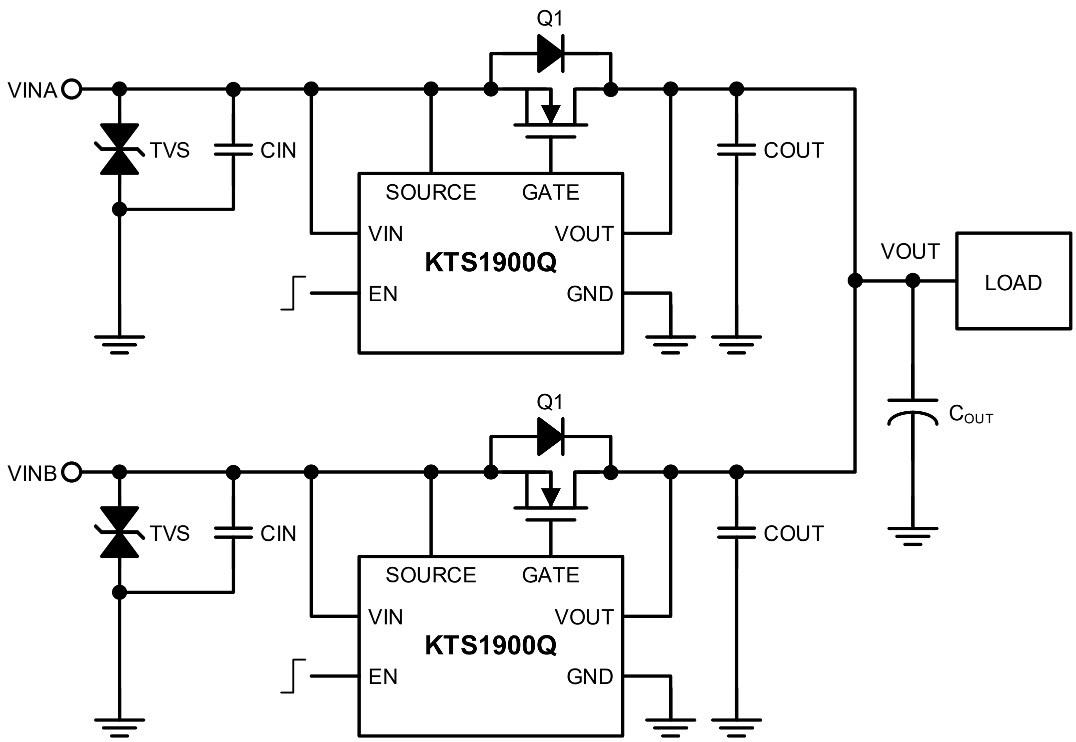


Figure 10. Typical OR-ing Application (Redundant Power Supplies)

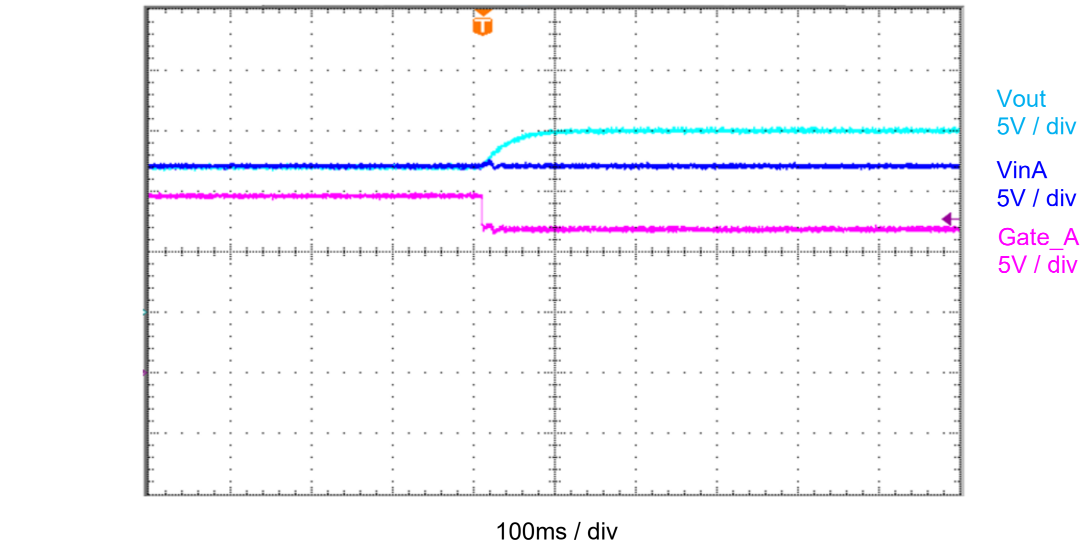


Figure 11. OR-Ing Performance VINB = 15V Step-up When VINA = 12V

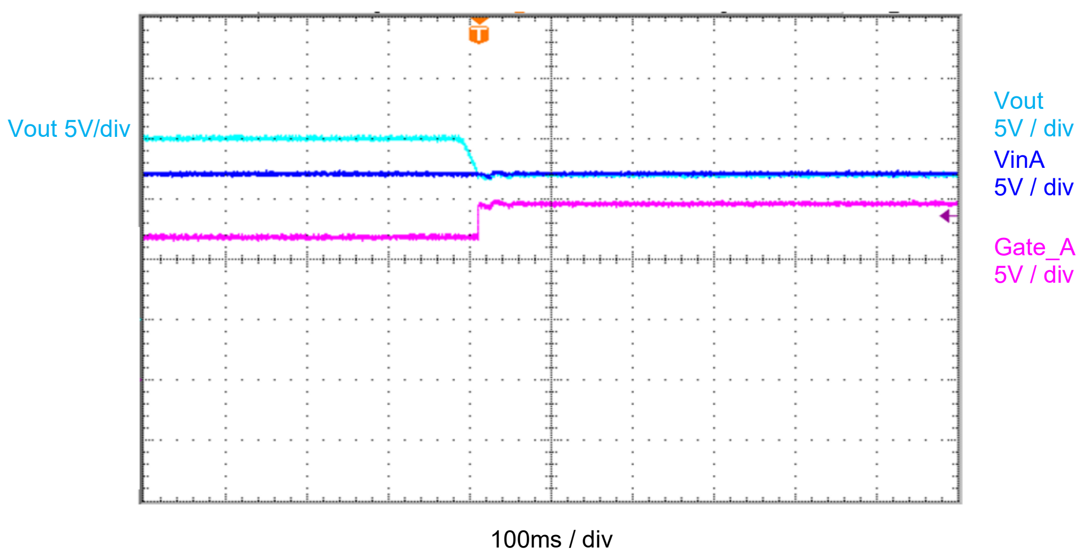


Figure 12. OR-Ing Performance VINB = 15V turns off When VINA = 12V

Load Switch Configuration

In load switch configuration, an additional MOSFET (Q2) can be used in KTS1900Q circuit to shut down the current to the load. In this case, Q1 acts as the ideal diode, while Q2 acts as a switch to control forward current flow. The circuit is shown in Figure 13. In addition, the back-to-back body diodes of two MOSFETs prohibit current flow, in both directions, when the MOSFETs are off. The turn on is inherently slow due to the low charge pump current of 15µA and the total gate capacitance.

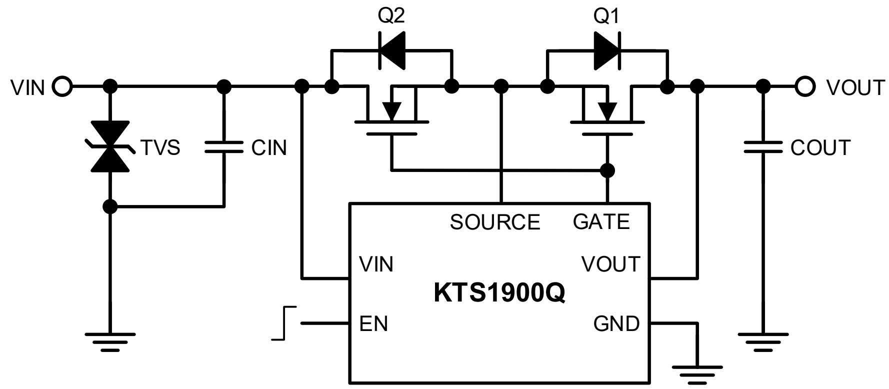


Figure 13. Load Switch Circuit Configuration with two MOSFETs

Operational Waveform

The normal turn on and off waveforms are shown in Figure 14 and Figure 15.

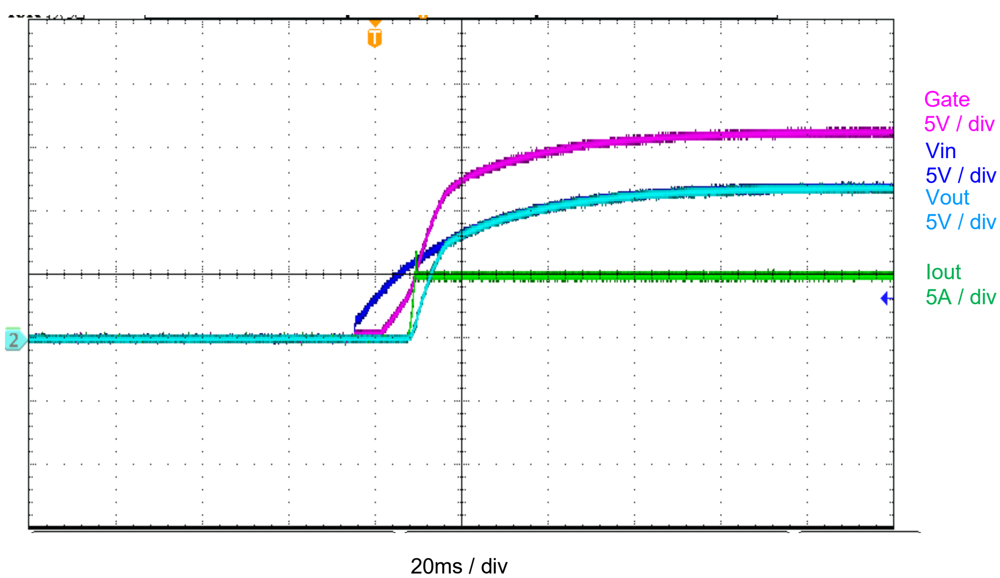


Figure 14. Start up at 12V Vin, and 5A Load

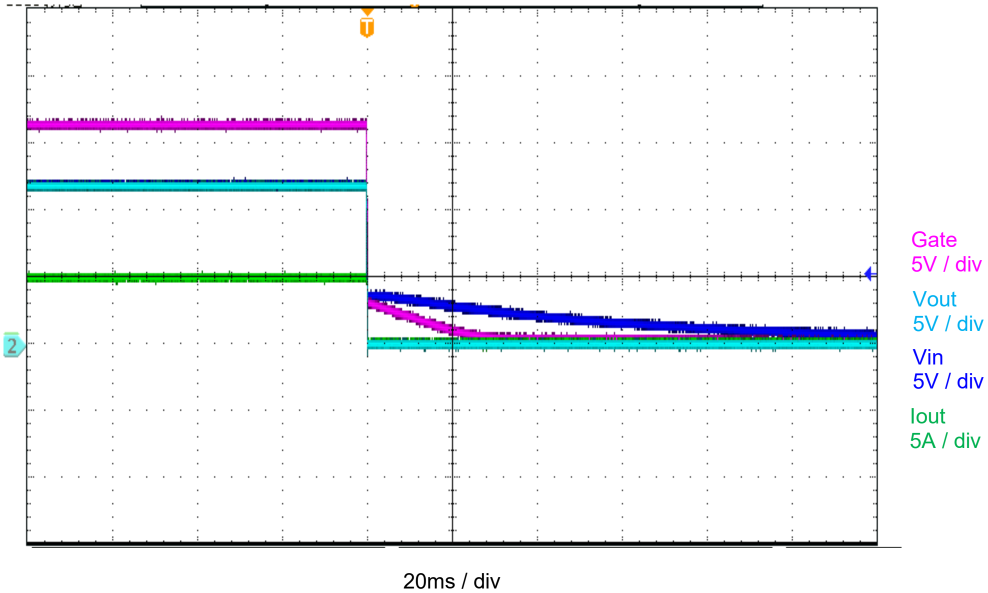


Figure 15. Turn off at 12V Vin, and 5A Load

Reverse Polarity Protection

To test the dynamic input reverse protection a –12V or -24V source is connected to the input of the KTS1900Q. Figure 16 and Figure 17 show that the VOUT remains at a constant 0V in this situation. This test shows that the KTS1900Q can protect the load from negative input voltage.

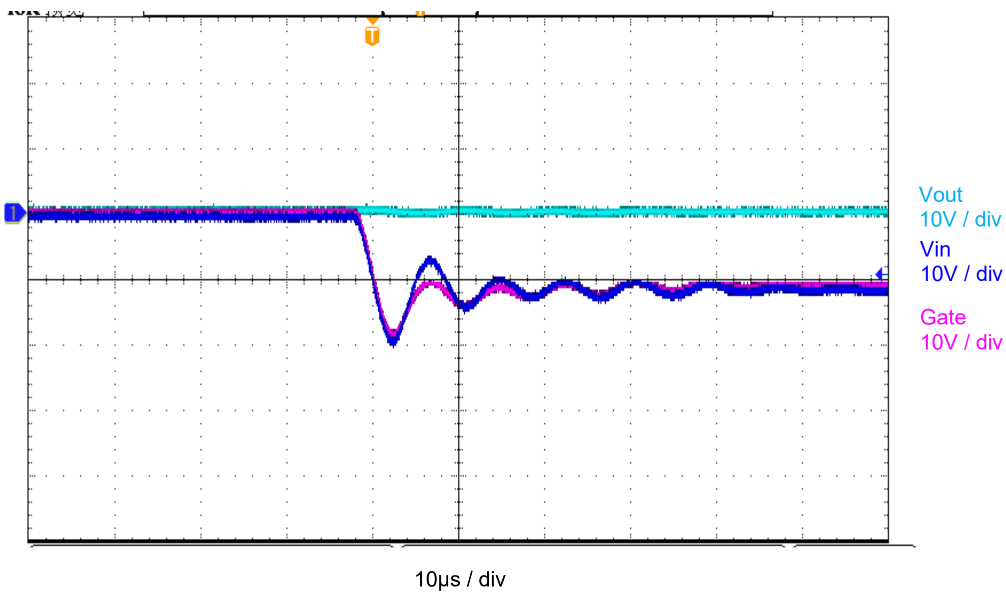


Figure 16. VIN Switch from 0V to -12V Reverse Protection

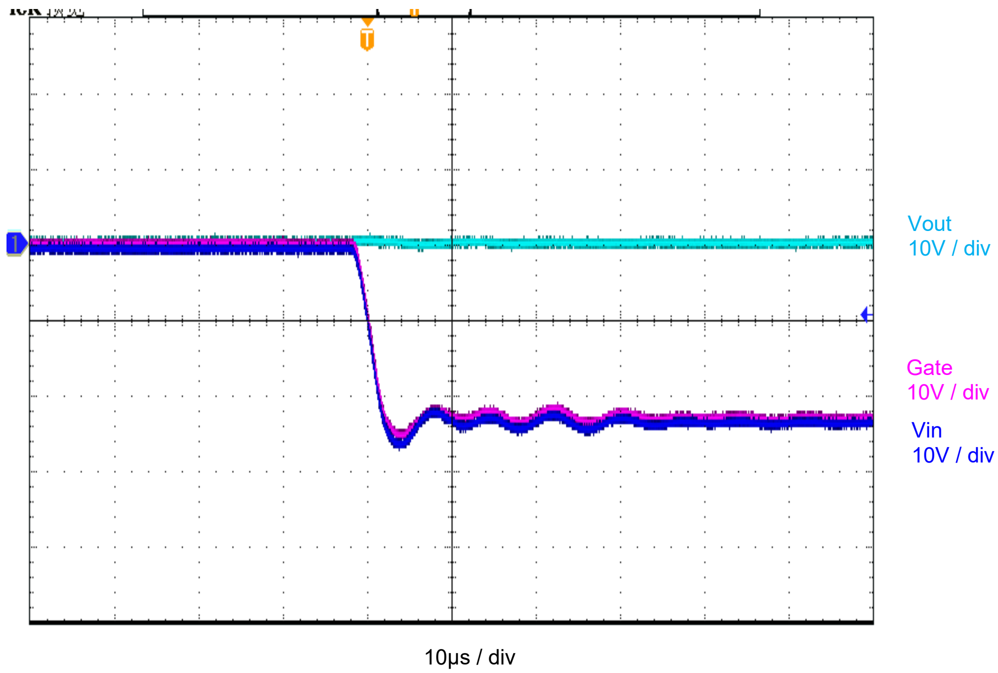


Figure 17. VIN Switch from 0V to -24V Reverse Protection

Input Voltage Short Protection

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

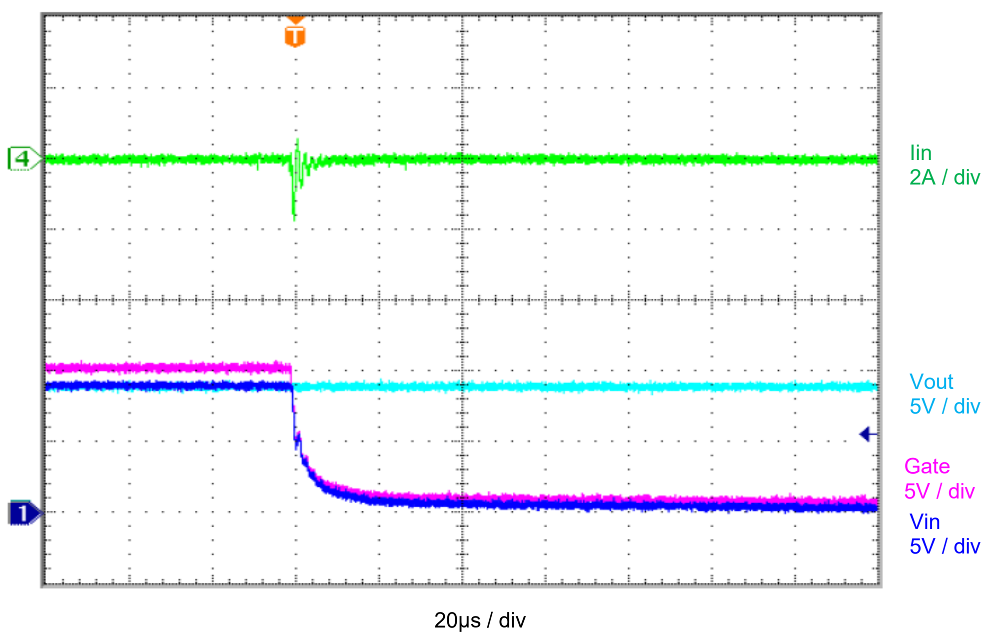


Figure 18. VIN Switch from 12V to 0V Short Protection

ISO7637-2 Pulse Test

To ensure the compatibility of KTS1900Q to conducted electrical transients for automotive applications; ISO7637-2 Pulse test is used as the reference with 12V or 24V electrical systems. This test is a simulation of transients due to supply disconnection from inductive loads. The test waveform details, and the related parameters are shown in Figure 19 and Table 2.

During dynamic reverse polarity conditions specified in ISO 7637-2 for 12 volt systems, a negative voltage transient is applied at the 12V battery supply line (VIN). A -150 volt transient is generated from a 10Ω generator impedance for 2ms. The 24 Volt system is hit with a -600V, 50Ω generator for 1ms. When the ISO 7637-2 test pulse is applied to VIN, the load current starts to reverse quickly and tries to pull the VOUT negative. KTS1900Q detects the reverse current and turns OFF the MOSFET to block reverse current and prevent the VOUT from dropping. Downstream, bulk holdup capacitors, provide energy to the rest of the module during such transients. With a bi-direction TVS, the input voltage is clamped from exceeding the absolute maximum ratings of KTS1900Q and N-MOSFET.

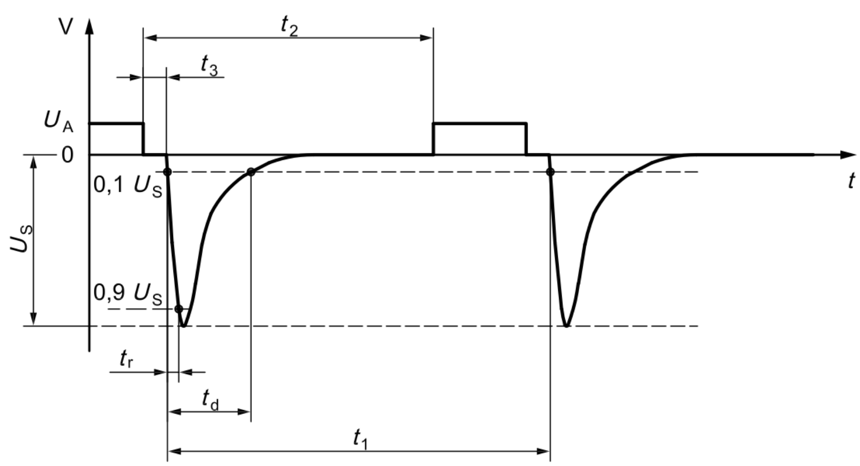


Figure 19. Test Pulse 1 Reference Waveform Details in ISO7637-2 Pulse Test Standard

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

Figure 20 shows the result of KTS1900Q for -600V transient pulse test that can be used as the reference for 24V system. The large current spike seen in the Iin trace is the conduction of the TVS diode. The Vin trace shows the input voltage is clamped to -65 Volts during the Iin current spike.

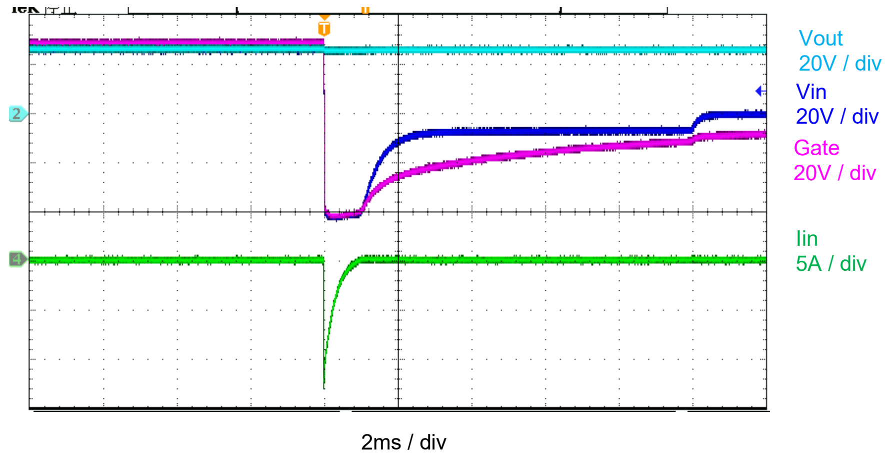
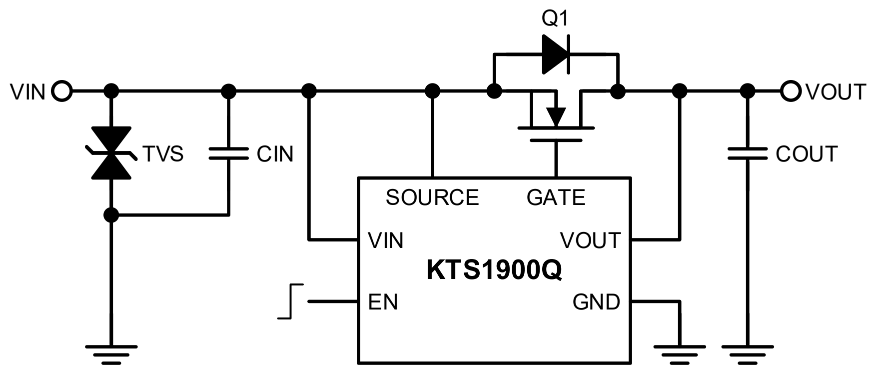
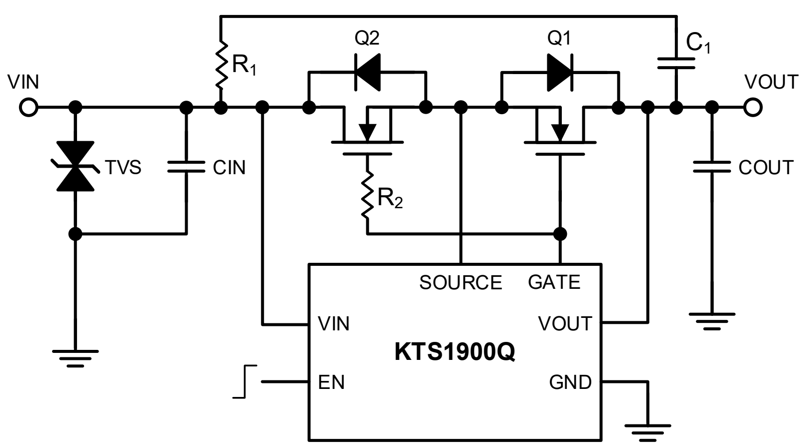


Figure 20. -600V Transient Results Based on ISO7367-2 Pulse Test

Typical Application Circuits

<table>
<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, 100V, ±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
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
R1 = 100Ω, 1/2W, 5%, 1210
R2 = 10Ω, 1/8W, 5%, 0805</td></tr>
</table>

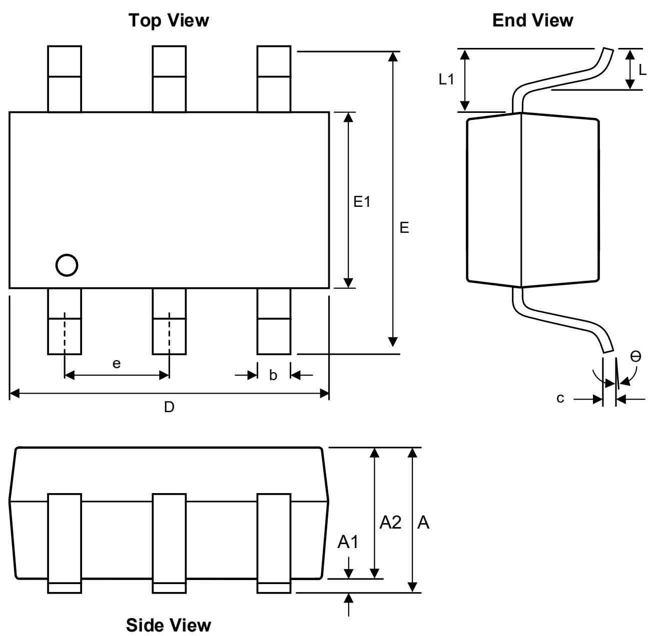
Recommended PCB Layout

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

1. Connect a 2.2µF capacitor CIN as close as possible to the VIN and GND pins using wide metal traces and ground plane.
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 KTS1900Q with short lead lengths.
4. Connect a 2.2µF capacitor, COUT, as close as possible to the GND and VOUT pins.
5. Check the creepage and clearance details and guidelines to determine spacing between high voltage (VIN) and other nearby traces.

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