

# ACPL-K43T, ACPL-K44T

Automotive R<sup>2</sup>Coupler™ Wide Operating Temperature 1MBd Digital Optocoupler in a Stretched 8-Pin Surface Mount Plastic Package



## Data Sheet



Lead (Pb) Free  
RoHS 6 fully compliant

RoHS 6 fully compliant options available;  
-xxxE denotes a lead-free product

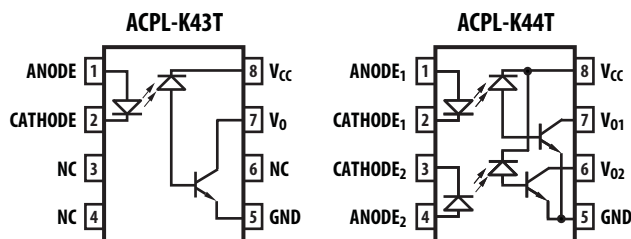
### Description

The 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.

Avago R<sup>2</sup>Coupler isolation products provide with reinforced insulation and reliability that delivers safe signal isolation critical in automotive and high temperature industrial applications.

### Functional Diagram



### Truth Table

| LED | Vo   |
|-----|------|
| ON  | LOW  |
| OFF | HIGH |

Note: The connection of a 0.1  $\mu$ F bypass capacitor between pins 5 and 8 is recommended.

### Features

- High Temperature and Reliability low speed digital interface for Automotive Application
- Ultra low drive for status feedback at  $I_F = 0.8$  mA or 1.5 mA
- 30 kV/ $\mu$ 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:  $-40^\circ$  C to  $+125^\circ$  C
- High Speed: 1 MBd
- Low Propagation Delay: 1  $\mu$ s max. at  $I_F = 10$  mA
- Worldwide Safety Approval:
  - UL 1577 approval, 5 kV<sub>RMS</sub>/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:** It is advised that normal static precautions be taken in handling and assembly of this component to prevent damage and/or degradation which may be induced by ESD.

## Ordering Information

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

| Part number | Option (RoHS Compliant) | Package        | Surface Mount | Tape & Reel | UL 5000 V <sub>rms</sub> / 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 |

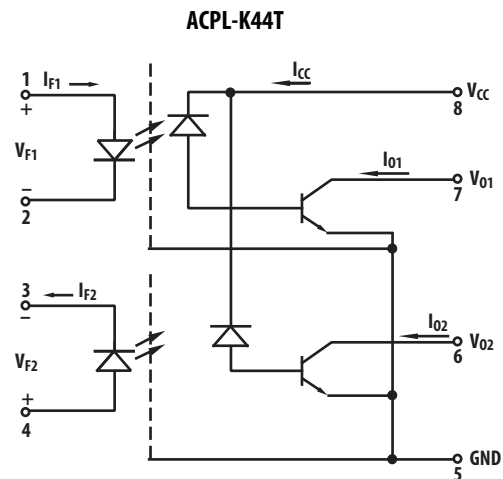
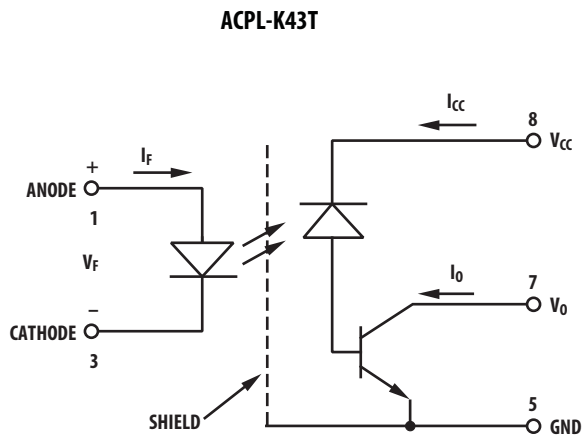
To order, choose a part number from the part number column and combine with the desired option from the option column to form an order entry.

### 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.

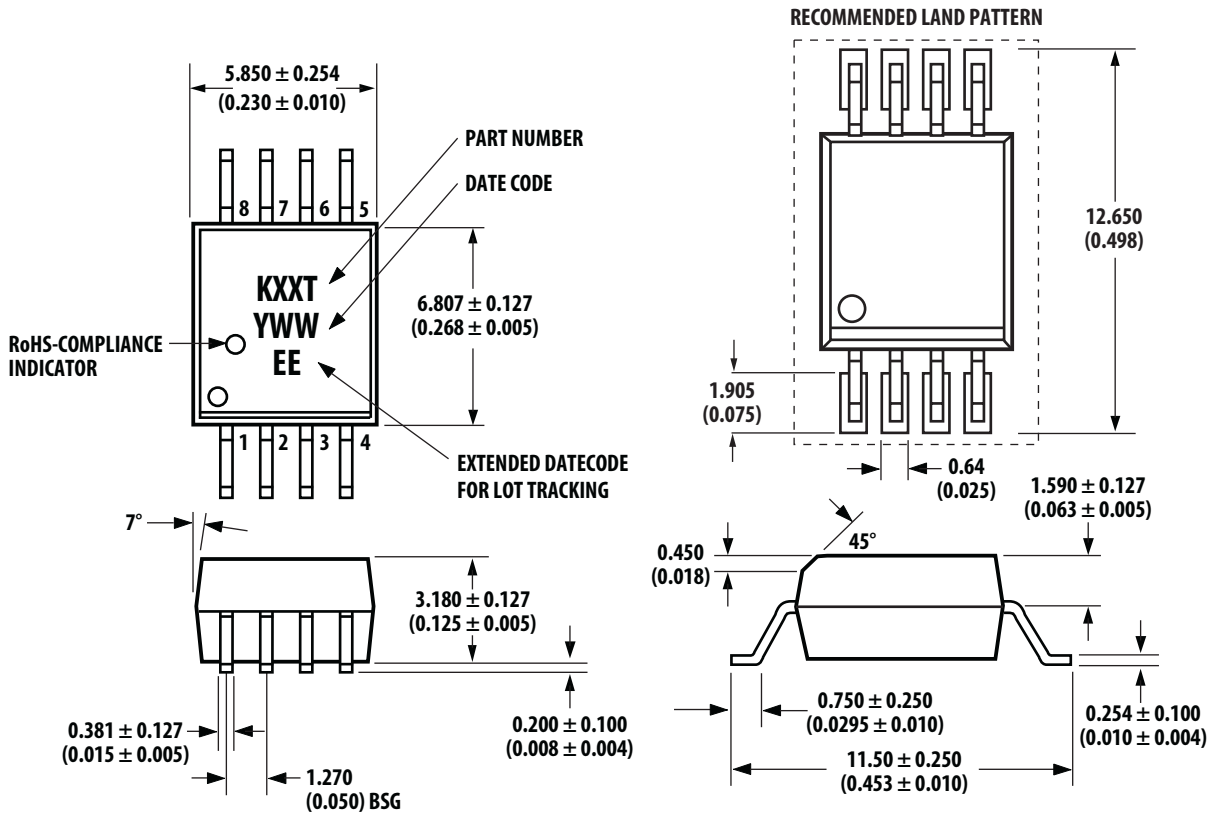
Option datasheets are available. Contact your Avago sales representative or authorized distributor for information.

## Schematic



USE OF 0.1  $\mu$ F BYPASS CAPACITOR CONNECTED BETWEEN PINS 5 AND 8 IS RECOMMENDED.

## Package Outline Dimensions (Stretched S08)



Dimensions in millimeters and (inches).

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

## Recommended Pb-Free IR Profile

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

Note: Non-halide flux should be used.

## Regulatory Information

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

### UL

UL 1577, component recognition program up to  $V_{ISO} = 5$  kV<sub>RMS</sub>.

### 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 |  | Units | Conditions   |
|---|--------|-----------|--|-------|--|
|   |        | ACPL-K44T |  |       |  |
| 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 Characteristic (Option 060E and 560E)

| Description  | Symbol          | Characteristic | Units       |
|--|-----------------|----------------|-------------|
| Installation classification per DIN VDE 0110/1.89, Table 1   |                 |                |             |
| for rated mains voltage $\leq 150 V_{rms}$   |                 | I – IV         |             |
| for rated mains voltage $\leq 300 V_{rms}$   |                 | I – IV         |             |
| for rated mains voltage $\leq 450 V_{rms}$   |                 | I – IV         |             |
| for rated mains voltage $\leq 600 V_{rms}$   |                 | I – IV         |             |
| for rated mains voltage $\leq 1000 V_{rms}$  |                 | 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*  | $V_{PR}$        | 2137           | $V_{peak}$  |
| $V_{IORM} \times 1.875 = V_{PR}$ , 100% Production Test with $t_m = 1$ sec, Partial discharge $< 5$ pC |                 |                |             |
| Input to Output Test Voltage, Method a*  | $V_{PR}$        | 1824           | $V_{peak}$  |
| $V_{IORM} \times 1.6 = V_{PR}$ , Type and Sample Test, $t_m = 10$ sec, Partial discharge $< 5$ pC      |                 |                |             |
| Highest Allowable Overvoltage (Transient Overvoltage $t_{ini} = 60$ sec)                               | $V_{IOTM}$      | 8000           | $V_{peak}$  |
| Safety Limiting Values (Maximum values allowed in the event of a failure)                              |                 |                |             |
| Case Temperature   | $T_S$           | 175            | $^{\circ}C$ |
| Input Current  | $I_{S, INPUT}$  | 230            | mA          |
| Output Power   | $P_{S, OUTPUT}$ | 600            | mW          |
| Insulation Resistance at $T_S$ , $V_{IO} = 500$ V  | $R_S$           | $>10^9$        | $\Omega$    |

## Absolute Maximum Ratings

| Parameter   | Symbol         | Min. | Max. | Units | Note |
|---|----------------|------|------|-------|------|
| 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<br>(50% duty cycle, 1 ms pulse width)      | $I_{F(peak)}$  |      | 40   | mA    |      |
| Peak Transient Input Current<br>( $\leq 1 \mu s$ 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 | Note |
|-----------------------|----------|------|------|-------|------|
| 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  $125^\circ\text{C}$ , unless otherwise specified

| Parameter                                  | Sym.                      | Min. | Typ.               | Max. | Units         | Test Conditions   | Fig.    | Note |
|--|---------------------------|------|--------------------|------|---------------|---|---------|------|
| Current Transfer Ratio                     | CTR                       | 32   | 65                 | 100  | %             | $T_A = 25^\circ\text{C}$ $V_{CC} = 4.5\text{V}$ , $V_O = 0.4\text{V}$ , $I_F = 10\text{mA}$ | 1, 2, 4 | 1    |
|  |                           | 24   | 65                 |      |               |   |         |      |
|  |                           | 33   | 160                |      |               | $V_{CC} = 4.5\text{V}$ , $V_O = 0.4\text{V}$ , $I_F = 1.5\text{mA}$                         |         |      |
|  |                           | 25   | 165                |      |               | $V_{CC} = 4.5\text{V}$ , $V_O = 0.4\text{V}$ , $I_F = 0.8\text{mA}$                         |         |      |
| Logic Low Output Voltage                   | $V_{OL}$                  |      | 0.1                | 0.5  | V             | $V_{CC} = 4.5\text{V}$ , $I_O = 2.4\text{mA}$ , $I_F = 10\text{mA}$                         |         |      |
|  |                           |      | 0.1                |      |               | $V_{CC} = 4.5\text{V}$ , $I_O = 0.5\text{mA}$ , $I_F = 1.5\text{mA}$                        |         |      |
|  |                           |      | 0.1                |      |               | $V_{CC} = 4.5\text{V}$ , $I_O = 0.2\text{mA}$ , $I_F = 0.8\text{mA}$                        |         |      |
| Logic High Output Current                  | $I_{OH}$                  |      | $3 \times 10^{-5}$ | 0.5  | $\mu\text{A}$ | $T_A = 25^\circ\text{C}$ $V_O = V_{CC} = 5.5\text{V}$ $I_F = 0\text{mA}$                    | 11, 12  |      |
|  |                           |      | $8 \times 10^{-5}$ | 5    |               | $V_O = V_{CC} = 20\text{V}$   |         |      |
| Logic Low Supply Current (per Channel)     | $I_{CCL}$                 |      | 85                 | 200  | $\mu\text{A}$ | $I_F = 10\text{mA}$ , $V_O = \text{open}$ , $V_{CC} = 20\text{V}$                           |         |      |
|  |                           |      | 15                 |      |               | $I_F = 1.5\text{mA}$ , $V_O = \text{open}$ , $V_{CC} = 20\text{V}$                          |         |      |
| Logic High Supply Current (per Channel)    | $I_{CCH}$                 |      | 0.02               | 1    | $\mu\text{A}$ | $T_A = 25^\circ\text{C}$ $I_F = 10\text{mA}$ , $V_O = \text{open}$ , $V_{CC} = 20\text{V}$  |         |      |
|  |                           |      |                    | 2.5  |               |   |         |      |
| Input Forward Voltage                      | $V_F$                     | 1.45 | 1.55               | 1.75 | V             | $T_A = 25^\circ\text{C}$ $I_F = 10\text{mA}$  | 3       |      |
|  |                           | 1.25 | 1.55               | 1.85 |               |   |         |      |
| Input Reversed Breakdown Voltage           | $BV_R$                    | 5    |                    |      | V             | $I_R = 10\mu\text{A}$   |         |      |
| Temperature Coefficient of Forward Voltage | $\Delta V_F / \Delta T_A$ |      | -1.5               |      | mV/°C         | $I_F = 10\text{mA}$   |         |      |
|  |                           |      | -1.8               |      |               | $I_F = 1.5\text{mA}$  |         |      |
| Input Capacitance                          | $C_{IN}$                  |      | 90                 |      | pF            | $F = 1\text{MHz}$ , $V_F = 0$   |         |      |

## Switching Specifications (AC)

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

| Parameter   | Symbol    | Min  | Typ  | Max  | Units                   | Test Conditions   | Fig.   | Note                        |         |
|---|-----------|------|------|------|-------------------------|---|--|-----------------------------|---------|
| Propagation Delay<br>Time to Logic Low<br>at Output       | $t_{PHL}$ | 0.07 | 0.15 | 0.8  | $\mu\text{s}$           | $T_A = 25^\circ\text{C}$<br>$I_F = 10\text{mA}$ ,<br>$R_L = 1.9\text{k}\Omega$<br>$I_F = 1.5\text{mA}$ ,<br>$R_L = 10\text{k}\Omega$<br>$I_F = 0.8\text{mA}$ ,<br>$R_L = 27\text{k}\Omega$  | Pulse: $f = 10\text{kHz}$ ,<br>Duty cycle = 50%,<br>$V_{CC} = 5.0\text{V}$ , $C_L = 15\text{pF}$ ,<br>$V_{THHL} = 1.5\text{V}$ | 5, 6, 7,<br>8, 9, 10,<br>13 | 2, 3    |
|   |           | 0.06 |      | 1.0  |                         |   |  |                             |         |
|   |           |      | 0.7  | 5    |                         |   |  |                             |         |
|   |           | 1    | 10   |      |                         |   |  |                             |         |
| Propagation Delay<br>Time to Logic High<br>at Output      | $t_{PLH}$ | 0.15 | 0.5  | 0.8  | $\mu\text{s}$           | $T_A = 25^\circ\text{C}$<br>$I_F = 10\text{mA}$ ,<br>$R_L = 1.9\text{k}\Omega$<br>$I_F = 1.5\text{mA}$ ,<br>$R_L = 10\text{k}\Omega$<br>$I_F = 0.8\text{mA}$ ,<br>$R_L = 27\text{k}\Omega$  | Pulse: $f = 10\text{kHz}$ ,<br>Duty cycle = 50%,<br>$V_{CC} = 5.0\text{V}$ , $C_L = 15\text{pF}$ ,<br>$V_{THHL} = 2.0\text{V}$ | 5, 6, 7,<br>8, 9, 10,<br>13 | 2, 3    |
|   |           | 0.03 |      | 1.0  |                         |   |  |                             |         |
|   |           |      | 0.9  | 5    |                         |   |  |                             |         |
|   |           | 2    | 10   |      |                         |   |  |                             |         |
| Pulse Width<br>Distortion                                 | PWD       |      | 0.35 | 0.45 | $\mu\text{s}$           | $T_A = 25^\circ\text{C}$<br>Pulse: $f = 10\text{kHz}$ , Duty cycle = 50%,<br>$I_F = 10\text{mA}$ , $V_{CC} = 5.0\text{V}$ , $R_L = 1.9\text{k}\Omega$ ,<br>$C_L = 15\text{pF}$ , $V_{THHL} = 1.5\text{V}$ ,<br>$V_{THLH} = 2.0\text{V}$ |  |                             | 2, 3, 4 |
|   |           |      |      | 0.85 |                         |   |  |                             |         |
| Propagation Delay<br>Difference Between<br>Any 2 Parts    | PDD       |      | 0.35 | 0.5  | $\mu\text{s}$           | $T_A = 25^\circ\text{C}$<br>Pulse: $f = 10\text{kHz}$ , Duty cycle = 50%,<br>$I_F = 10\text{mA}$ , $V_{CC} = 5.0\text{V}$ , $R_L = 1.9\text{k}\Omega$ ,<br>$C_L = 15\text{pF}$ , $V_{THHL} = 1.5\text{V}$ ,<br>$V_{THLH} = 2.0\text{V}$ |  |                             | 2, 3, 5 |
|   |           |      |      | 0.9  |                         |   |  |                             |         |
| Common Mode<br>Transient Immunity<br>at Logic High Output | $ CM_H $  | 15   | 30   |      | $\text{kV}/\mu\text{s}$ | $I_F = 0\text{mA}$<br>$V_{CM} = 1500\text{V}_{p-p}$ , $R_L = 1.9\text{k}\Omega$ ,<br>$V_{CC} = 5\text{V}$ , $T_A = 25^\circ\text{C}$  | 14   |                             | 6       |
| Common Mode<br>Transient Immunity<br>at Logic Low Output  | $ CM_L $  | 15   | 30   |      | $\text{kV}/\mu\text{s}$ | $I_F = 10\text{mA}$   |  |                             |         |
| Common Mode<br>Transient Immunity<br>at Logic High Output | $ CM_H $  |      | 5    |      | $\text{kV}/\mu\text{s}$ | $I_F = 0\text{mA}$<br>$V_{CM} = 1500\text{V}_{p-p}$ , $R_L = 10\text{k}\Omega$ ,<br>$V_{CC} = 5\text{V}$ , $T_A = 25^\circ\text{C}$   | 14   |                             | 6       |
| Common Mode<br>Transient Immunity<br>at Logic Low Output  | $ CM_L $  |      | 5    |      | $\text{kV}/\mu\text{s}$ | $I_F = 1.5\text{mA}$  |  |                             |         |

## Package Characteristics

| Parameter                                    | Symbol    | Min. | Typ.      | Max. | Units       | Test Conditions   | Fig. | Note |
|--|-----------|------|-----------|------|-------------|---|------|------|
| Input-Output Momentary<br>Withstand Voltage* | $V_{ISO}$ | 5000 |           |      | $V_{RMS}$   | $RH \leq 50\%$ , $t = 1\text{min.}$ ,<br>$T_A = 25^\circ\text{C}$ |      | 7, 8 |
| Input-Output Resistance                      | $R_{I-O}$ |      | $10^{14}$ |      | $\Omega$    | $V_{I-O} = 500\text{Vdc}$   |      | 7    |
| Input-Output Capacitance                     | $C_{I-O}$ |      | 0.6       |      | $\text{pF}$ | $f = 1\text{MHz}$ , $V_{I-O} = 0\text{Vdc}$                       |      | 7    |

\* The Input-Output Momentary Withstand Voltage is a dielectric voltage rating that should not be interpreted as an input-output continuous voltage rating.

Notes:

- 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.
- Use of a  $0.1\ \mu\text{F}$  bypass capacitor connected between pins 5 and 8 is recommended.
- The  $1.9\text{k}\Omega$  load represents 1 TTL unit load of  $1.6\text{mA}$  and the  $5.6\text{k}\Omega$  pull-up resistor.
- Pulse Width Distortion (PWD) is defined as  $|t_{PHL} - t_{PLH}|$  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 (i.e.,  $V_O > 2.0\text{V}$ ). 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 (i.e.,  $V_O < 0.8\text{V}$ ).
- Device considered a two terminal device: pins 1, 2, 3 and 4 shorted together, and pins 5, 6, 7 and 8 shorted together.
- In accordance with UL 1577, each optocoupler is proof tested by applying an insulation test voltage  $\geq 6000\text{V}_{RMS}$  for 1 second.

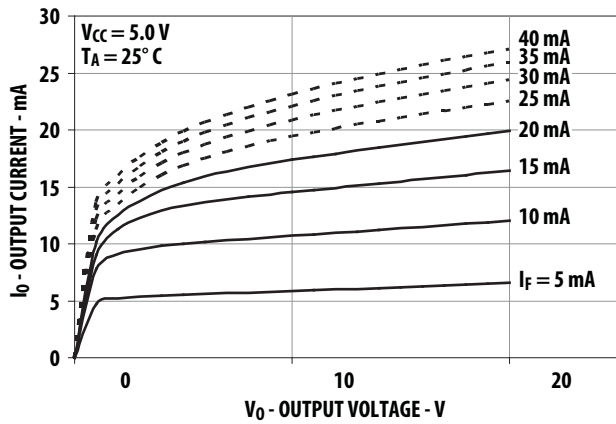


Figure 1. DC and Pulsed Transfer Characteristics

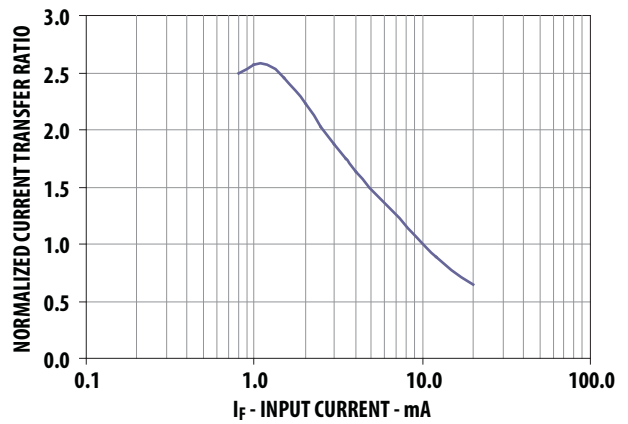


Figure 2. Current Transfer Ratio vs. Input Current  $V_O = 0.4\text{ V}$ ,  $V_{CC} = 5\text{ V}$ ,  $T_A = 25^\circ\text{ C}$

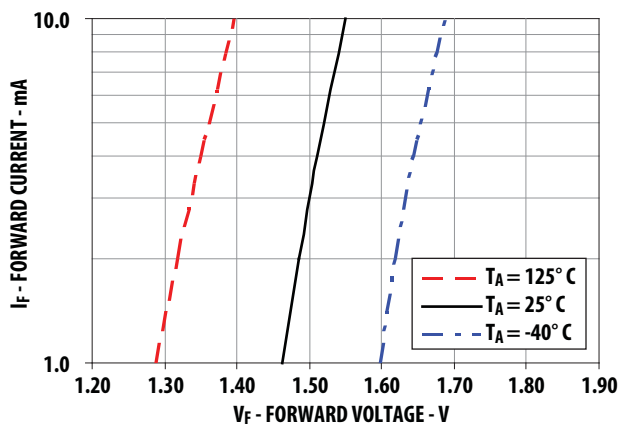


Figure 3. Input Current vs. Forward Voltage

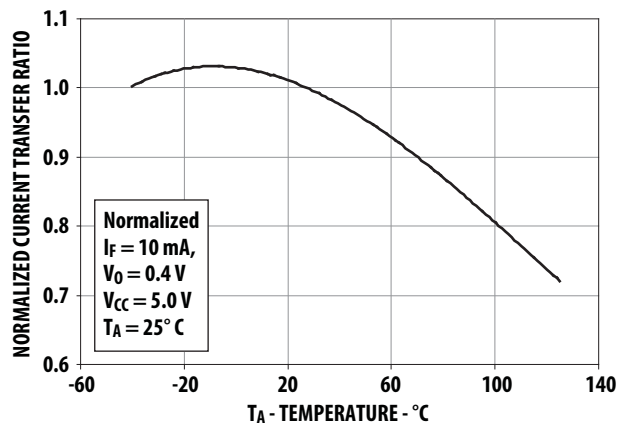


Figure 4. Current Transfer Ratio vs. Temperature

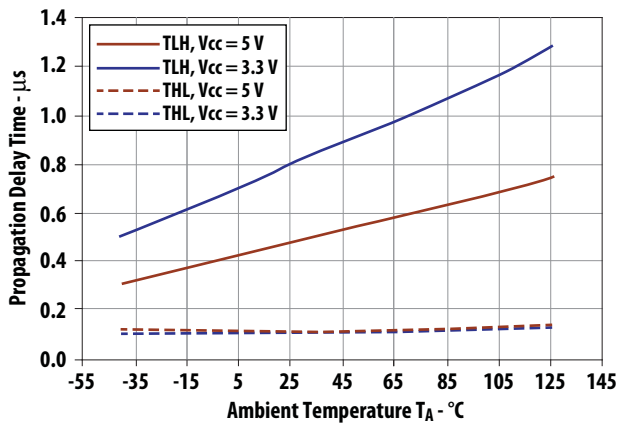


Figure 5, Propagation Delay Time vs. Temperature  
 $I_F = 10\text{ mA}$ ,  $R_L = 1.9\text{ k}\Omega$ ,  $C_L = 15\text{ pF}$

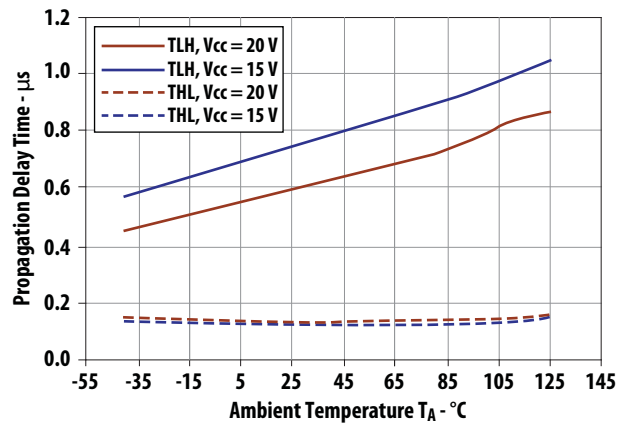


Figure 6. Propagation Delay Time vs. Temperature  
 $I_F = 10\text{ mA}$ ,  $R_L = 20\text{ k}\Omega$ ,  $C_L = 100\text{ pF}$

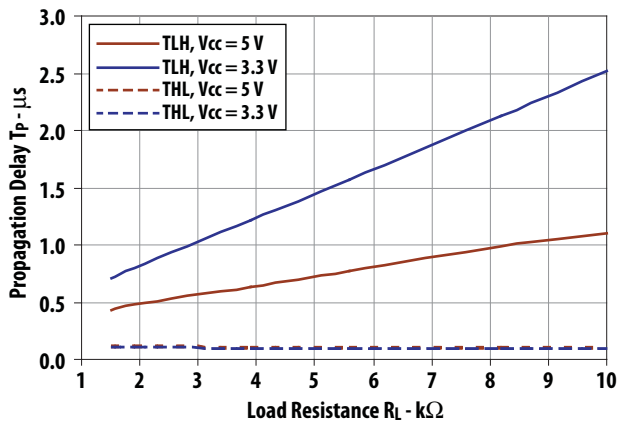


Figure 7. Propagation Delay Time vs. Load Resistance

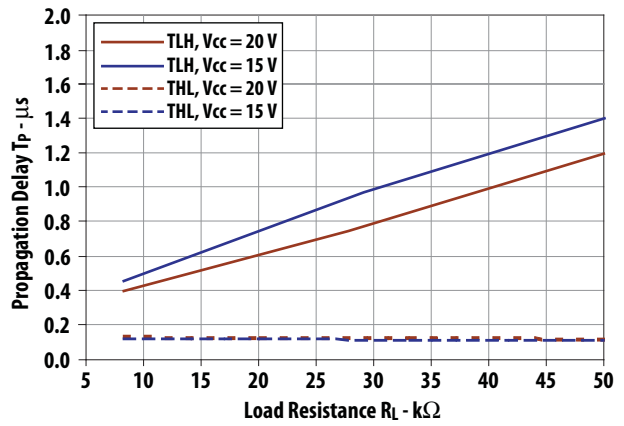


Figure 8. Propagation Delay Time vs. Load Resistance

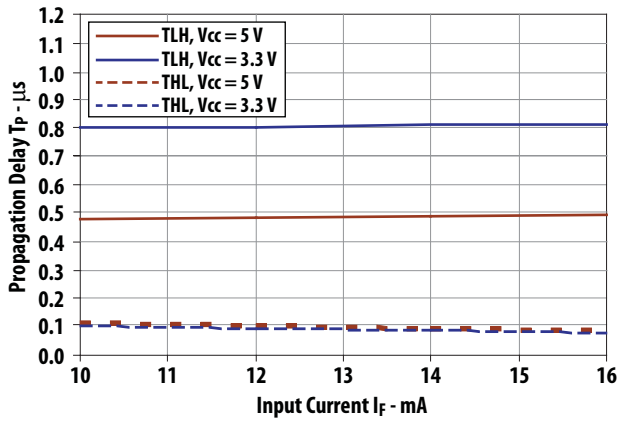


Figure 9. Propagation Delay Time vs. Input Current  
 $R_L = 1.9\text{ k}\Omega$ ,  $C_L = 15\text{ pF}$ ,  $T_A = 25^\circ\text{C}$

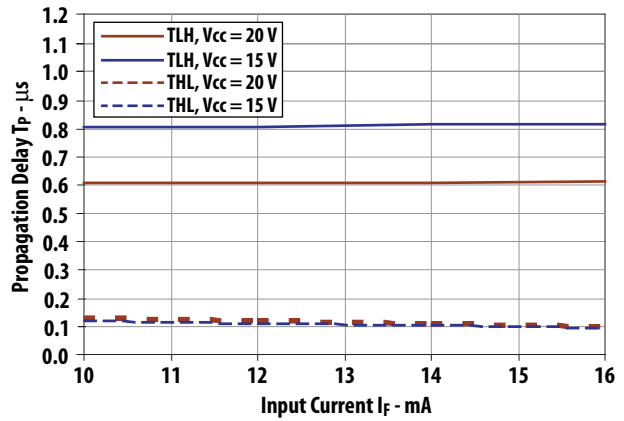


Figure 10. Propagation Delay Time vs. Input Current  
 $R_L = 20\text{ k}\Omega$ ,  $C_L = 15\text{ pF}$ ,  $T_A = 25^\circ\text{C}$

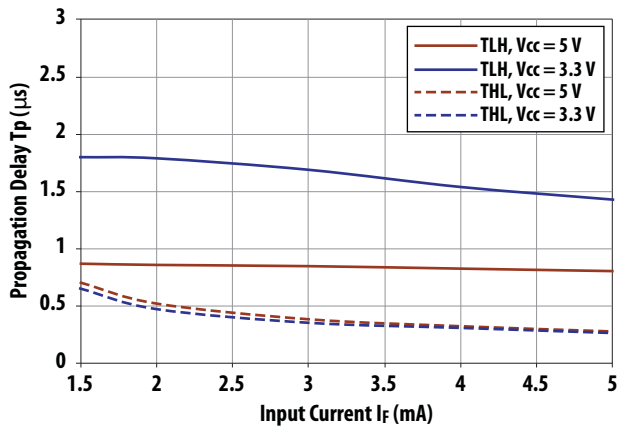


Figure 10a. Propagation Delay Time vs. Input Current  
 $R_L = 10\text{ k}\Omega$ ,  $C_L = 15\text{ pF}$ ,  $T_A = 25^\circ\text{C}$

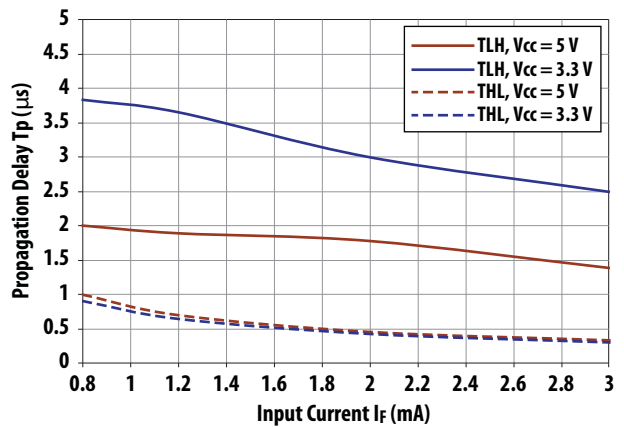


Figure 10b. Propagation Delay Time vs. Input Current  
 $R_L = 27\text{ k}\Omega$ ,  $C_L = 15\text{ pF}$ ,  $T_A = 25^\circ\text{C}$



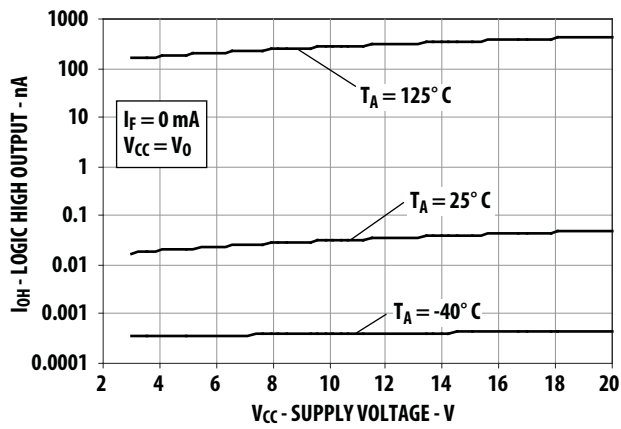


Figure 11. Logic High Output Current vs Supply Voltage

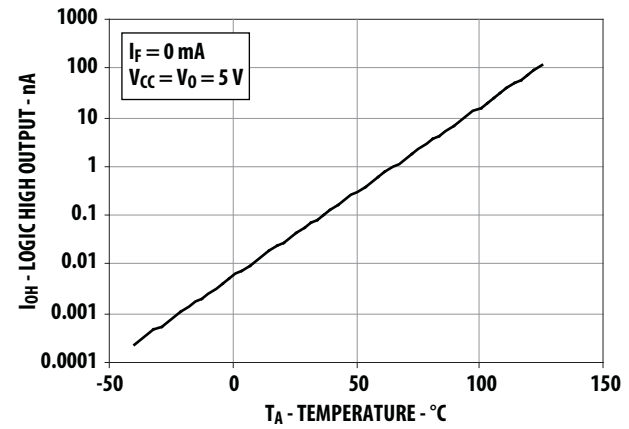


Figure 12. Logic High Output Current vs Temperature

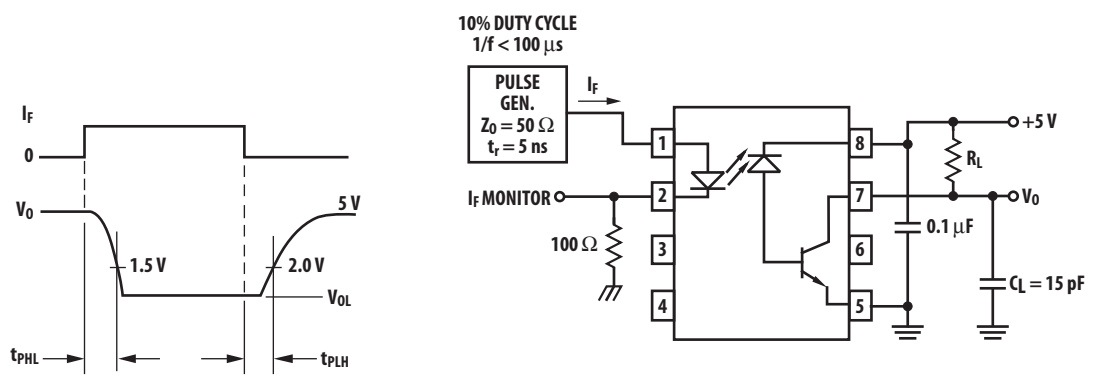


Figure 13. Switching Test Circuit

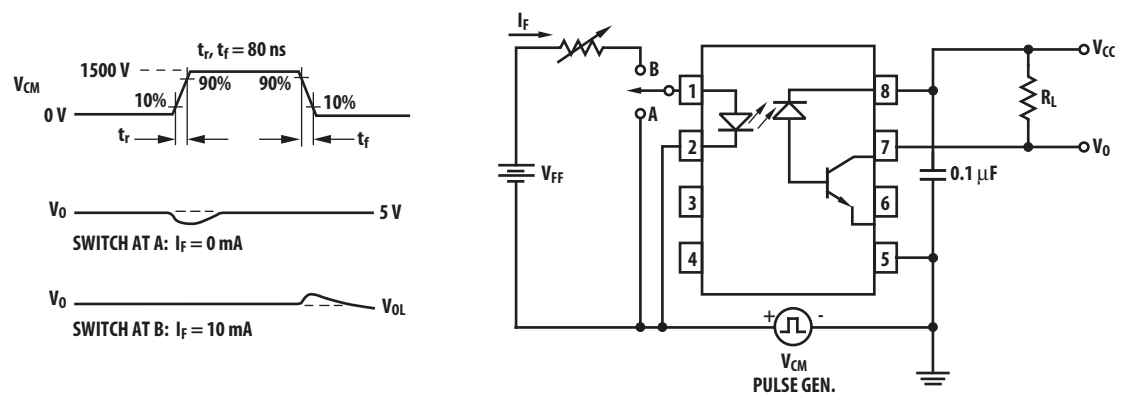


Figure 14. Test Circuit for Transient Immunity and Typical Waveforms

### Thermal Resistance Model for ACPL-K43T

The diagram of ACPL-K43T for measurement is shown in Figure 15. Here, one die is heated first and the temperatures of all the dice are recorded after thermal equilibrium is reached. Then, the 2<sup>nd</sup> 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 our case of two heat sources.

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

$R_{11}$  : Thermal Resistance of Die1 due to heating of Die1 (°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)

$\Delta T_1$  : Temperature difference between Die1 junction and ambient (°C)

$\Delta T_2$  : 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:

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

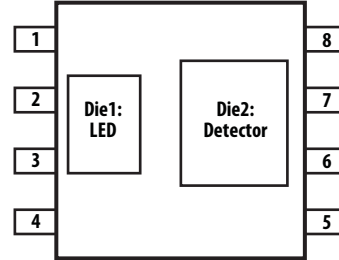


Figure 15. Diagram of ACPL-K43T for measurement

### Thermal Resistance Model for ACPL-K44T

The diagram of ACPL-K44T for measurement is shown in Figure 16. Here, one die is heated first and the temperatures of all the dice are recorded after thermal equilibrium is reached. Then, the 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> 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 4 by 4 matrix for our case of two heat sources.

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

$R_{11}$  : 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)

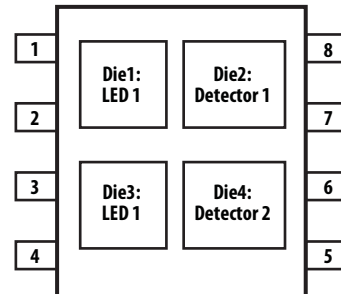


Figure 16. Diagram of ACPL-K44T for measurement

$R_{31}$  : Thermal Resistance of Die3 due to heating of Die1 ( $^{\circ}C/W$ )  
 $R_{32}$  : Thermal Resistance of Die3 due to heating of Die2 ( $^{\circ}C/W$ )  
 $R_{33}$  : Thermal Resistance of Die3 due to heating of Die3 ( $^{\circ}C/W$ )  
 $R_{34}$  : Thermal Resistance of Die3 due to heating of Die4 ( $^{\circ}C/W$ )  
 $R_{41}$  : Thermal Resistance of Die4 due to heating of Die1 ( $^{\circ}C/W$ )  
 $R_{42}$  : Thermal Resistance of Die4 due to heating of Die2 ( $^{\circ}C/W$ )  
 $R_{43}$  : Thermal Resistance of Die4 due to heating of Die3 ( $^{\circ}C/W$ )  
 $R_{44}$  : Thermal Resistance of Die4 due to heating of Die4 ( $^{\circ}C/W$ )  
 $P_1$  : Power dissipation of Die1 (W)  
 $P_2$  : Power dissipation of Die2.  
 $P_3$  : Power dissipation of Die3 (W)  
 $P_4$  : Power dissipation of Die4.  
 $T_1$  : Junction temperature of Die1 due to heat from all dice ( $^{\circ}C$ )  
 $T_2$  : Junction temperature of Die2 due to heat from all dice ( $^{\circ}C$ )  
 $T_3$  : Junction temperature of Die3 due to heat from all dice ( $^{\circ}C$ )  
 $T_4$  : Junction temperature of Die4 due to heat from all dice ( $^{\circ}C$ )  
 $T_a$  : Ambient temperature ( $^{\circ}C$ )  
 $\Delta T_1$  : Temperature difference between Die1 junction and ambient ( $^{\circ}C$ )  
 $\Delta T_2$  : Temperature deference between Die2 junction and ambient ( $^{\circ}C$ )  
 $\Delta T_3$  : Temperature difference between Die3 junction and ambient ( $^{\circ}C$ )  
 $\Delta T_4$  : Temperature deference between Die4 junction and ambient ( $^{\circ}C$ )  
 $T_1 = (R_{11} \times P_1 + R_{12} \times P_2 + R_{13} \times P_3 + R_{14} \times P_4) + T_a -- (1)$   
 $T_2 = (R_{21} \times P_1 + R_{22} \times P_2 + R_{23} \times P_3 + R_{24} \times P_4) + T_a -- (2)$   
 $T_3 = (R_{31} \times P_1 + R_{32} \times P_2 + R_{33} \times P_3 + R_{34} \times P_4) + T_a -- (3)$   
 $T_4 = (R_{41} \times P_1 + R_{42} \times P_2 + R_{43} \times P_3 + R_{44} \times P_4) + T_a -- (4)$

**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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 AV02-3179EN - June 20, 2012

