

ACPL-K43T, ACPL-K44T

Automotive R²Coupler™ Wide Operating Temperature 1-MBd Digital Optocoupler in a Stretched 8-Pin Surface-Mount Plastic Package

Description

The Broadcom® ACPL-K43T is a single-channel, high-temperature, high-CMR, high-speed digital optocoupler in an eight-lead miniature footprint specifically used in the automotive applications. The ACPL-K44T is a dual-channel equivalent of the ACPL-K43T. Both products are available in the stretched SO-8 package outline designed to be compatible with standard surface-mount processes.

This digital optocoupler uses an insulating layer between the light-emitting diode and an integrated photo detector to provide electrical insulation between input and output. Separate connections for the photodiode bias and output transistor collector increase the speed up to a hundred times over that of a conventional photo-transistor coupler by reducing the base-collector capacitance.

Broadcom R²Coupler™ isolation products provide with reinforced insulation and reliability that deliver safe signal isolation, which is critical in automotive and high-temperature industrial applications.

Features

- High temperature and reliability low-speed digital interface for automotive applications
- Ultra-low drive for status feedback at $I_F = 0.8$ mA or 1.5 mA
- 30 kV/ μ s (typ.) high common-mode rejection at $V_{CM} = 1500$ V
- Compact, auto-insertable stretched SO8 packages
- Qualified to AEC Q100 Grade 1 test guidelines
- Wide operating temperature range: -40°C to $+125^{\circ}\text{C}$
- High speed: 1 MBd
- Low propagation delay: 1 μ s max. at $I_F = 10$ mA
- Worldwide safety approval:
 - UL 1577 approval, 5 kV_{RMS}/1 min.
 - CSA approval
 - IEC/EN/DIN EN 60747-5-5

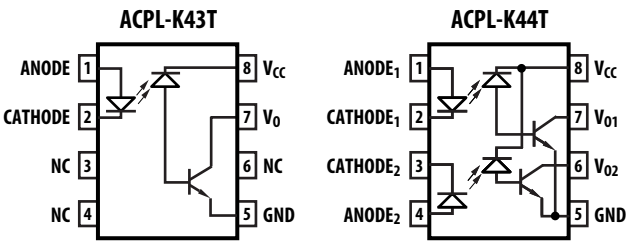
Applications

- Automotive IPM driver for DC-DC converters and motor inverters
- Status feedback and wake-up signal isolation
- CANBus and SPI communications interface
- High-temperature digital/analog signal isolation

CAUTION! Take normal static precautions in handling and assembly of this component to prevent damage, degradation, or both, which may be induced by ESD.

Functional Diagram

Truth Table



LED	V _O
ON	LOW
OFF	HIGH

NOTE: The connection of a 0.1-μF bypass capacitor between pins 5 and 8 is recommended.

Ordering Information

Specify part number followed by option number (if desired).

Part Number	Option (RoHS Compliant)	Package	Surface Mount	Tape and Reel	UL 5000 Vrms / 1-Minute Rating	IEC/EN/DIN EN 60747-5-5	Quantity
ACPL-K43T	-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
ACPL-K44T	-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 order, choose a part number from the part number column and combine with the desired option from the option column to form an order entry.

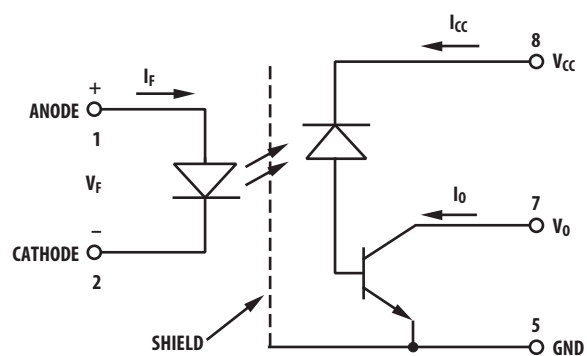
Example 1:

ACPL-K43T-560E to order product of SSO-8 Surface Mount package in Tape and Reel packaging with IEC/EN/DIN EN 60747-5-5 Safety Approval in RoHS compliant.

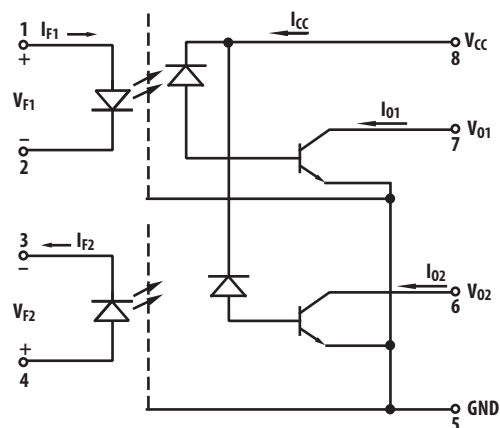
Option data sheets are available. Contact your Broadcom sales representative or authorized distributor for information.

Schematic

ACPL-K43T

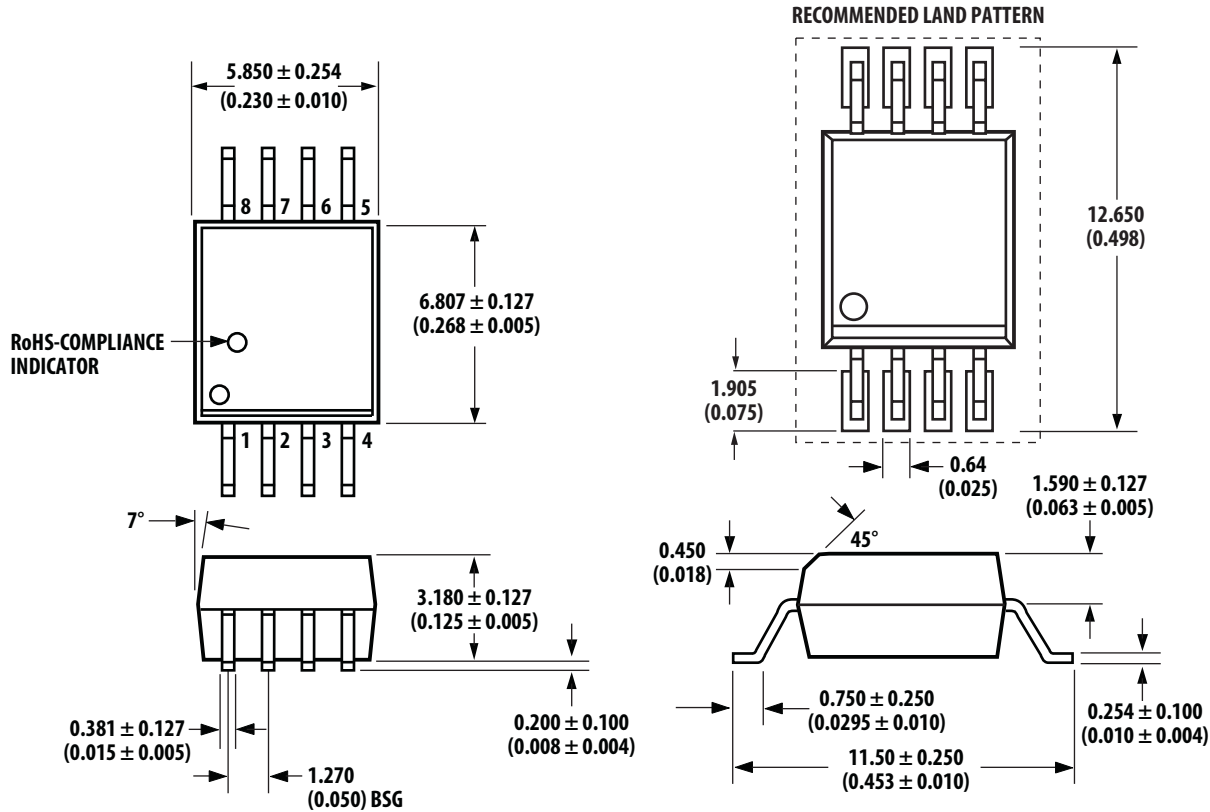


ACPL-K44T



USE OF 0.1 μ F BYPASS CAPACITOR CONNECTED BETWEEN PINS 5 AND 8 IS RECOMMENDED.

Package Outline Dimensions (Stretched SO8)



Recommended Pb-Free IR Profile

Recommended reflow condition as per JEDEC Standard, J-STD-020 (latest revision).

NOTE: Use non-halide flux.

Regulatory Information

The ACPL-K43T and ACPL-K44T are approved by the following organizations.

UL	UL 1577, component recognition program up to $V_{ISO} = 5 \text{ kV}_{RMS}$.
CSA	CSA Component Acceptance Notice #5.
IEC/EN/DIN EN 60747-5-5	IEC 60747-5-5 EN 60747-5-5 DIN EN 60747-5-5

Insulation and Safety-Related Specifications

Parameter	Symbol	ACPL-K43T ACPL-K44T	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 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 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 Characteristics (Options 060E and 560E)

Description	Symbol	Characteristic	Units
Installation classification per DIN VDE 0110/1.89, Table 1			
for rated mains voltage ≤ 150 Vrms		I-IV	
for rated mains voltage ≤ 300 Vrms		I-IV	
for rated mains voltage ≤ 450 Vrms		I-IV	
for rated mains voltage ≤ 600 Vrms		I-IV	
for rated mains voltage ≤ 1000 Vrms		I-III	
Climatic Classification		55/100/21	
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 $t_m = 1$ s, 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, $t_m = 10$ s, Partial discharge < 5 pC	V_{PR}	1824	V_{peak}
Highest Allowable Overvoltage (Transient Overvoltage $t_{ini} = 60$ s)	V_{IOTM}	8000	V_{peak}
Safety Limiting Values (Maximum values allowed in the event of a failure)			
Case Temperature	T_S	175	$^{\circ}\text{C}$
Input Current	$I_{S, INPUT}$	230	mA
Output Power	$P_{S, OUTPUT}$	600	mW
Insulation Resistance at T_S , $V_{IO} = 500$ V	R_S	$>10^9$	Ω

Absolute Maximum Ratings

Parameter	Symbol	Min.	Max.	Units	Notes
Storage Temperature	T_{STG}	−55	150	°C	
Operating Ambient Temperature	T_A	−40	125	°C	
Average Forward Input Current	$I_{F(avg)}$	—	20	mA	
Peak Forward Input Current (50% duty cycle, 1-ms pulse width)	$I_{F(peak)}$	—	40	mA	
Peak Transient Input Current ($\leq 1\text{-}\mu\text{s}$ pulse width, 300 ps)	$I_{F(trans)}$	—	100	mA	
Reversed Input Voltage	V_R	—	5	V	
Input Power Dissipation (per channel)	P_{IN}	—	30	mW	
Output Power Dissipation	P_O	—	100	mW	
Average Output Current	I_O	—	8	mA	
Peak Output Current	$I_{O(pk)}$		16	mA	
Supply Voltage	V_{CC}	−0.5	30	V	
Output Voltage	V_O	−0.5	20	V	
Lead Soldering Cycle	Temperature	—	260	°C	
	Time	—	10	s	

Recommended Operating Conditions

Parameter	Symbol	Min.	Max.	Units	Notes
Supply Voltage	V_{CC}	—	20	V	
Operating Temperature	T_A	−40	125	°C	

Electrical Specifications (DC)

Over recommended operating $T_A = -40^{\circ}\text{C}$ to 125°C , unless otherwise specified.

Parameter	Symbol	Min.	Typ.	Max.	Units	Test Conditions		Figure	Notes
Current Transfer Ratio	CTR	32	65	100	%	T _A = 25°C	V _{CC} = 4.5V, V _O = 0.4V, I _F = 10 mA	1, 2, 4	a
		24	65	—					
		33	160	—			V _{CC} = 4.5V, V _O = 0.4V, I _F = 1.5 mA		
		25	165	—			V _{CC} = 4.5V, V _O = 0.4V, I _F = 0.8 mA		
Logic Low Output Voltage	V _{OL}	—	0.1	0.5	V	V _{CC} = 4.5V, I _O = 2.4 mA, I _F = 10 mA			
		—	0.1	—		V _{CC} = 4.5V, I _O = 0.5 mA, I _F = 1.5 mA			
		—	0.1	—		V _{CC} = 4.5V, I _O = 0.2 mA, I _F = 0.8 mA			
Logic High Output Current	I _{OH}	—	3×10 ⁻⁵	0.5	μA	T _A = 25°C	V _O = V _{CC} = 5.5V, I _F = 0 mA	13, 14	
		—	8×10 ⁻⁵	5			V _O = V _{CC} = 20V, I _F = 0 mA		
Logic Low Supply Current (per Channel)	I _{CCL}	—	85	200	μA	I _F = 10 mA, V _O = open, V _{CC} = 20V			
		—	15	—		I _F = 1.5 mA, V _O = open, V _{CC} = 20V			
Logic High Supply Current (per Channel)	I _{CCH}	—	0.02	1	μA	T _A = 25°C	I _F = 0 mA, V _O = open, V _{CC} = 20V		
		—	—	2.5					
Input Forward Voltage	V _F	1.45	1.55	1.75	V	T _A = 25°C	I _F = 10 mA	3	
		1.25	1.55	1.85					
Input Reversed Breakdown Voltage	BV _R	5	—	—	V	I _R = 10 μA			
Temperature Coefficient of Forward Voltage	ΔV _F /ΔT _A	—	-1.5	—	mV/°C	I _F =10 mA			
		—	-1.8	—		I _F =1.5 mA			
Input Capacitance	C _{IN}	—	90	—	pF	F = 1 MHz, V _F = 0			

a. Current transfer ratio in percent is defined as the ratio of output collector current, I_O , to the forward LED input current, I_F , times 100.

Switching Specifications (AC)

Over recommended operating ($T_A = -40^{\circ}\text{C}$ to 125°C), $V_{CC} = 5.0\text{V}$ unless otherwise specified.

Parameter	Symbol	Min	Typ	Max	Units	Test Conditions			Figure	Note
Propagation Delay Time to Logic Low at Output	t_{PHL}	0.07	0.15	0.8	μs	$T_{\text{A}} = 25^{\circ}\text{C}$	$I_{\text{F}} = 10\text{ mA}$, $R_{\text{L}} = 1.9\text{ k}\Omega$	Pulse: $f = 10\text{ kHz}$, Duty cycle = 50%, $V_{\text{CC}} = 5.0\text{V}$, $C_{\text{L}} = 15\text{ pF}$, $V_{\text{THHL}} = 1.5\text{V}$	5, 6, 7, 8, 9, 10, 11, 12, 15	a, b
		0.06	—	1.0						
		—	0.7	5			$I_{\text{F}} = 1.5\text{ mA}$, $R_{\text{L}} = 10\text{ k}\Omega$			
		—	1	10			$I_{\text{F}} = 0.8\text{ mA}$, $R_{\text{L}} = 27\text{ k}\Omega$			
Propagation Delay Time to Logic High at Output	t_{PLH}	0.15	0.5	0.8	μs	$T_{\text{A}} = 25^{\circ}\text{C}$	$I_{\text{F}} = 10\text{ mA}$, $R_{\text{L}} = 1.9\text{ k}\Omega$	Pulse: $f = 10\text{ kHz}$, Duty cycle = 50%, $V_{\text{CC}} = 5.0\text{V}$, $C_{\text{L}} = 15\text{ pF}$, $V_{\text{THHL}} = 2.0\text{V}$	5, 6, 7, 8, 9, 10, 11, 12, 15	a, b
		0.03	—	1.0						
		—	0.9	5			$I_{\text{F}} = 1.5\text{ mA}$, $R_{\text{L}} = 10\text{ k}\Omega$			
		—	2	10			$I_{\text{F}} = 0.8\text{ mA}$, $R_{\text{L}} = 27\text{ k}\Omega$			
Pulse Width Distortion	PWD	—	0.35	0.45	μs	$T_{\text{A}} = 25^{\circ}\text{C}$	Pulse: $f = 10\text{ kHz}$, Duty cycle = 50%, $I_{\text{F}} = 10\text{ mA}$, $V_{\text{CC}} = 5.0\text{V}$, $R_{\text{L}} = 1.9\text{ k}\Omega$, $C_{\text{L}} = 15\text{ pF}$, $V_{\text{THHL}} = 1.5\text{V}$, $V_{\text{THLH}} = 2.0\text{V}$			a, b, c
		—	—	0.85						
Propagation Delay Difference Between Any 2 Parts	PDD	—	0.35	0.5	μs	$T_{\text{A}} = 25^{\circ}\text{C}$	Pulse: $f = 10\text{ kHz}$, Duty cycle = 50%, $I_{\text{F}} = 10\text{ mA}$, $V_{\text{CC}} = 5.0\text{V}$, $R_{\text{L}} = 1.9\text{ k}\Omega$, $C_{\text{L}} = 15\text{ pF}$, $V_{\text{THHL}} = 1.5\text{V}$, $V_{\text{THLH}} = 2.0\text{V}$			a, b, d
		—	—	0.9						
Common Mode Transient Immunity at Logic High Output	$ \text{CM}_{\text{H}} $	15	30	—	$\text{kV}/\mu\text{s}$	$I_{\text{F}} = 0\text{ mA}$	$V_{\text{CM}} = 1500\text{ V}_{\text{p-p}}$, $R_{\text{L}} = 1.9\text{ k}\Omega$, $V_{\text{CC}} = 5\text{ V}$, $T_{\text{A}} = 25^{\circ}\text{C}$	16		e
Common Mode Transient Immunity at Logic Low Output	$ \text{CM}_{\text{L}} $	15	30	—	$\text{kV}/\mu\text{s}$	$I_{\text{F}} = 10\text{ mA}$				
Common Mode Transient Immunity at Logic High Output	$ \text{CM}_{\text{H}} $	—	5	—	$\text{kV}/\mu\text{s}$	$I_{\text{F}} = 0\text{ mA}$	$V_{\text{CM}} = 1500\text{ V}_{\text{p-p}}$, $R_{\text{L}} = 10\text{ k}\Omega$, $V_{\text{CC}} = 5\text{ V}$, $T_{\text{A}} = 25^{\circ}\text{C}$	16		e
Common Mode Transient Immunity at Logic Low Output	$ \text{CM}_{\text{L}} $	—	5	—	$\text{kV}/\mu\text{s}$	$I_{\text{F}} = 1.5\text{ mA}$				

- Use of a 0.1- μF bypass capacitor connected between pins 5 and 8 is recommended.
- The 1.9-k Ω load represents one TTL unit load of 1.6 mA and the 5.6-k Ω pull-up resistor.
- Pulse Width Distortion (PWD) is defined as $|t_{\text{PHL}} - t_{\text{PLH}}|$ for any given device.
- The difference between t_{PLH} and t_{PHL} between any two parts under the same test condition.
- Common transient immunity in a Logic High level is the maximum tolerable (positive) dV_{CM}/dt on the rising edge of the common mode pulse, V_{CM} , to assure that the output will remain in a Logic High state (that is, $V_O > 2.0\text{V}$). Common mode transient immunity in a Logic Low level is the maximum tolerable (negative) dV_{CM}/dt on the falling edge of the common mode pulse signal, V_{CM} to assure that the output will remain in a Logic Low state (that is, $V_O < 0.8\text{ V}$).

Package Characteristics

Parameter	Symbol	Min.	Typ.	Max.	Units	Test Conditions	Figure	Note
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 ¹⁴	—	Ω	V _{I-O} = 500 Vdc		b
Input-Output Capacitance	C _{I-O}	—	0.6	—	pF	f = 1 MHz, V _{I-O} = 0 Vdc		b

- The Input-Output Momentary Withstand Voltage is a dielectric voltage rating that should not be interpreted as an input-output continuous voltage rating.
- The device is considered a two terminal device: pins 1, 2, 3, and 4 shorted together, and pins 5, 6, 7, and 8 are shorted together.
- In accordance with UL 1577, each optocoupler is proof-tested by applying an insulation test voltage ≥ 6000 V_{RMS} for 1 second.

Figure 1: DC and Pulsed Transfer Characteristics

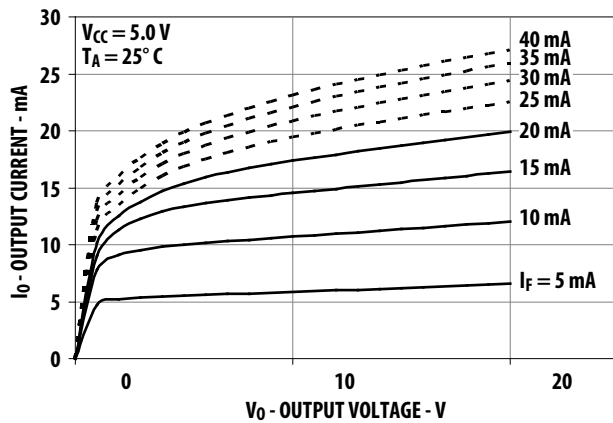


Figure 2: Current Transfer Ratio vs. Input Current.

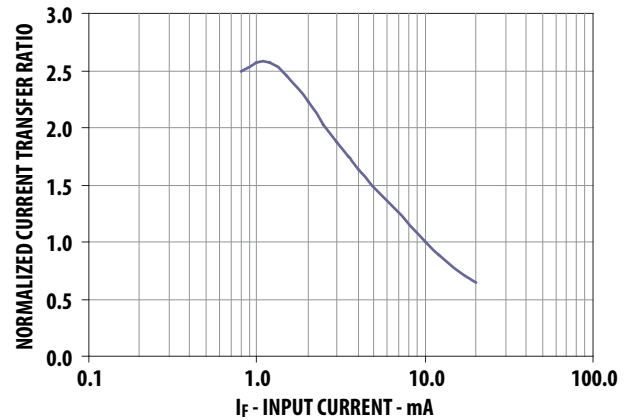
 $V_O = 0.4\text{ V}, V_{CC} = 5\text{ V}, T_A = 25^\circ\text{C}.$


Figure 3: Input Current vs. Forward Voltage

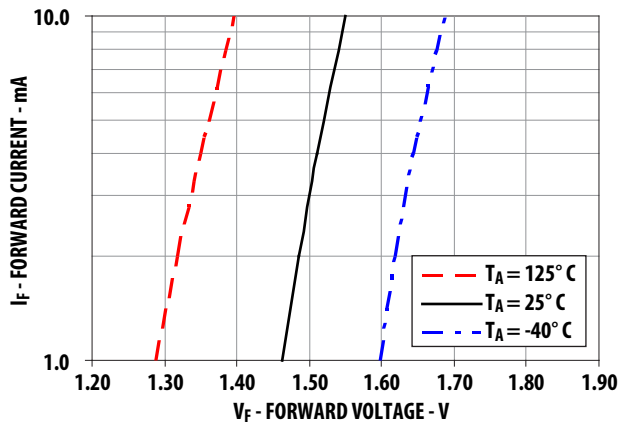


Figure 4: Current Transfer Ratio vs. Temperature

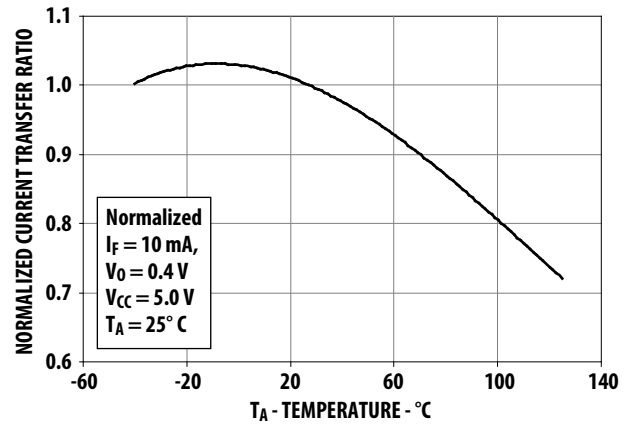


Figure 5: Propagation Delay Time vs. Temperature.

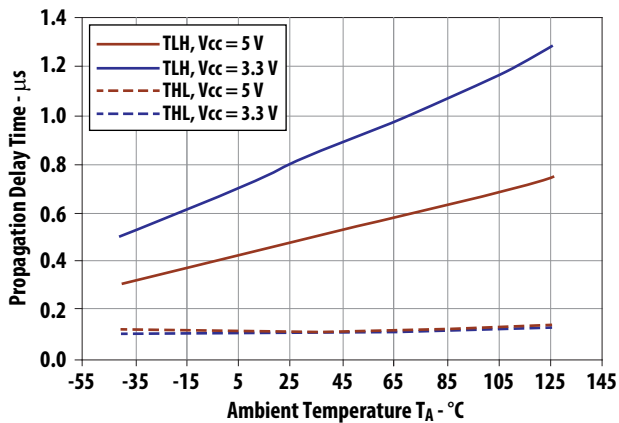
 $I_F = 10\text{ mA}, R_L = 1.9\text{ k}\Omega, C_L = 15\text{ pF}.$


Figure 6: Propagation Delay Time vs. Temperature.

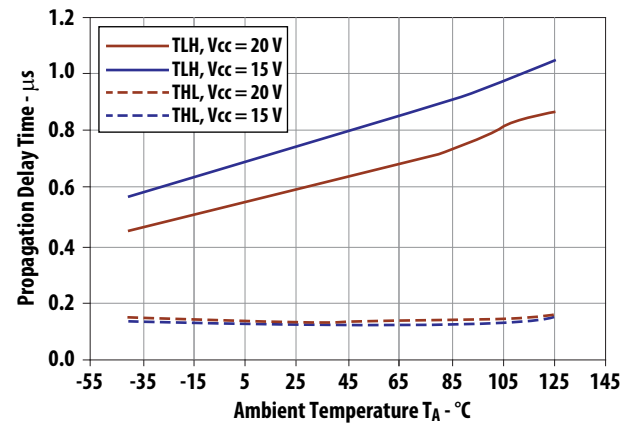
 $I_F = 10\text{ mA}, R_L = 20\text{ k}\Omega, C_L = 100\text{ pF}.$


Figure 7: Propagation Delay Time vs. Load Resistance

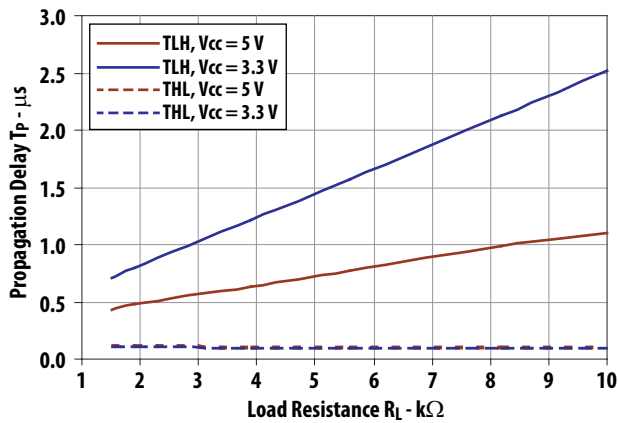


Figure 8: Propagation Delay Time vs. Load Resistance

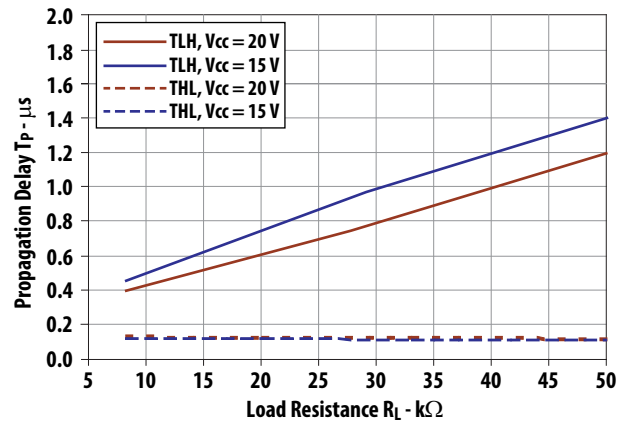
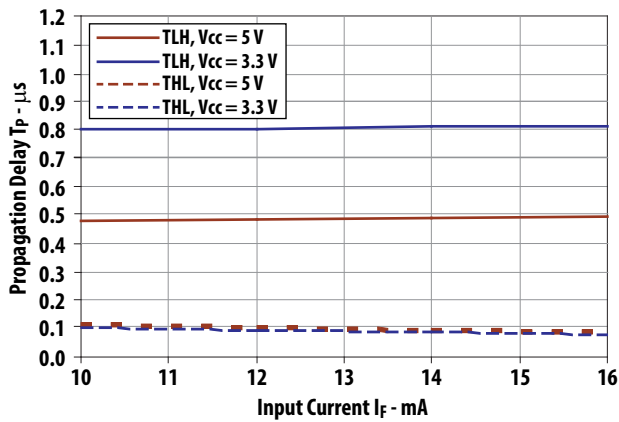
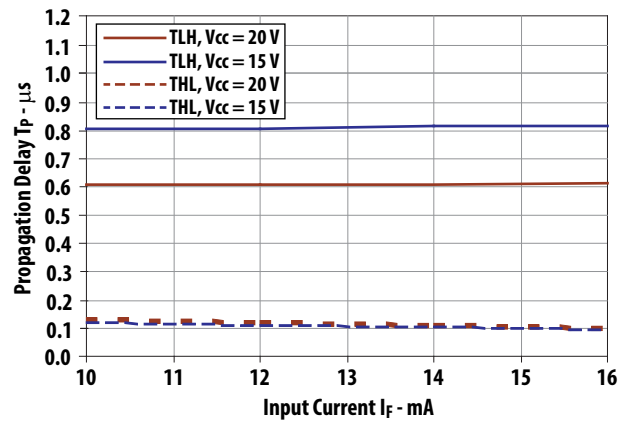
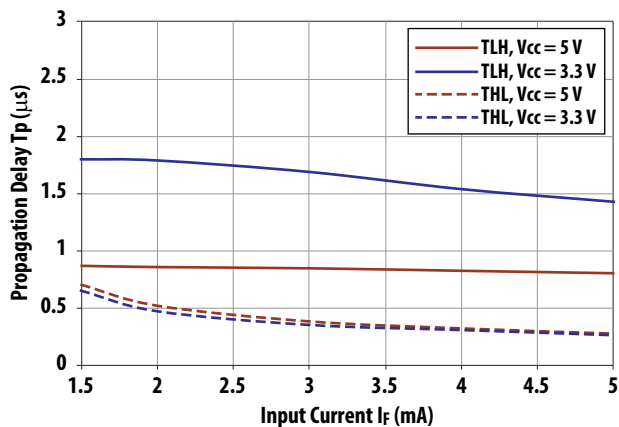
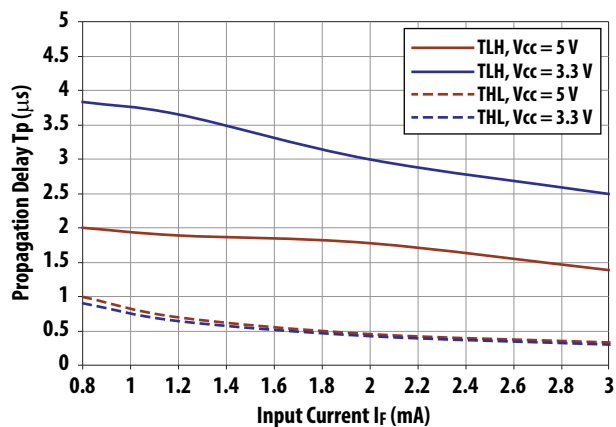
Figure 9: Propagation Delay Time vs. Input Current.
 $R_L = 1.9 k\Omega$, $C_L = 15 pF$, $T_A = 25^\circ C$.Figure 10: Propagation Delay Time vs. Input Current.
 $R_L = 20 k\Omega$, $C_L = 15 pF$, $T_A = 25^\circ C$.Figure 11: Propagation Delay Time vs. Input Current.
 $R_L = 10 k\Omega$, $C_L = 15 pF$, $T_A = 25^\circ C$.Figure 12: Propagation Delay Time vs. Input Current.
 $R_L = 27 k\Omega$, $C_L = 15 pF$, $T_A = 25^\circ C$.

Figure 13: Logic High Output Current vs Supply Voltage

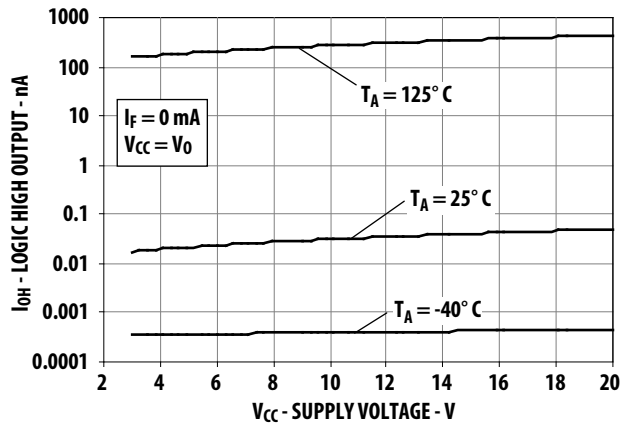


Figure 14: Logic High Output Current vs Temperature

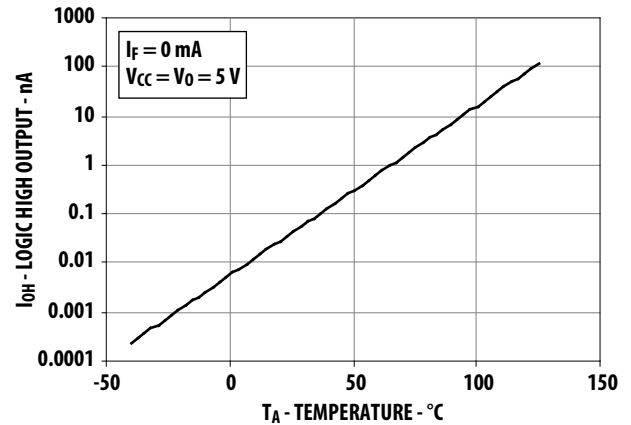


Figure 15: Switching Test Circuit

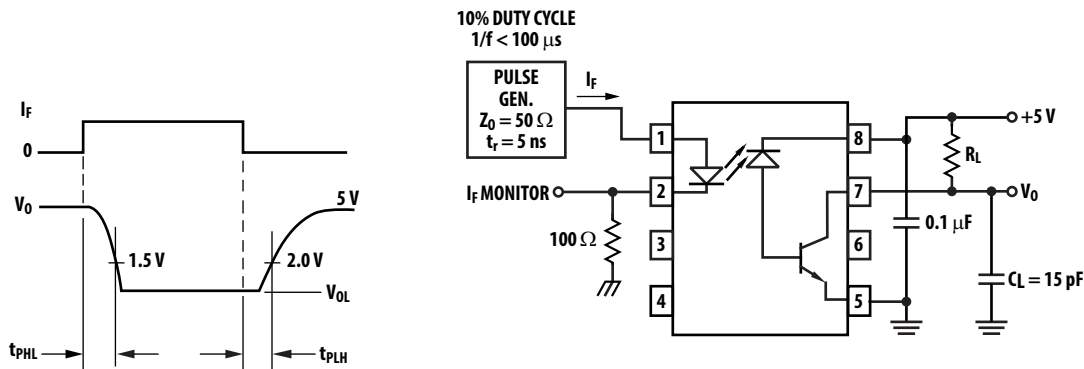
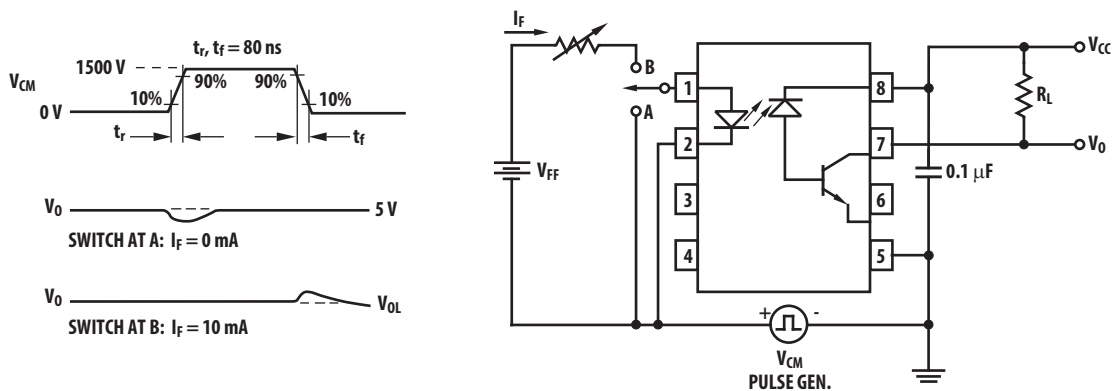


Figure 16: Test Circuit for Transient Immunity and Typical Waveforms

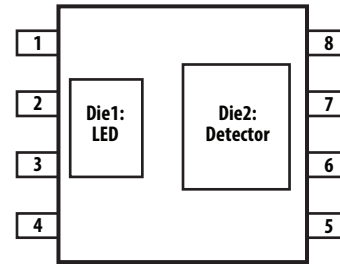


Thermal Resistance Model for ACPL-K43T

The diagram of ACPL-K43T for measurement is shown in [Figure 17](#). 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 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 the case of two heat sources.

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

Figure 17: Diagram of ACPL-K43T for Measurement



R_{11} : Thermal Resistance of Die1 due to heating of Die1 (°C/W)

R_{12} : Thermal Resistance of Die1 due to heating of Die2 (°C/W)

R_{21} : Thermal Resistance of Die2 due to heating of Die1 (°C/W)

R_{22} : Thermal Resistance of Die2 due to heating of Die2 (°C/W)

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 (°C)

T_a : Ambient temperature (°C)

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 board:

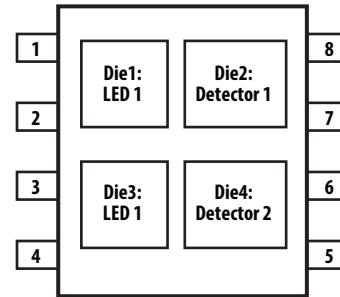
$$R_{11} = 160^\circ\text{C/W}, R_{12} = R_{21} = 74^\circ\text{C/W}, R_{22} = 115^\circ\text{C/W}$$

Thermal Resistance Model for ACPL-K44T

The diagram of ACPL-K44T for measurement is shown in [Figure 18](#). Here, one die is heated first and the temperatures of all the dice are recorded after thermal equilibrium is reached. Then, the second, third, and fourth die are heated and all the dice temperatures are recorded. With the known ambient temperature, the die junction temperature and power dissipation, the thermal resistance can be calculated. The thermal resistance calculation can be cast in matrix form. This yields a 4 by 4 matrix for the case of two heat sources.

$$\begin{bmatrix} R_{11} & R_{12} & R_{13} & R_{14} \\ R_{21} & R_{22} & R_{23} & R_{24} \\ R_{31} & R_{32} & R_{33} & R_{34} \\ R_{41} & R_{42} & R_{43} & R_{44} \end{bmatrix} \times \begin{bmatrix} P_1 \\ P_2 \\ P_3 \\ P_4 \end{bmatrix} = \begin{bmatrix} \Delta T_1 \\ \Delta T_2 \\ \Delta T_3 \\ \Delta T_4 \end{bmatrix}$$

Figure 18: Diagram of ACPL-K44T for Measurement



R_{11} : Thermal Resistance of Die1 due to heating of Die1 (°C/W)
 R_{12} : Thermal Resistance of Die1 due to heating of Die2 (°C/W)
 R_{13} : Thermal Resistance of Die1 due to heating of Die3 (°C/W)
 R_{14} : Thermal Resistance of Die1 due to heating of Die4 (°C/W)
 R_{21} : Thermal Resistance of Die2 due to heating of Die1 (°C/W)
 R_{22} : Thermal Resistance of Die2 due to heating of Die2 (°C/W)
 R_{23} : Thermal Resistance of Die2 due to heating of Die3 (°C/W)
 R_{24} : Thermal Resistance of Die2 due to heating of Die4 (°C/W)
 R_{31} : Thermal Resistance of Die3 due to heating of Die1 (°C/W)
 R_{32} : Thermal Resistance of Die3 due to heating of Die2 (°C/W)
 R_{33} : Thermal Resistance of Die3 due to heating of Die3 (°C/W)
 R_{34} : Thermal Resistance of Die3 due to heating of Die4 (°C/W)
 R_{41} : Thermal Resistance of Die4 due to heating of Die1 (°C/W)
 R_{42} : Thermal Resistance of Die4 due to heating of Die2 (°C/W)
 R_{43} : Thermal Resistance of Die4 due to heating of Die3 (°C/W)
 R_{44} : Thermal Resistance of Die4 due to heating of Die4 (°C/W)

P_1 : Power dissipation of Die1 (W)
 P_2 : Power dissipation of Die2 (W)
 P_3 : Power dissipation of Die3 (W)
 P_4 : Power dissipation of Die4 (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 (°C)
 T_3 : Junction temperature of Die3 due to heat from all dice (°C)
 T_4 : Junction temperature of Die4 due to heat from all dice (°C)
 T_a : Ambient temperature (°C)
 ΔT_1 : Temperature difference between Die1 junction and ambient (°C)
 ΔT_2 : Temperature deference between Die2 junction and ambient (°C)
 ΔT_3 : Temperature difference between Die3 junction and ambient (°C)
 ΔT_4 : Temperature deference between Die4 junction and ambient (°C)

$$T_1 = (R_{11} \times P_1 + R_{12} \times P_2 + R_{13} \times P_3 + R_{14} \times P_4) + T_a \text{ -- (1)}$$

$$T_2 = (R_{21} \times P_1 + R_{22} \times P_2 + R_{23} \times P_3 + R_{24} \times P_4) + T_a \text{ -- (2)}$$

$$T_3 = (R_{31} \times P_1 + R_{32} \times P_2 + R_{33} \times P_3 + R_{34} \times P_4) + T_a \text{ -- (3)}$$

$$T_4 = (R_{41} \times P_1 + R_{42} \times P_2 + R_{43} \times P_3 + R_{44} \times P_4) + T_a \text{ -- (4)}$$

Measurement data on a low K board:

R_{11}	R_{12}	R_{13}	R_{14}	R_{21}	R_{22}	R_{23}	R_{24}	R_{31}	R_{32}	R_{33}	R_{34}	R_{41}	R_{42}	R_{43}	R_{44}
160	76	76	76	76	115	76	76	76	76	160	76	76	76	76	115

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