Load Switch with OVP and Reverse Polarity Protection

Features

- Wide input operating range from 6V to 40V DC Input
- Low resistance MOSFET Switch typ. 41mΩ
- Reverse Polarity Protection to -28V
- Fixed over-voltage protection
  - Fixed: 27V ± 0.8V or 20.3V ± 0.8V
- Fast OVP response time typ. 360ns
- Continuous output current up to 6A
- Over-temperature Protection with Auto-Retry
- Open drain fault flag
- Shutdown pin with low shutdown current
- Voltage Input detection output
- Input ESD protection to IEC61000-4-2 (Level 4)
  - Contact: ±8kV
  - Air: ±15kV
  - Other pins HBM: ±2kV
- Pb-free TDFN44-12 package
- -40°C to +85°C operating temperature range

Applications

- Reverse Power Supply Protection
- Telecom/Server/Networking System
- Industrial and Medical Systems
- Portable Instrumentation

Brief Description

The KTS1640 and KTS1641 are low-resistance, electronically controlled load switches, with enhanced protection features, used to protect loads from abnormal power supply or load problems. Operating from a wide input supply voltage of between 6V and 40V, the KTS1640 and KTS1641 protect the system from reverse input supplies down to -28V.

Integrating two N-Channel MOSFETs, the device includes fixed over-voltage protection of 27V (KTS1640) or 20.3V (KTS1641) along with over-temperature protection with auto-retry. Following an over-voltage condition only, KTS1640 and KTS1641 will automatically resume operation, when the over-voltage condition is removed.

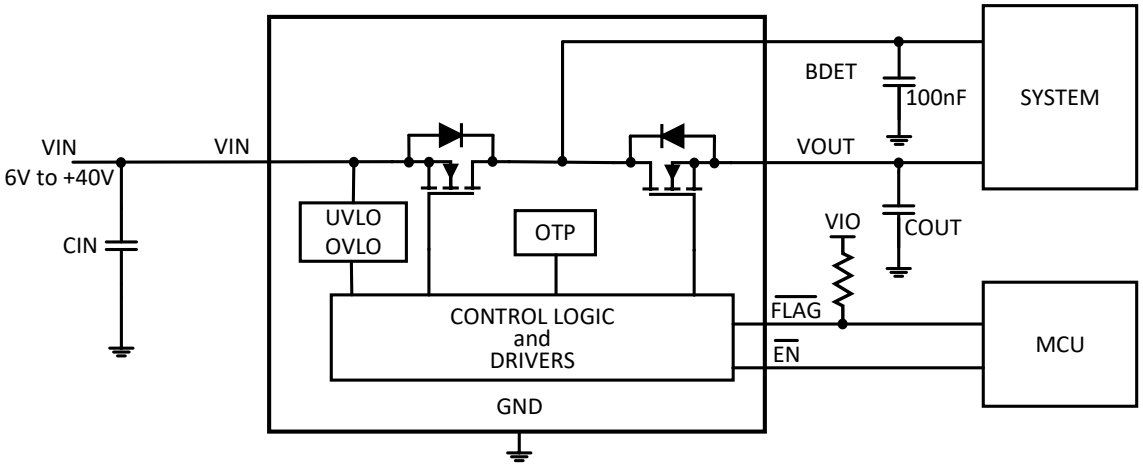
An ENABLE pin allows the MOSFET switch to be enabled or disabled, placing the device in a low current shutdown mode. System monitoring is provided by a fault $\overline{\text{FLAG}}$.

To inform the system that the battery or power supply is connected, BDET mirrors the input voltage less the drop across the reverse battery protection MOSFET and sources up to a maximum of 120mA

Further protection includes over-temperature shutdown and the input pin is fully ESD protected to comply with the IEC61000-4-2 (Level 4) specification.

The KTS1640 and KTS1641 are packaged in an advanced, fully green compliant, TDFN44-12 package.

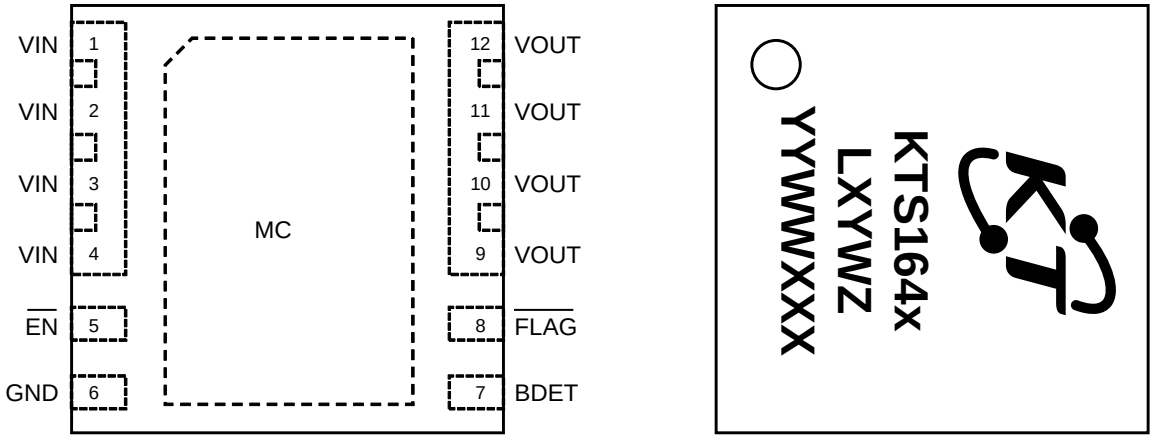
Typical Application



Pin Descriptions

Pin #	Name	Function		
1, 2, 3, 4	VIN	Input to the power switch and device supply. The VIN pins must be decoupled to GND via a minimum 1µF ceramic capacitor.		
5	$\overline{EN}$	Active LOW enable pin. Connect to GND to turn the power switch ON.		
6	GND	Ground		
7	BDET	Battery Detection, and supply. Should be decoupled by a 100nF capacitor to GND	$\overline{EN}$ = HIGH	BDET = VIN - 0.7V
			$\overline{EN}$ = LOW	BDET = VIN – (r_{DS} x I_D)
8	$\overline{FLAG}$	Active LOW, open drain fault pin. Connect an external pull-up resistor to the system logic supply. $\overline{FLAG}$ is asserted during any fault condition.		
9, 10, 11, 12	VOUT	Power switch output to the load. The VOUT pins must be decoupled to GND via a minimum 1µF ceramic capacitor.		
MC	MC	Metal chassis. Connect to ground for electrical and thermal usage. MC is internally connected to GND.		

TDFN44-12
Top View



12-Lead 4.00mm x 4.00mm x 0.75mm
TDFN Package

Top Mark
KT Logo

KTS164x = Part Number
XX = Device ID Code, YWZ = Assembly Code

YYWWXXX = Serial Number

Absolute Maximum Ratings[1]

(T_A = 25°C unless otherwise noted)

Symbol	Description	Value	Units
VIN	Input Voltage to GND	-30 to 42	V
VIN to VOUT	Input voltage to VOUT	-30 to +42	V
VOUT,	Output Voltage to GND	-0.3 to +30	V
BDET	BDET output voltage to GND	-0.3 to +42	V
$\overline{FLAG}$, $\overline{EN}$,	$\overline{FLAG}$, $\overline{EN}$, pins to GND	-0.3 to 7	V
IBDET[2]	Battery Detect Continuous Current	120	mA
IOUT	VIN to VOUT Continuous Current	6	A
T_{STG}	Storage Temperature Range	-55 to 150	°C
T_J	Junction Operating Temperature	-40 to 150	°C
T_{LEAD}	Maximum Soldering Temperature (at leads, 10sec)	260	°C

Thermal Capabilities[3]

Symbol	Description	Value	Units
θ_{JA}	Thermal Resistance, Junction−to−Air	38	°C/W
P_D	Maximum Power Dissipation at 25℃	3.29	W
$\Delta P_D/\Delta_T$	Derating Factor Above T_A = 25℃	-26.3	mW/°C

ESD Ratings

Symbol	Description	Conditions	Value	Units
V_{ESD}	IEC61000-4-2 Air Discharge	VIN Only	±15	kV
	IEC61000-4-2 Contact Discharge		±8	kV
	Human-body Model (HBM)	All Pins	±2	kV
	Charged-device Model (CDM)		±1	kV

1. 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.
2. Maximum output current pin limited. Output not short-circuit protected
3. 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.

Ordering Information

Part Number	Marking[4]	OVP	Fault Response	Ambient Operating Temperature	Package
KTS1640EDV-TR	LXYWZ	27V	Auto Retry	-40°C to +85°C	TDFN44-12
KTS1641EDV-TR	NAYWZ	20.3V	Auto Retry	-40°C to +85°C	TDFN44-12

Recommended Operating Range

Description	System Condition	Value
Input Voltage	NORMAL	6V to OVP
	PROTECTED	-28V to +40V
Continuous Output Current	NORMAL	Up to 6A
BDET Output Current[5]	NORMAL	100mA max
Operating Temperature	ALL	-40°C to +85°C

4. “XXYWZ” is the device code, date code and assembly code.

5. Output not short circuit protected

Electrical Characteristics[6]

Unless otherwise noted, the *Min* and *Max* specs are applied over the full operation temperature range of -40°C to +85°C. Typical values are specified at room temperature (25°C) with VIN = 14V, IOUT ≤ 5A, $\overline{EN}$ = LOW, $\overline{FLAG}$ = OPEN, CIN = 1.0µF, COUT = 1.0µF, CBDET = 100nF and T_A = 25°C.

Symbol	Description	Conditions		Min	Typ	Max	Units
INPUT							
I_Q	Input Quiescent Current				145	200	µA
I_{LK}	Input Leakage Current	$\overline{EN}$ = HIGH, No load			5	8	µA
I_{LK_RB}	Input Leakage Current in Reverse Battery	V_{IN} = -28V, $\overline{EN}$ = HIGH, No load			52	70	µA
I_{OVLO_Q}	Input Supply Current in Over-voltage mode	KTS1641	V_{IN} = 20.3V		150	180	µA
		KTS1640	V_{IN} = 27V		150	180	µA
V_{IN_UVLO}	Under Voltage Lockout	V_{IN} Rising		5.5	5.7	5.9	V
		V_{IN} Falling		5.3	5.5	5.7	V
OUTPUT							
R_{ON_OUT}	On-resistance VIN to VOUT	I_{OUT} = 1A	T_A = 25°C		41	50	mΩ
		I_{OUT} = 5A			44.5		mΩ
V_{OUT_OVLO}	Over-Voltage Trip Level	V_{IN} Rising	KTS1640	26.2	27	27.8	V
		V_{IN} Falling		25.6			V
		V_{IN} Rising	KTS1641	19.5	20.3	21.1	V
		V_{IN} Falling		17.9			V
I_{OUT_RC}	OUT Reverse Current	V_{IN} = 0V, V_{OUT} = 28V, T_A = 25°C			38		µA
DIGITAL SIGNALS ($\overline{FLAG}$, $\overline{EN}$)							
V_{FLAG_OL}	$\overline{FLAG}$ Output Low Voltage	V_{IO} = 5V, sinking 1.0mA				0.5	V
I_{FLAG}	$\overline{FLAG}$ Leakage Current	V_{IO} = 5V				1	µA
V_{EN_IH}	$\overline{EN}$ High Voltage	V_{IO} = 5V		1.2			V
V_{EN_IL}	$\overline{EN}$ Low Voltage	V_{IO} = 5V				0.35	V
I_{EN}	$\overline{EN}$ Leakage Current	V_{IO} = 5V				4	µA
TIMING CHARACTERISTICS (Figures 1 – 3)							
t_{OUT_DB}	VOUT Debounce Time	Time from V_{IN} = V_{IN_UVLO} to 10% of V_{OUT},			2		ms
t_{ON_OUT}	OUT Switch Turn-on Time	V_{OUT} from 10% of V_{IN} to 90% of V_{IN}, R_L = 100Ω, C_L = 22µF			10		ms
$t_{OFF_OUT_F}$	OUT Switch Turn-Off Time Under Fault Conditions or by $\overline{EN}$ [7]	V_{IN} > V_{OUT_OVLO} to V_{OUT} Stop rising, R_L = 100Ω, No C_L, $\overline{EN}$ = Low			360		ns

6. KTS1640 and KTS1641 are guaranteed to meet performance specifications over the –40°C to +85°C ambient operating temperature range by design, characterization and correlation with statistical process controls.

7. Guaranteed by characterization and design

Electrical Characteristics[6]

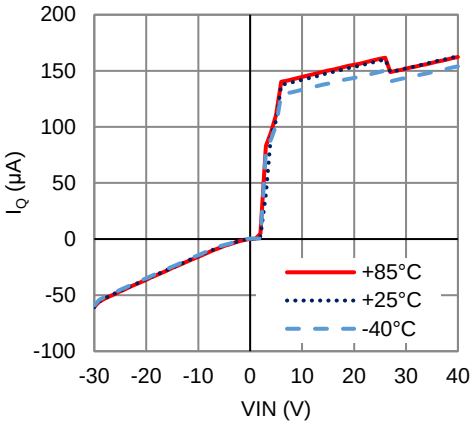
Unless otherwise noted, the *Min* and *Max* specs are applied over the full operation temperature range of -40°C to +85°C. Typical values are specified at room temperature (25°C) with VIN = 14V, IOUT ≤ 5A, $\overline{EN}$ = LOW, $\overline{FLAG}$ = OPEN, CIN = 1.0µF, COUT = 1.0µF, CBDET = 100nF and T_A = 25°C.

Symbol	Description	Conditions	Min	Typ	Max	Units
TIMING CHARACTERISTICS Cont. (Figures 1 – 3)						
$t_{EN(ON)}$	Switch Turn-ON	$\overline{EN}$ High to Low, VOUT		14		ms
$t_{EN(OFF)}$	Switch Turn-OFF	$\overline{EN}$ Low to High, V_{OUT} falls to 90% V_{OUT}, R_L = 100Ω, No C_L		350		ns
THERMAL SHUTDOWN						
T_{SHDN}	Shutdown Temperature			150		°C
	Shutdown Temperature Hysteresis			20		°C

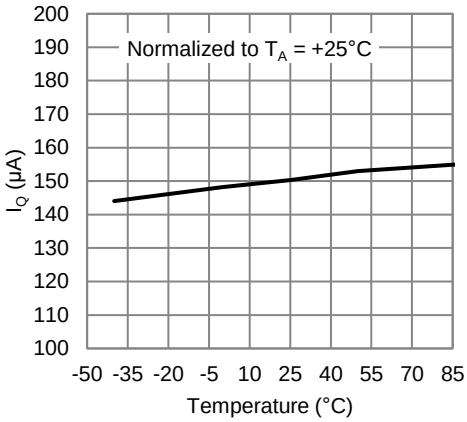
Typical Characteristics

VIN = 14V, $\overline{EN}$ = GND, CIN = 1µF, COUT = 1µF, CBDET = 100nF, T_A = 25°C unless otherwise specified.

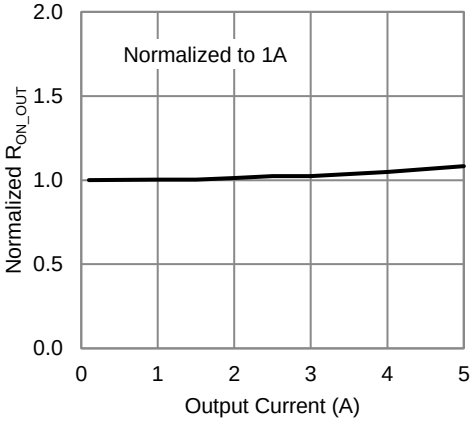
Input Supply Current vs. VIN (no load)[8]



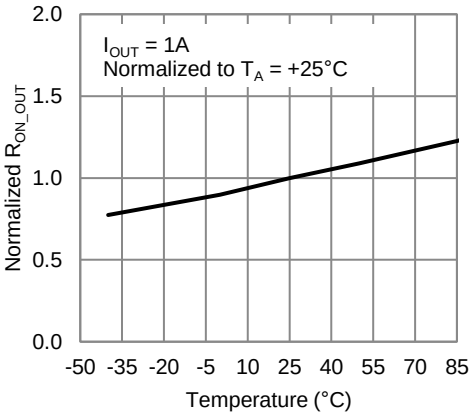
Input Supply Current vs. Temperature



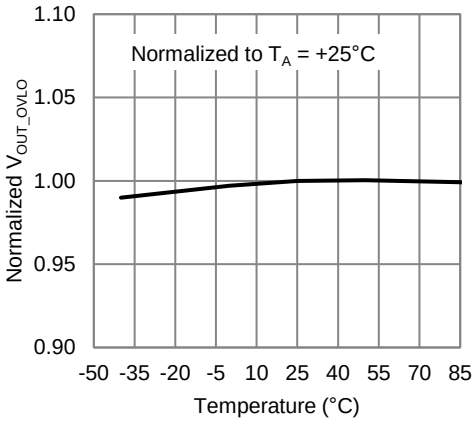
Normalized R_{ON_OUT} vs. Output Current



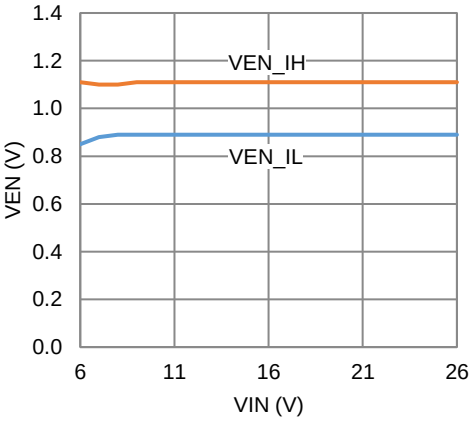
Normalized R_{ON_OUT} vs. Temperature



Normalized OVLO Threshold vs. Temperature



Enable Logic Threshold vs. VIN

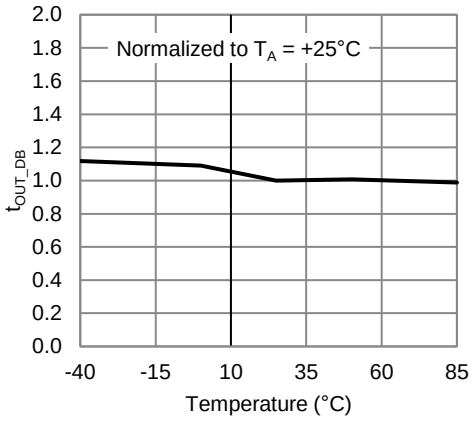


8. Shown for KTS1640

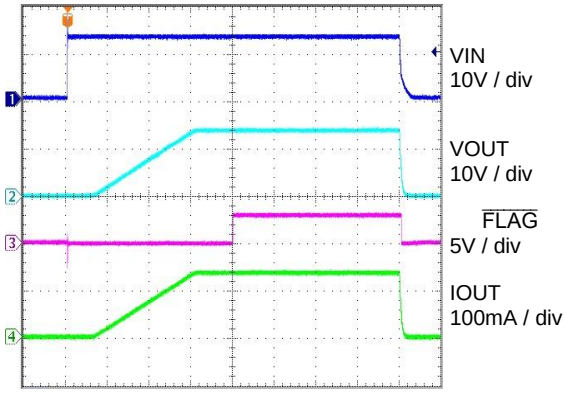
Typical Characteristics

VIN = 14V, $\overline{EN}$ = LOW, CIN = 1µF, COUT = 1µF, CBDET = 100nF, T_A = 25°C unless otherwise specified.

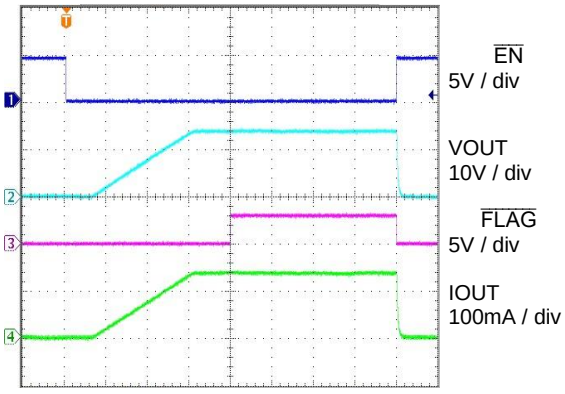
Normalized Debounce Time vs. Temperature



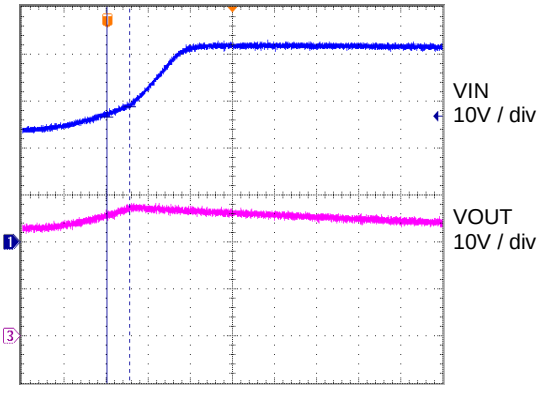
Power Up and Down (100Ω load)



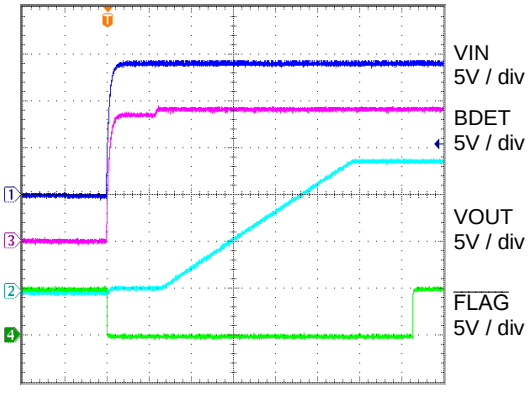
Turn On and Off by Enable



OVP Transient[8]



Power-up with BDET



Timing Diagrams[9]

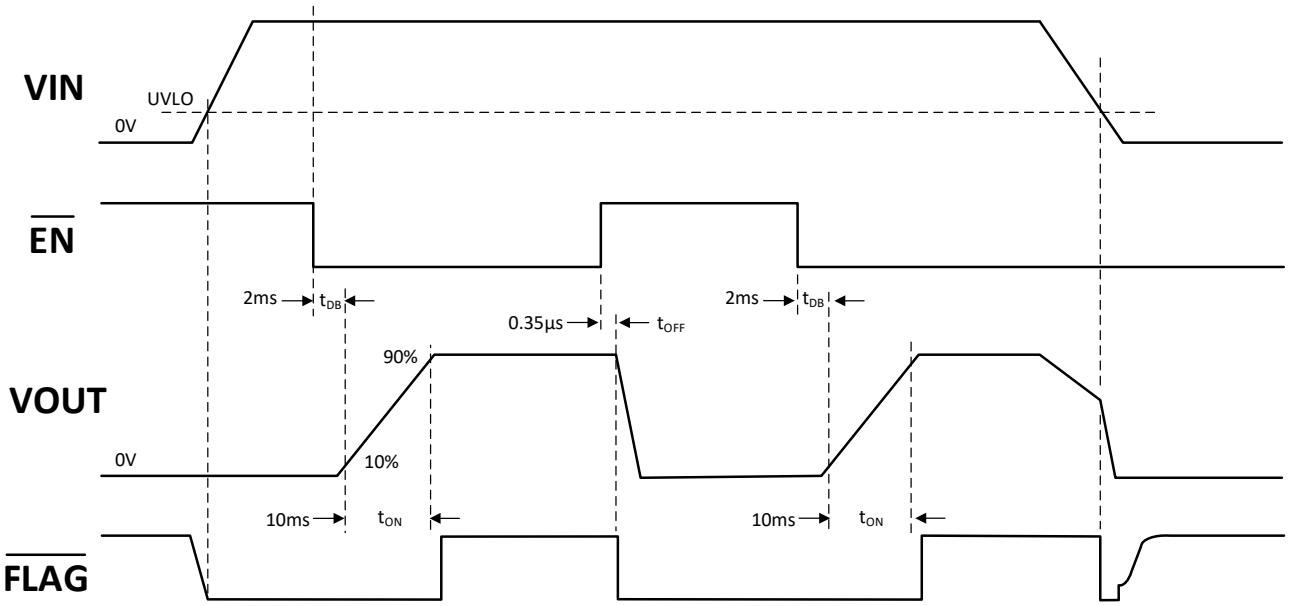


Figure 1. TURN-ON/TURN-OFF, When initially VIN = 0V, $\overline{EN}$ = H

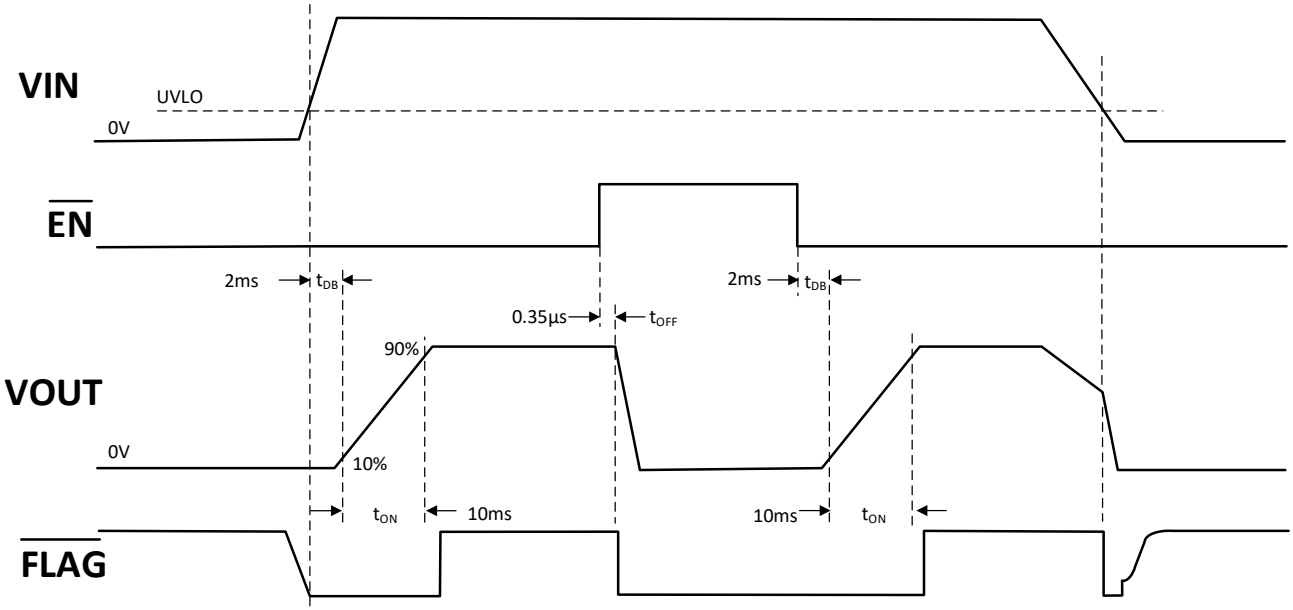


Figure 2. TURN-ON/TURN-OFF, When initially VIN = 0V, $\overline{EN}$ = L

9. All timing diagrams are for illustration purposes only and not to scale.

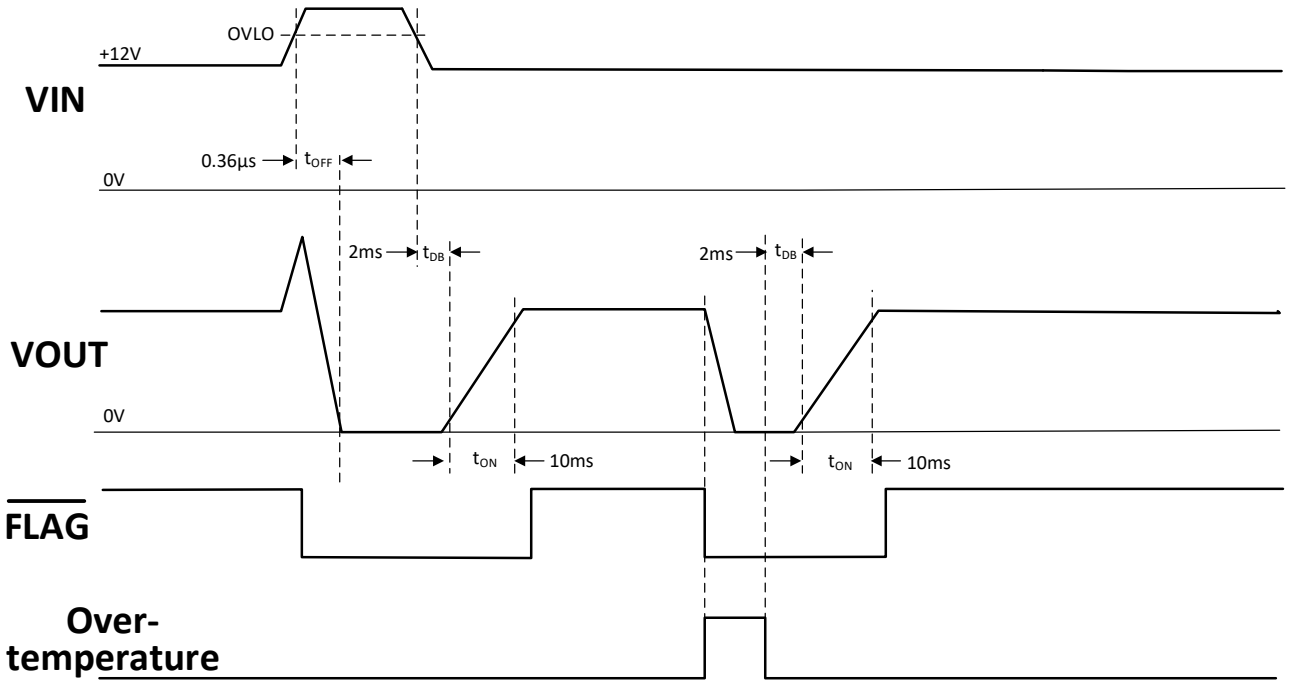
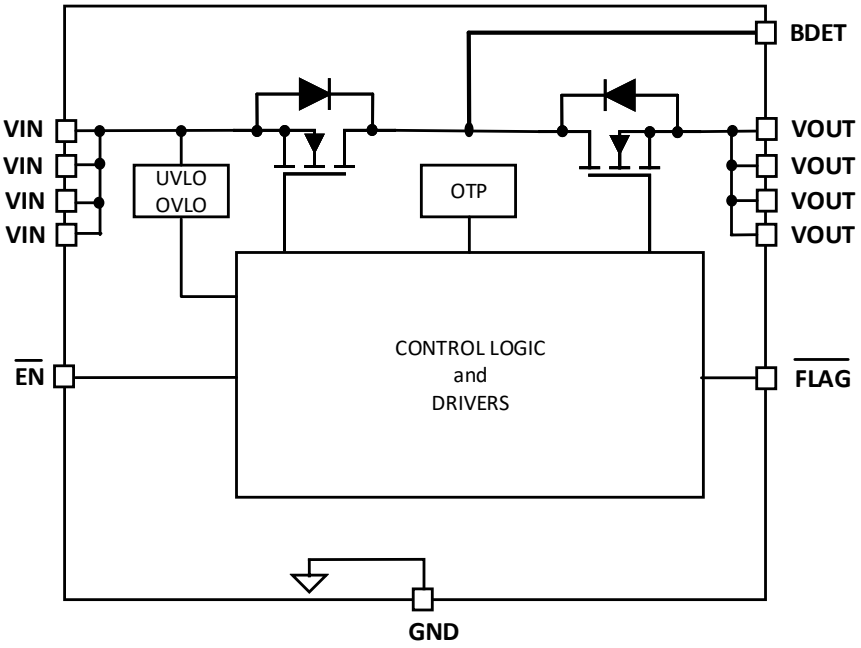


Figure 3. Over-voltage and Over-temperature, $\overline{EN}$ = L

Functional Block Diagram



Functional Description

The KTS1640 and KTS1641 are low-resistance, electronically controlled load switches, with enhanced protection features, used to protect loads from abnormal power supply or load problems. Operating from a wide input supply voltage of between 6V and 40V, the KTS1640 and KTS1641 protects the system from reverse input supplies down to -28V, over-voltage conditions, and over-temperature.

The KTS1640 and KTS1641 integrates two low-resistance, active LOW enabled, N-Channel MOSFETs, in common drain configuration. The first MOSFET will provide protection to the system if the input supply is accidentally reversed. The second MOSFET provides the controlled turn-on and protection of the input voltage to the system load. The KTS1640 includes fixed over-voltage protection of 27V±0.8V, while the KTS1641 includes fixed over-voltage protection of typical 20.3V. Both devices also include over-temperature protection with auto-retry[10].

An ENABLE $\overline{EN}$ pin allows the MOSFET switch to be enabled or disabled, placing the device in a low current shutdown mode. System monitoring is provided by a digital output fault $\overline{FLAG}$. When a fault condition occurs, the fault $\overline{FLAG}$ is pulled down to GND. An external pull-up resistor connected to the system power supply is required.

Further protection includes ESD protection and the input pin is fully protected to comply with the IEC61000-4-2 (Level 4) specification.

Internal MOSFET Switch

In normal operating mode (main power switches turned on), the $\overline{EN}$ input must be set to the logic low state ($\overline{EN}$ = GND). The KTS1640 and KTS1641 integrate two N-Channel power MOSFETs in a back-to-back configuration with ultra-low 41mΩ (typical) on-resistance between VIN and VOUT. The MOSFETs are internally driven by a charge pump supply that generates a gate voltage (VGS) greater than VIN.

To prevent downstream systems from being damaged by a reverse voltage condition, the KTS1640 and KTS1641 include an integrated synchronous MOSFET diode to protect against voltages down to -28V.

10. For an alternative response to fault conditions, please contact marketing

Under-voltage Lockout

When the input voltage VIN is below the normal operating range, either during operation or start-up, the internal switch will turn-off and the fault flag asserted low. The UVLO is internally set to 5.7V typical with 200mV hysteresis.

Over-voltage Lockout Protection

The KTS1640 and KTS1641 features a fixed over-voltage threshold of 27V typical (KTS1640) or 20.3V typical (KTS1641). If VIN is above this threshold, the internal MOSFET switches are turned OFF and VOUT is disconnected from VIN, protecting the load. $\overline{\text{FLAG}}$ is asserted low during the over-voltage period. Once the over-voltage condition is removed the switch will automatically restart.

Battery Present Output

BDET provides an unregulated output, whenever VIN is present. When the switch is enabled, BDET is equal to VIN less the voltage dropped across the input MOSFET ($V = r_{DS} \times I_{SW}$). When the switch is disabled, BDET is equal to VIN less one diode drop, due to the reverse battery protection MOSFET ($BDET = V_{IN} – V_F$ (~0.7V)). This output is capable of supplying up to a maximum of 120mA output current. However, care should be taken not to exceed this value as this pin is not short-circuit protected.

Over-temperature Protection

During an over-temperature event, KTS1640 and KTS1641 will immediately turn OFF both switches and $\overline{\text{FLAG}}$ will be asserted low. The over-temperature threshold is 150°C typical.

Once T_J falls by 20°C the device automatically retries and will continually retry indefinitely.

The $\overline{\text{FLAG}}$ signal remains asserted low until the fault condition is removed and the device resumes normal operation.

Application Information

Input Capacitor

A 1µF or larger capacitor is typically recommended for C_{IN}. C_{IN} should be located as close to the device VIN pin as practically possible. 50V rated capacitors are recommended to support input voltage up to 40V.

Output Capacitor

The soft-start function provides a slow turn-on that allows the device to charge large output capacitors with minimum in-rush current. It is recommended to bypass VOUT pin with a 1µF minimum ceramic capacitor with 35V rating.

Recommended PCB Layout

For high output current, the power dissipation may be large. The TDFN package allows to dissipate well the heat to the PCB when using proper PCB layout technic. To improve the board thermal conductivity, large copper area around GND, VIN and VOUT pins are recommended. Thermal vias under the package exposed center pad help to spread the heat throughout the board ground plane.

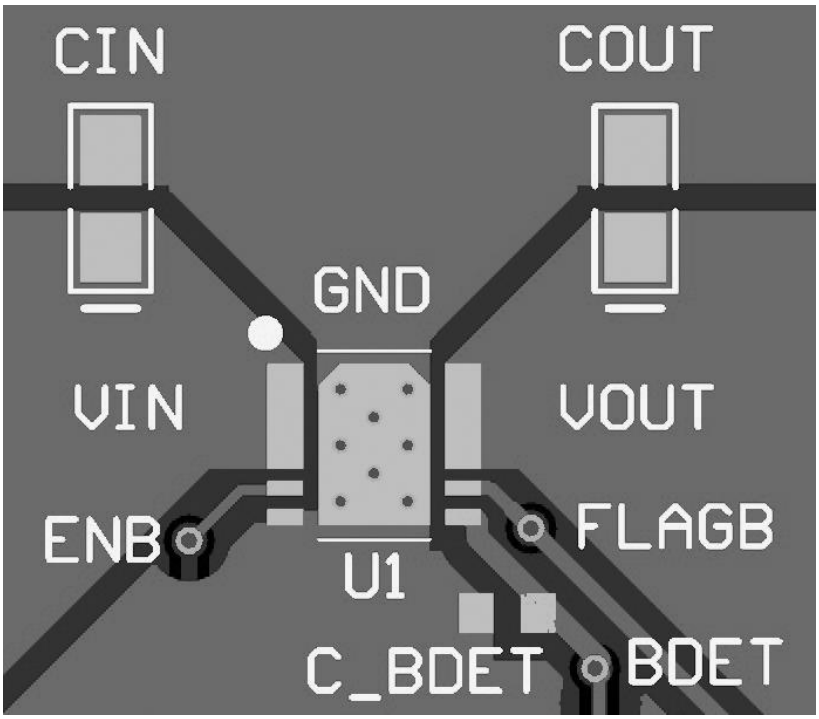
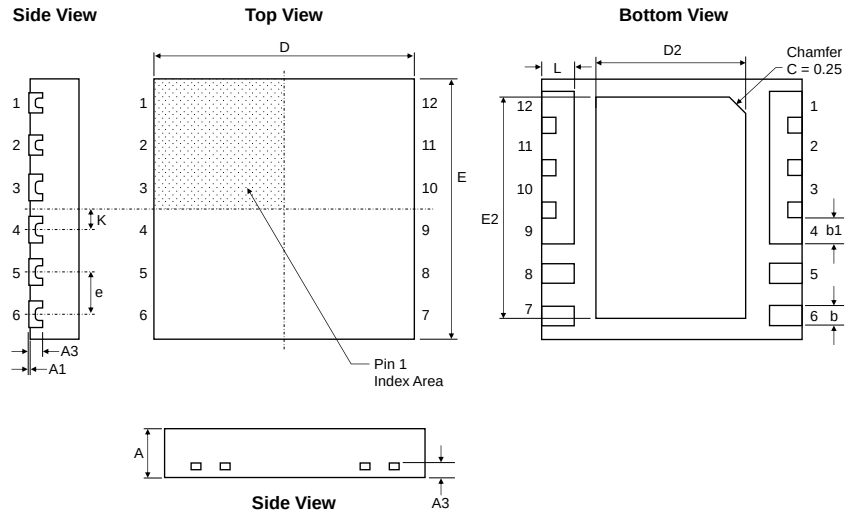


Figure 4. Recommended PCB Layout

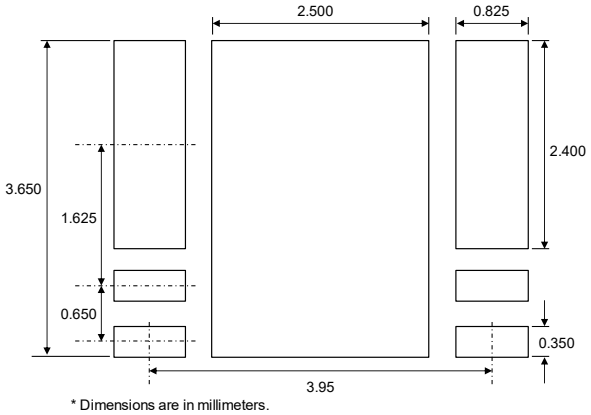
Package Information

TDFN44-12 (4.00mm x 4.00mm x 0.75mm)



Dimension	mm		
	Min.	Typ.	Max.
A	0.70	0.75	0.80
A1	0.00	0.02	0.05
A3		0.203 REF	
b	0.25	0.30	0.35
b1	0.35	0.40	0.45
D	3.90	4.00	4.10
D2	2.25	2.30	2.35
E	3.90	4.00	4.10
E2	3.35	3.40	3.45
e		0.650 BSC.	
L	0.45	0.50	0.55
K		0.035 REF	

Recommended Footprint



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