Data Sheet

ACPL-K30T

Automotive Photovoltaic MOSFET Driver with R^2Coupler™ Isolation

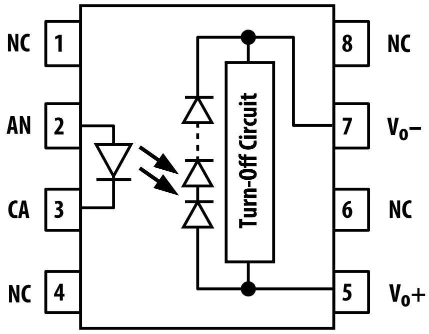
Description

The Broadcom® ACPL-K30T is specially designed to drive high-voltage MOSFETs. It consists of an AlGaAs infrared light-emitting diode (LED) input stage that is optically coupled to an output detector circuit. The detector consists of a high-speed photovoltaic diode array and a turn-off circuit. The photovoltaic driver is turned on (contact closes) with a minimum input current of 5 mA through the input LED. The relay driver is turned off (contact opens) with an input voltage of 0.8V or less.

The ACPL-K30T is available in a stretched SO-8 package outline, which is designed to be compatible with standard surface-mount processes.

Broadcom R^2Coupler™ isolation products provide reinforced insulation and reliability that delivers safe signal isolation critical in automotive and high-temperature industrial applications.

Figure 1: ACPL-K30T Functional Diagram



Features

- Qualified to AEC-Q100 grade 1 test guidelines
- Automotive temperature range: –40°C to +125°C
- Photovoltaic driver for high-voltage MOSFETs for automotive applications
- Open-circuit voltage: 7V typical at I_F = 10 mA
- Short-circuit current: 5 µA typical at I_F = 10 mA
- Logic circuit compatibility
- Switching speed: 0.8 ms (T_{ON}), 0.04 ms (T_{OFF}) typical at I_F = 10 mA, C_L = 1 nF
- Configurable to a wide portfolio of high-voltage MOSFETs
- Galvanic isolation
- High input-to-output insulation voltage
- Safety and regulatory approvals:
  - IEC/EN/DIN EN 60747-5-5
    Maximum working insulation voltage: 1140 V_{PEAK}
  - 5000 V_{RMS} for 1 minute per UL1577
  - CSA component acceptance

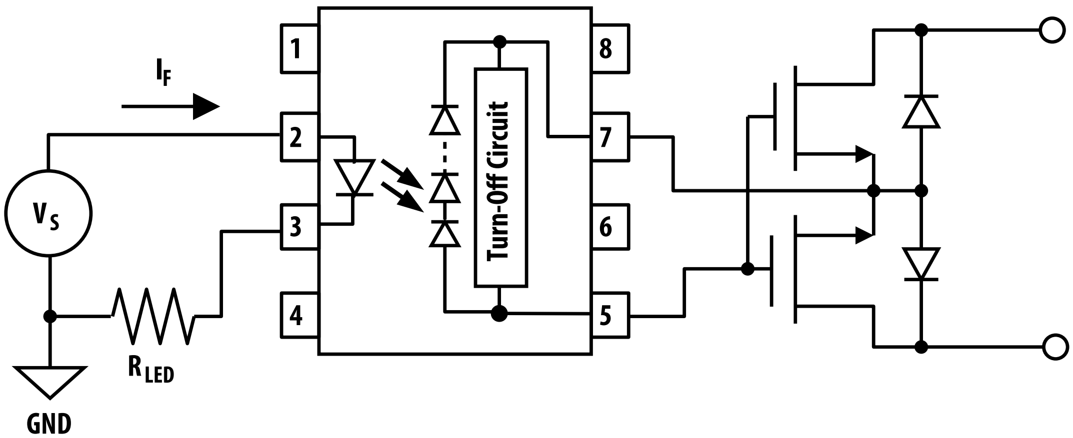
Applications

- Battery insulation resistance measurement/leakage detection
- BMS flying capacitor topology for sensing batteries
- Solid-state relay module

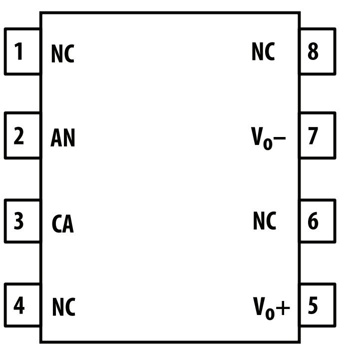
CAUTION! Take normal static precautions in handling and assembling this component to prevent damage and/or degradation that might be induced by electrostatic discharge (ESD). The components featured in this data sheet are not to be used in military or aerospace applications or environments.

Typical Application Circuit

Figure 2: Application Circuit



Package Pinout



Pin Description

Pin No.	Pin Name	Description
2	AN	Anode
3	CA	Cathode
5	V_O+	Positive Output
7	V_O-	Negative Output
1, 4, 6, 8	NC	Not Connected

Ordering Information

Part Number	Option (RoHS Compliant)	Package	Surface Mount	Tape & Reel	UL 5000 V_{RMS}/ 1-Minute Rating	IEC/EN/DIN EN 60747-5-5	Quantity
ACPL-K30T	-000E	Stretched SO-8	X		X		80 per tube
	-060E		X		X	X	80 per tube
	-500E		X	X	X		1000 per reel
	-560E		X	X	X	X	1000 per reel

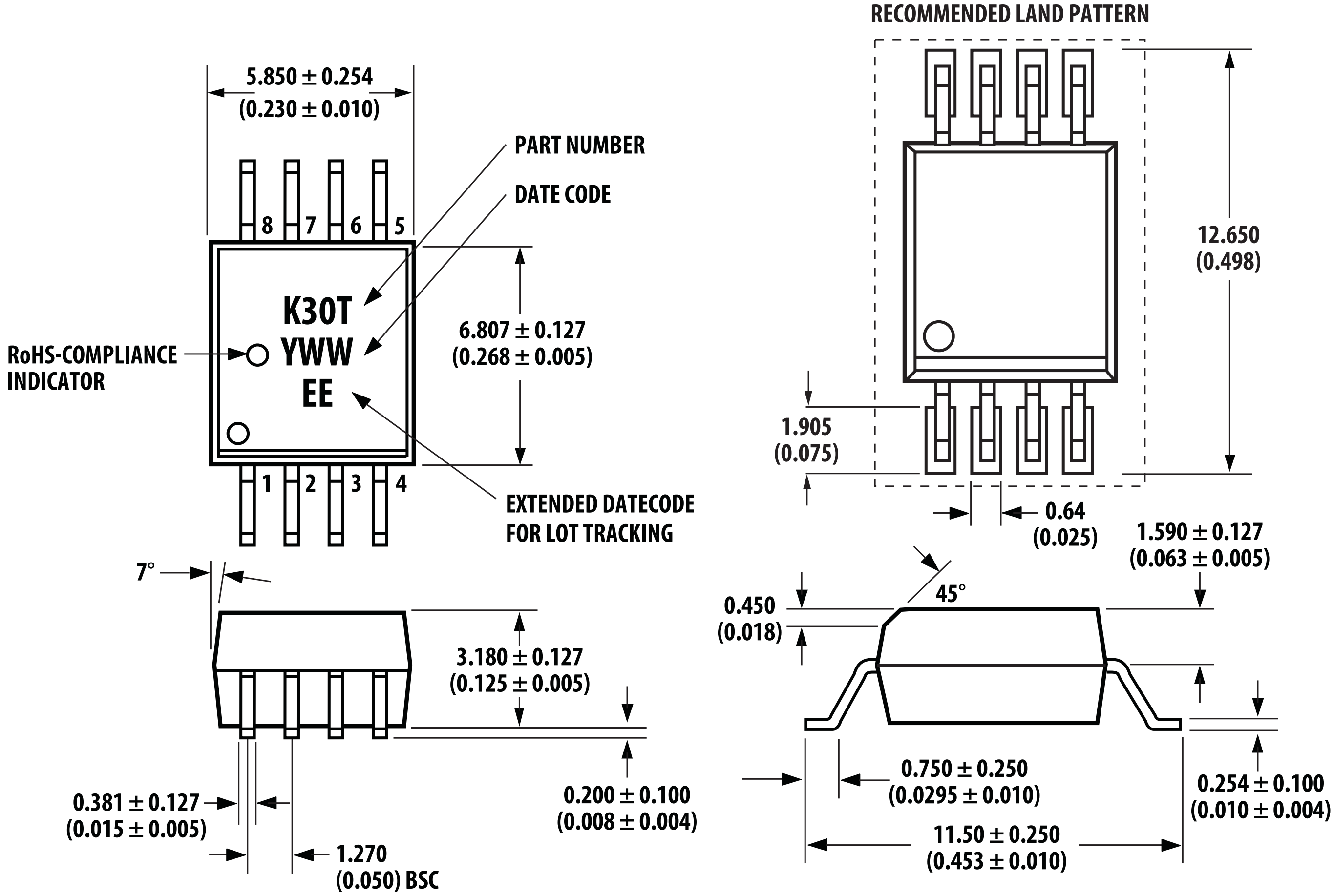
To form an order entry, choose a part number from the Part Number column and combine it with the desired option from the Option column.

Example 1:

ACPL-K30T-560E: to order the product with an SSO-8 surface mount package in tape and reel packaging with IEC/EN/DIN EN 60747-5-5 safety approval and RoHS compliant.

Option data sheets are available. Contact your Broadcom sales representative or authorized distributor for information.

Package Outline Drawings (Stretched SO-8)



Dimensions in millimeters and (inches).

Notes:
Lead coplanarity = 0.1 mm (0.004 inches).
Floating lead protrusion = 0.25 mm (10 mils) max.

Recommended Pb-Free IR Profile

The recommended reflow condition is as per JEDEC Standard J-STD-020 (latest revision).

NOTE: Non-halide flux should be used.

Regulatory Information

The ACPL-K30T is approved by the following organizations:

UL	CSA	IEC/EN/DIN EN 60747-5-5
UL 1577, component recognition program up to V_{ISO} = 5 kV_{RMS}	Approved under CSA Component Acceptance Notice #5	IEC 60747-5-5 EN 60747-5-5 DIN EN 60747-5-5

Insulation and Safety Related Specifications

Parameter	Symbol	ACPL-K30T	Units	Conditions
Minimum External Air Gap (Clearance)	L(101)	8	mm	Measured from input terminals to output terminals, shortest distance through air.
Minimum External Tracking (Creepage)	L(102)	8	mm	Measured from input terminals to output terminals, shortest distance path along the body.
Minimum Internal Plastic Gap (Internal Clearance)	—	0.08	mm	Through insulation distance conductor to conductor, usually the straight line distance thickness between the emitter and the detector.
Tracking Resistance (Comparative Tracking Index)	CTI	175	V	DIN IEC 112/VDE 0303 Part 1
Isolation Group (DIN VDE0109)	—	IIIa	—	Material Group (DIN VDE 0109)

IEC/EN/DIN EN 60747-5-5 Insulation Related Characteristic (Option 060 and 560 Only)

Description	Symbol	Option 060 and 560	Units
Installation classification per DIN VDE 0110/1.89, Table 1 For rated mains voltage < 600 V_{RMS} For rated mains voltage < 1000 V_{RMS}	—	 I - IV I - III	—
Climatic Classification	—	40/125/21	—
Pollution Degree (DIN VDE 0110/1.89)	—	2	—
Maximum Working Insulation Voltage	V_{IORM}	1140	V_{PEAK}
Input to Output Test Voltage, Method b $V_{IORM} \times 1.875 = V_{PR}$, 100% Production Test with $t_m = 1$ second Partial Discharge < 5 pC	V_{PR}	2137	V_{PEAK}
Input to Output Test Voltage, Method a $V_{IORM} \times 1.6 = V_{PR}$, Type and Sample Test, $t_m = 10$ seconds Partial Discharge < 5 pC	V_{PR}	1824	V_{PEAK}
Highest Allowable Overvoltage (Transient Overvoltage, $t_{ini} = 60$ seconds)	V_{IOTM}	8000	V_{PEAK}
Safety Limiting Values (Maximum Values Allowed in the Event of a Failure) Case Temperature Input Current Output Power	 Ts $I_{S,INPUT}$ $P_{S,OUTPUT}$	 175 230 600	 °C mA mW
Insulation Resistance at T_S, $V_{IO} = 500V$	R_S	$>10^9$	Ω

Absolute Maximum Ratings

Parameter		Symbol	Min.	Max.	Units	Notes
Storage Temperature		T_S	–55	150	°C	
Operating Ambient Temperature		T_A	–40	125	°C	
Input Current	Average	$I_{F(avg)}$	—	30	mA	
	Surge (50% duty cycle)	$I_{F(surge)}$	—	60	mA	
	Transient (≤1 µs pulse width, 300 pps)	$I_{F(trans)}$	—	1	A	
Reversed Input Voltage		V_R	—	6	V	
Input Power Dissipation		P_{IN}	—	60	mW	
Lead Soldering Cycle	Temperature	—	—	260	°C	
	Time	—	—	10	s	
Solder Reflow Temperature Profile		Recommended reflow condition as per JEDEC Standard J-STD-020 (Latest Revision)				

Recommended Operating Conditions

Parameter	Symbol	Min.	Max.	Units	Note
Input Current (ON)	$I_{F(ON)}$	10	20	mA	
		—	30		Pulse width < 1 second, duty cycle < 50%
Input Voltage (OFF)	$V_{F(OFF)}$	0	0.8	V	
Operating Temperature	T_A	–40	125	°C	

Electrical Specifications (DC)

Unless otherwise stated, all minimum/maximum specifications are over the recommended operating conditions. All typical values are at T_A = 25°C.

Parameter	Symbol	Min.	Typ.	Max.	Units	Test Conditions	Figures	Notes
Open-Circuit Voltage	V_{OC}	4.0	7	—	V	I_F = 10 mA, I_O = 0 mA	3, 4	
		4.5	—	—		I_F = 10 mA, I_O = 0 mA, T_A = 105°C	—	
		4.5	7.5	—		I_F = 20 mA, I_O = 0 mA	3, 4	
Temperature Coefficient of Open-Circuit Voltage	$\Delta V_{OC}/\Delta T_A$	—	–21	—	mV/°C	I_F = 10 mA, I_O = 0 mA	4	
Short-Circuit Current	I_{SC}	2.0	5.0	—	µA	I_F = 10 mA, V_O = 0V	5, 6	
		4.0	10.0	—		I_F = 20 mA, V_O = 0V	5, 6	
Input Forward Voltage	V_F	1.25	1.55	1.85	V	I_F = 10 mA	—	
Temperature Coefficient of Forward Voltage	$\Delta V_F/\Delta T_A$	—	–1.5	—	mV/°C	I_F = 10 mA	—	
Input Reverse Breakdown Voltage	BV_R	6	—	—	V	I_R = 10 µA	—	

Switching Specifications (AC)

Unless otherwise stated, all minimum/maximum specifications are over the recommended operating conditions. All typical values are at T_A = 25°C.

Parameter	Symbol	Min.	Typ.	Max.	Units	Test Conditions	Figures	Notes
Turn-On Time	T_{ON}	—	0.8	2.0	ms	I_F = 10 mA, C_L = 1 nF	7, 10, 11	
		—	0.4	1.0	ms	I_F = 20 mA, C_L = 1 nF	7, 10, 11	
Turn-Off Time	T_{OFF}	—	0.04	0.12	ms	I_F = 10 mA/20 mA, C_L = 1 nF	8, 9, 11	

Package Characteristics

Unless otherwise stated, all minimum/maximum specifications are over the recommended operating conditions. All typical values are at T_A = 25°C.

Parameter	Symbol	Min.	Typ.	Max.	Units	Test Conditions	Figures	Notes
Input-Output Momentary Withstand Voltage[a]	V_{ISO}	5000	—	—	V_{RMS}	RH ≤ 50%, t = 1 minute, T_A = 25°C	—	b, c
Input-Output Resistance	R_{I-O}	10^9	10^{14}	—	Ω	V_{I-O} = 500 V_{DC}	—	b
Input-Output Capacitance	C_{I-O}	—	0.6	—	pF	f = 1 MHz, V_{I-O} = 0 V_{DC}	—	b

a. The input-output momentary withstand voltage is a dielectric voltage rating that should not be interpreted as an input-output continuous voltage rating.

b. The device is considered a two-terminal device: pins 1, 2, 3, and 4 are shorted together, and pins 5, 6, 7, and 8 are shorted together.

c. In accordance with UL 1577, each optocoupler is proof-tested by applying an insulation test voltage > 6000 V_{RMS} for 1 second.

Typical Characteristic Plots and Test Conditions

Unless otherwise stated, all typical values are at T_A = 25°C.

Figure 3: Open-Circuit Voltage vs. Input LED Current

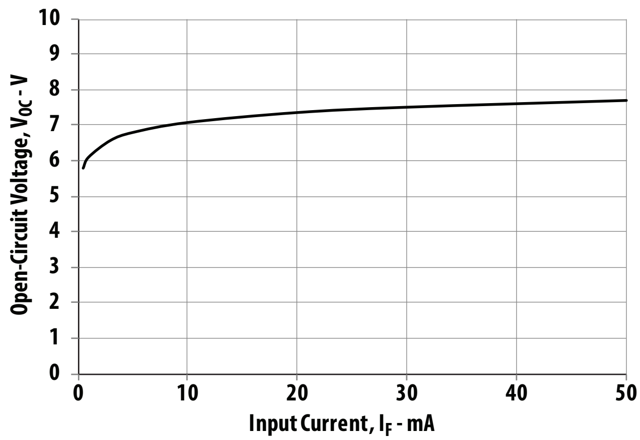


Figure 4: Open-Circuit Voltage vs. Temperature

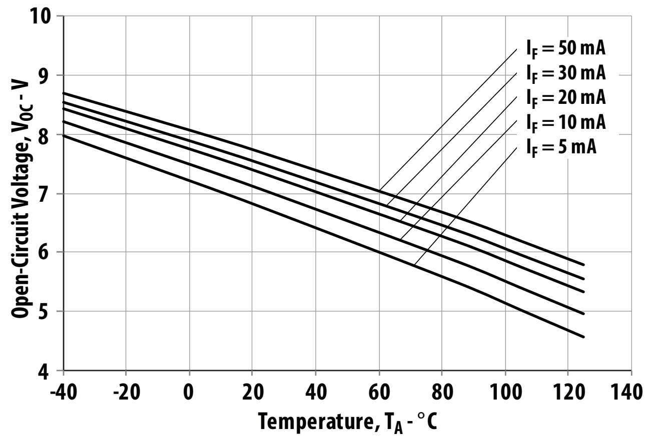


Figure 5: Short-Circuit Current vs. Input LED Current

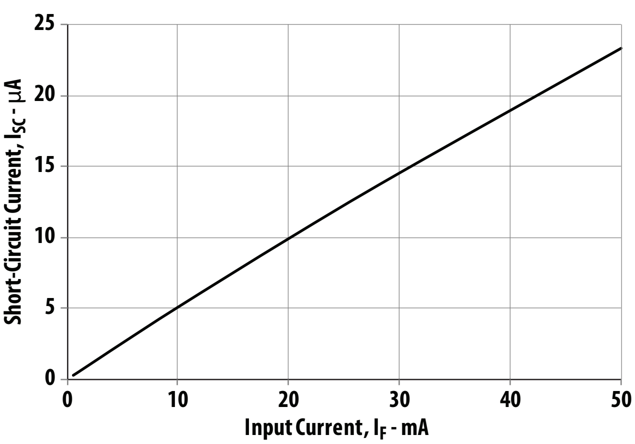


Figure 6: Short-Circuit Current vs. Temperature

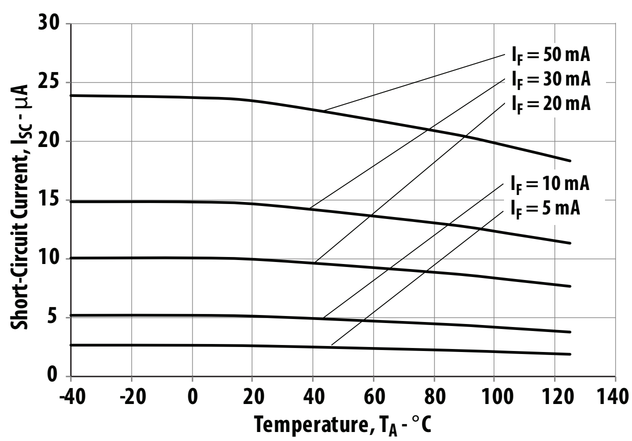


Figure 7: Turn-On Time vs. Temperature

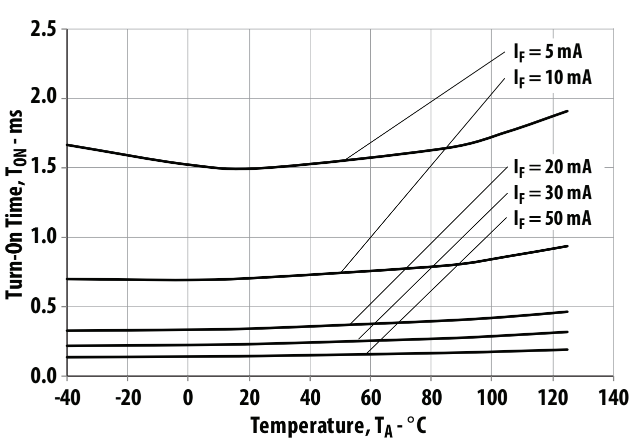


Figure 8: Turn-Off Time vs. Temperature

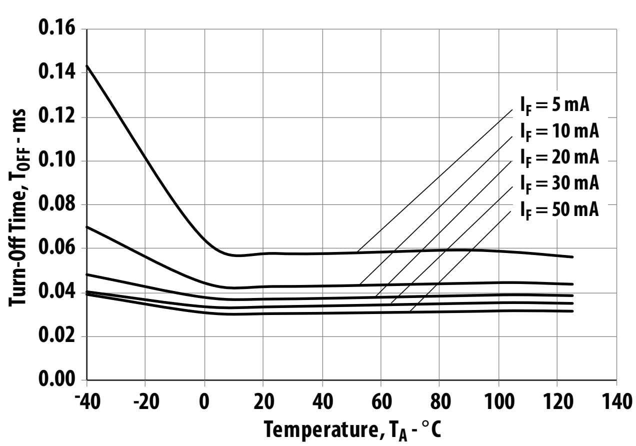


Figure 9: Turn-Off Time vs. Load Capacitance

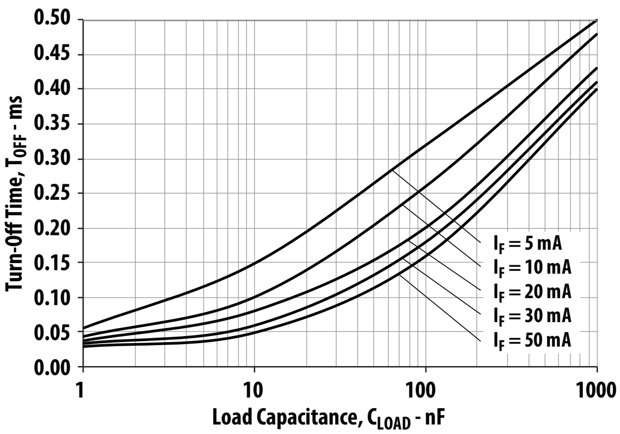


Figure 10: Turn-On Time vs. Load Capacitance

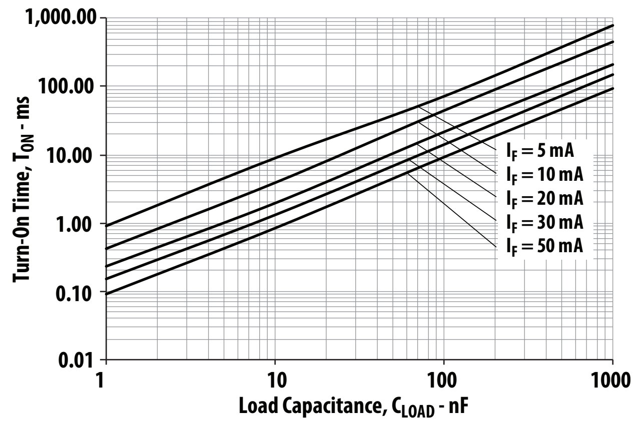
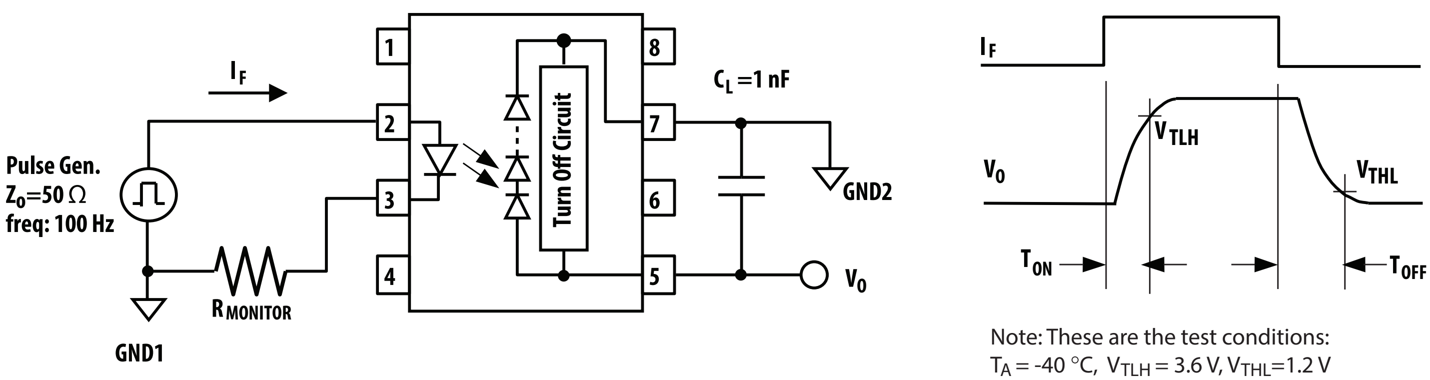


Figure 11: Switching Time Test Circuit and Waveform



Note: These are the test conditions:
T_A = -40 °C, V_{TLH} = 3.6 V, V_{THL}=1.2 V
T_A = 25 °C, V_{TLH} =3.6 V, V_{THL}=1.0 V
T_A = 125 °C, V_{TLH} = 3.6 V, V_{THL}=0.8 V

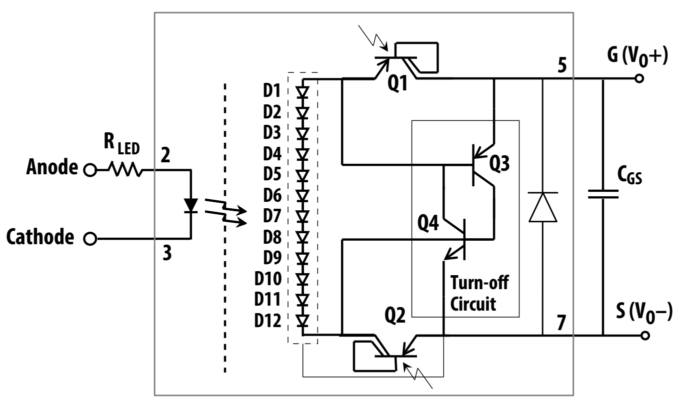
Application Information

The ACPL-K30T automotive photovoltaic (PV) driver is a device that is paired with MOSFETs to form a basic building block for several types of applications. It consists of an AlGaAs LED input that is optically coupled to a photovoltaic diode array. This becomes a voltage source with galvanic isolation. The advantage of a photovoltaic driver is its simple design, which does not require bias supply.

Basic Construction

As shown in Figure 12, the input side of the PV driver is LED driven. A current-limiting resistor is required to limit the current through the LED. The recommended input forward current is 10 mA to 20 mA. The LED is optically coupled through a photodiode stack (D1 to D12) that consists of 12 photodiodes connected in series. When current is driven into the LED on the input side, the light from the LED generates photocurrent on the string of photodiodes to charge the gate of the MOSFETs, generating a photovoltage proportional to the number of photodiodes, to switch and keep the power device on.

Figure 12: Basic Construction of the Photovoltaic Driver



PV Driver and MOSFET Configurations

The photovoltaic driver is a device that is combined with high-voltage MOSFETs to form a solid-state relay. The photovoltaic driver can be configured with a single MOSFET or two MOSFETS (back to back) for bidirectional application. Pin 5 is connected to the gate, and Pin 7 is connected to the source. Figure 13 and Figure 14 show sample application circuits for the two configurations.

Figure 13: Photovoltaic Driver + Single External MOSFET

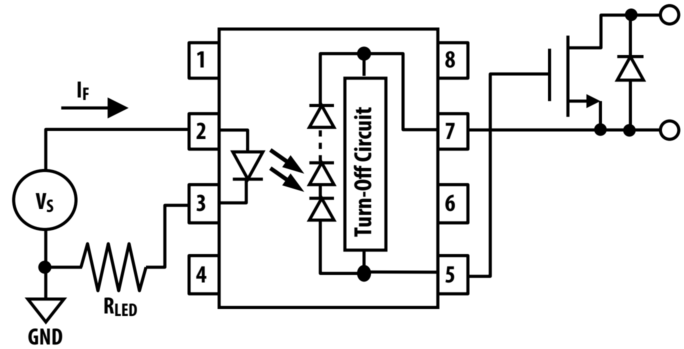
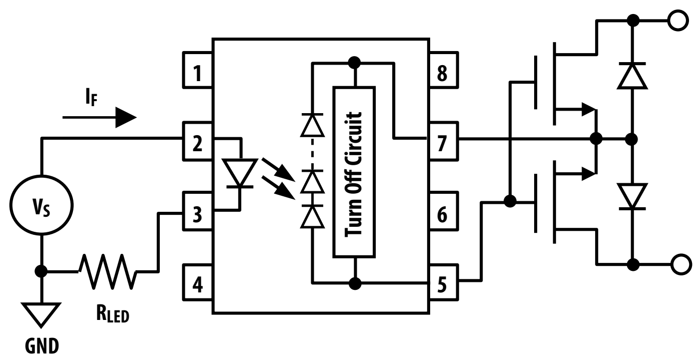


Figure 14: Photovoltaic Driver + Two Back-to-Back MOSFETs



Turn-Off Circuit

The photovoltaic driver has a built in turn-off circuit, which decreases the turn-off time. This circuit instantaneously discharges the gate capacitance of MOSFETs once the photovoltaic driver is turned off. The turn-off circuit is activated when the photovoltaic voltage is collapsing.

Sequence of Operation of the Turn-Off Circuit

When the LED is ON:

1. Q1 and Q2 are saturated.
2. SCR (Q3 and Q4) is disabled.
3. The photodiode array is connected to the gate and the source.

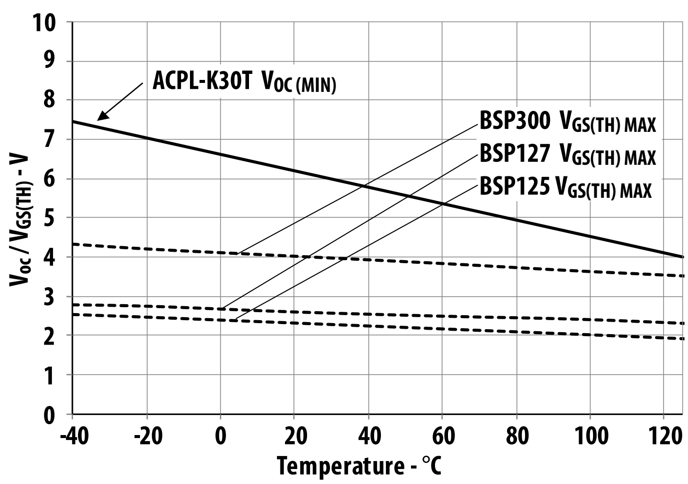
When the LED is OFF:

1. Q1 and Q2 cease to conduct.
2. The photodiode array is disconnected from the gate and the source.
3. SCR (Q3 and Q4) is triggered, and the gate capacitance (C_{GS}) is discharged rapidly.

V_{OC} and MOSFET $V_{GS(TH)}$

The ACPL-K30T has a typical V_{OC} of 7V and a minimum V_{OC} of 4V at 125°C. This is sufficient to drive most logic gate-level MOSFETs, with threshold voltages $V_{GS(TH)}$ of 4V or less. The V_{OC} has a typical temperature coefficient of –21 mV/°C. To serve as a guide in the design at different temperatures, Figure 15 shows the ACPL-K30T's minimum V_{OC} vs. the MOSFET's maximum $V_{GS(TH)}$.

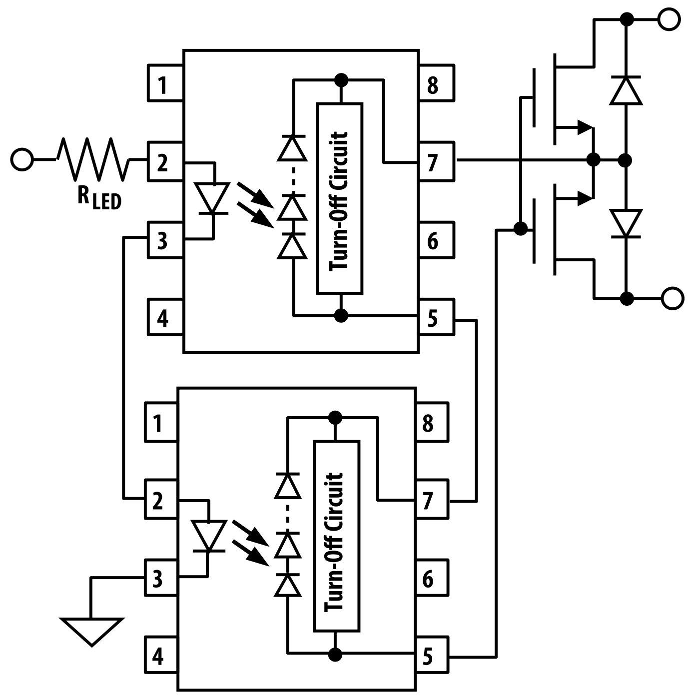
Figure 15: V_{OC} Minimum vs. MOSFET $V_{GS(TH)}$ Maximum



Two PV Drivers in Series

For high-voltage MOSFETs that require higher $V_{GS(TH)}$, two ACPL-K30T devices can be connected in series. Figure 16 shows the connection for this configuration. Two PV drivers in series will give a 2x higher V_{OC} (typical = 14V) compared with a single PV driver.

Figure 16: Two PV Drivers in Series



Thermal Resistance Model for the ACPL-K30T

Figure 17 shows the diagram of the ACPL-K30T for measurement. Here, one die is heated first, and the temperatures of all the dice are recorded after thermal equilibrium is reached. Then, the second die is heated, and all the dice temperatures are recorded. With the known ambient temperature, the die junction temperature, and the power dissipation, the thermal resistance can be calculated. The thermal resistance calculation can be cast in matrix form. This yields a 2-by-2 matrix for our case of two heat sources.

$$\begin{vmatrix} R_{11} & R_{12} \\ R_{21} & R_{22} \end{vmatrix} \cdot \begin{vmatrix} P_1 \\ P_2 \end{vmatrix} = \begin{vmatrix} \Delta T_1 \\ \Delta T_2 \end{vmatrix}$$

R_{11}: Thermal resistance of Die1 due to heating of Die1.

R_{12}: Thermal resistance of Die1 due to heating of Die2.

R_{21}: Thermal resistance of Die2 due to heating of Die1.

R_{22}: Thermal resistance of Die2 due to heating of Die2.

P_1: Power dissipation of Die1 (W).

P_2: Power dissipation of Die2 (W).

T_1: Junction temperature of Die1 due to heat from all dice (°C).

T_2: Junction temperature of Die2 due to heat from all dice.

T_A: Ambient temperature.

ΔT_1: Temperature difference between Die1 junction and ambient (°C).

ΔT_2: Temperature difference between Die2 junction and ambient (°C).

$T_1 = R_{11} \times P_1 + R_{12} \times P_2 + T_A$

$T_2 = R_{21} \times P_1 + R_{22} \times P_2 + T_A$

Measurement data on a low K (connectivity) board:

R_{11} = 258°C/W

R_{12} = 121°C/W

R_{21} = 119°C/W

R_{22} = 201°C/W

Measurement data on a high K (connectivity) board:

R_{11} = 194°C/W

R_{12} = 59°C/W

R_{21} = 53°C/W

R_{22} = 136°C/W

Figure 17: Diagram of ACPL-K30T for Measurement