Thermal Data for Agilent Optocouplers

Application Note 1087

Introduction

This document contains steady state thermal models for optocouplers based on empirical data and theoretical extrapolation.

Seven thermal models have been chosen to suit the type of optocoupler:

- Thermal Model-A for a hermetic-package optocoupler
- Thermal Model-B for a single-channel plastic-package optocoupler
- Thermal Model-C for a single-channel HCPL-3700/60 optocoupler with input buffer circuit
- Thermal Model-D for a dual-channel plastic-package optocoupler
- Thermal Model-E for a Single-Channel Optocoupler with input buffer circuit
- Thermal Model-F for a single channel SO-5 plastic-package optocoupler
- Thermal Model-G for a dual channel SO-16 plastic-package optocoupler

The thermal data in each of these models allows the user to calculate the approximate junction temperatures at various nodes in the optocoupler. The actual semiconductor junction temperatures may vary based upon the heat flows from the surrounding components on the printed circuit board. Each of the models assumes that the optocoupler is either soldered to a printed circuit board (PCB) or placed in a socket, which is soldered on a PCB. The PCB is further assumed to be in still air. In models that define the optocoupler case to be a node, the case-to-ambient thermal resistance will depend on the board design and the placement of the optocoupler. The package case temperature is measured at the center of the package bottom.

The data presented in each of these models is approximate and is meant to be an indicator, not a specification. To ensure reliability, the semiconductor junction temperatures in plastic-package optocouplers must not exceed 125 °C, and in hermetic-package optocouplers it must not exceed 175 °C unless otherwise specified.

All thermal data in this document are taken from testing on Agilent Technologies devices. They are not transferable to other manufacturers' part types.

Agilent Technologies

Table 1. Optocoupler Thermal Model Index.

Part Number	Thermal Model Type	Comments
4N45/6	Model-B	Approximates 6N138 data
4N55	Model-A	
6N134	Model-A	
6N135/6/7/8/9	Model-B	
6N140	Model-A	
HCNW135/6/7, HCNW4502/3, HCNW2601/11	Model-B	
HCNW138/9, HCNW4562	Model-B	Approximates HCNW135 data
HCNW2201/4504/4506	Model-B	Approximates HCNW2601 data
HCPL-0452/3, -0500/1, -050L	Model-B	
HCPL-0201/11, -0454, -0466, -0600/01/11, -0708, -060L	Model-B	Approximates HCPL-0600 data
HCPL-0700/1, 070L	Model-B	
HCPL-0530/1/4, -0630/1, -0730/1, -053L, -063L, -073L	Model-D	Approximates HCPL-0738 data
HCPL-0370	Model-E	
HCPL-0738	Model-D	
HCPL-1930/1	Model-A	
HCPL-2200/01/02/11/12/19	Model-B	
HCPL-2231/2	Model-D	Approximates HCPL-2430 data
HCPL-2300	Model-B	Approximates HCPL-2601 data
HCPL-2400/11	Model-B	
HCPL-2430	Model-D	
HCPL-2502/3, -250L	Model-B	Approximates 6N135 data
HCPL-2530/1/3, -253L	Model-D	Approximates HCPL-2430 data
HCPL-2601/11/12, -260L	Model-B	Approximates 6N137 data
HCPL-2630/1, -2730/1, -263L, -273L	Model-D	Approximates HCPL-2430 data
HCPL-3000, 3100/1		Refer to Application Note 1058
HCPL-3120/3150/3180		Refer to HCPL-3120/3150/3180 data sheets
HCPL-314J	Model-G	Approximates HCPL-315J data
HCPL-315J	Model-G	
HCPL-316J		Refer to HCPL-316J data sheets
HCPL-3700/3760	Model-C	
HCPL-4100/4200	Model-C	Approximates HCPL-3700 data
HCPL-4502/3/4/6	Model-B	Approximates 6N135 data
HCPL-4534	Model-D	Approximates HCPL-2430 data
HCPL-4562	Model-B	Approximates 6N135 data
HCPL-4661	Model-D	Approximates HCPL-2430 data
HCPL-4701	Model-B	Approximates 6N138 data
HCPL-4731	Model-D	Approximates HCPL-2430 data
HCPL-52XX, -54XX, -55XX, -56XX, -57XX, -62XX, -64XX, -65XX	Model-A	
HCPL-7100/01	Model-E	
HCPL-7710, -7720, -7721, -7723	Model-E	Approximates HCPL-7100 data
HCPL-0710, -0720, -0721, -0723	Model-E	Approximates HCPL-0370 data
HCPL-7601/7611	Model-B	Approximates 6N137 data
HCPL-7800/40, -7510/20,	Model-C	Approximates HCPL-3700 data
HCPL-7860/786J		Refer to HCPL-7860/786J data sheet
HSSR-7110		Refer to HSSR-7110 data sheet
HCPL-M600/601/611	Model-F	
HCPL-M452/3/4/6, -M700/701	Model-F	Approximates HCPL-M600/601/611 data

Thermal Model-A for a Hermetic-Package Optocoupler

Definitions

θ_{E-C}: Thermal impedance from emitter (input LED) junction to package case.

θ_{D-C}: Thermal impedance from detector (output IC) junction to package case.

θ_{C-A}: Thermal impedance from package case to ambient. The value q_{C-A} depends on the heat flows from surrounding components, and can be estimated to be in the range of 70 °C/W to 210 °C/W (see Note 5).

Package Case Temperature: Measured at center of package bottom, with no forced air. Ambient Temperature: Measured approximately 15 cm above the package.

Description

This thermal model assumes that an 8- or 16-pin dual-in-line package hermetic optocoupler is inserted into an IC socket, which is soldered into a 7.5 cm x 7.5 cm printed circuit board (PCB). The PCB is suspended in still air.

Thermal impedance values shown in the above figure can be used for calculating the temperatures at each node for a given operating condition. The thermal resistance between the LED and other internal nodes is very large in comparison with the terms shown in the figure, and is omitted for simplicity

For optocouplers that have more than one channel, the same values for q_{E-C} and q_{D-C} can be assumed to be in parallel, as shown by the dotted lines, for each of the additional LED and detector. Again, the direct thermal impedance between any two LEDs, any two detectors, or an LED and a detector is very large in comparison to q_{E-C} and q_{D-C}, and may be omitted.

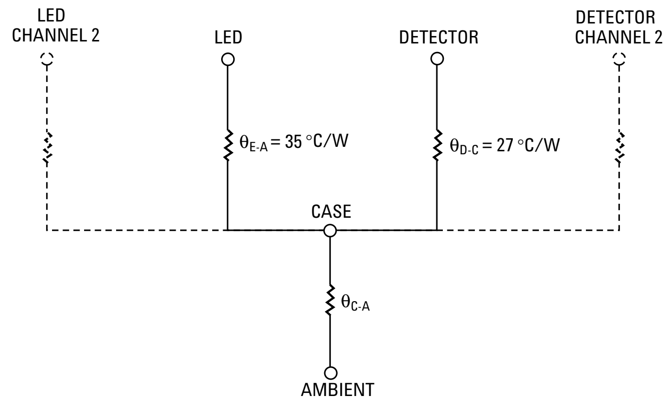

Figure 1. Thermal Model-A Diagram

Notes:

1. Above model is applicable for HCPL-52XX, -54XX, -55XX, -56XX, -57XX, -62XX, 64XX, -65XX, -66XX, -67XX; 4N55; 6N134; and 6N140.
2. For HSSR-7100/1 thermal model, refer to its data sheet.
3. HCPL-193X and HCPL-576X have an input buffer IC. The above model may be used for these optocouplers with an assumption that the Input Buffer IC and LED are a common node. The thermal impedance of this common node to case is approximately 35 °C/W.
4. Maximum Junction Temperature for HSSR-7110/1: 150 °C; for all other hermetic optocouplers: 175 °C.
5. The thermal data in this model assumes the optocoupler is inserted into a socket. Thermal impedance q_{C-A} is likely to be lower when the optocoupler is soldered to a printed circuit board.

Thermal Model-B for a Single-Channel Plastic-Package Optocoupler

Definitions

θ_1: Thermal impedance from LED junction to ambient

θ_2: Thermal impedance from LED to detector (output IC)

θ_3: Thermal impedance from detector (output IC) junction to ambient

Ambient Temperature: Measured approximately 1.25 cm above the optocoupler, with no forced air.

Description

This thermal model assumes that an 8-pin single-channel plastic package optocoupler is soldered into an 8.5 cm x 8.1 cm printed circuit board (PCB). The temperature at the LED and Detector junctions of the optocoupler can be calculated using the equations below.

$\Delta T_{EA} = A_{11}P_E + A_{12}P_D$

$\Delta T_{DA} = A_{21}P_E + A_{22}P_D$

where:

ΔT_{EA} = Temperature difference between ambient and LED
ΔT_{DA} = Temperature difference between ambient and detector
P_E = Power dissipation from LED
P_D = Power dissipation from detector
A_{11}, A_{12}, A_{21}, A_{22} thermal coefficients (units in °C/W) are functions of the thermal impedances θ_1, θ_2, θ_3 (See Note 2).

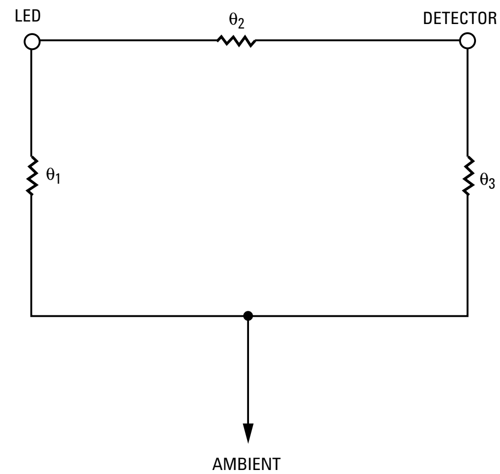

Figure 2. Thermal Model-B Diagram

Table 2 Thermal Model-B Coefficient Data (units in °C/W).

Part Number	A_{11}	A_{12}, A_{21}	A_{22}
6N135/6, HCPL-4503	323	154	225
HCNW135/6, HCNW4502/3	220	61	166
HCPL-0500/1, HCPL-0452/3	409	201	295
HCNW137, HCNW2601/11	219	51	139
HCPL-0600/01/11	455	216	308
HCPL-0700/1	396	193	290
HCPL-2200/01/02/11/12	304	149	216
HCPL-2400/11	337	139	215

Notes:
1. Maximum junction temperature for above parts: 125 °C.
2. $A_{11} = q_1 \| (q_2 + q_3)$; $A_{12} = A_{21} = (q_1 q_2) / (q_1 + q_2 + q_3)$; $A_{22} = q_3 \| (q_2 + q_3)$.

Thermal Model-C for HCPL-3700/60 Optocoupler with Input Buffer Circuit

Definitions

θ1: Thermal impedance from LED/input-buffer IC junctions to ambient

θ2: Thermal impedance from detector IC junction to ambient

Ambient Temperature: Measured approximately 1.25 cm above package, with no forced air.

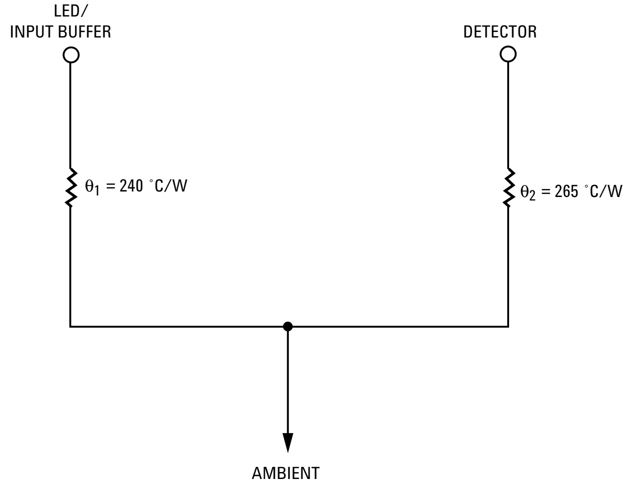

Figure 3. Thermal Model-C Diagram

Description

Thermal impedance values shown in the above figure can be used for calculating the temperatures at each node for a given operating condition. For simplification, the LED and the Input Buffer IC are assumed to be at the same node.

Furthermore, the thermal resistance between the LED and detector are very large in comparison with the terms shown in the figure, and are omitted for simplicity.

$\Delta T_{EA} = q_1 P_E$

$\Delta T_{DA} = q_2 P_D$

where:
ΔT_{EA} = Temperature difference between ambient and LED
ΔT_{DA} = Temperature difference between ambient and detector
P_E = Power dissipation from LED
P_D = Power dissipation from detector

Note:
1 Maximum junction temperature for above part: 125 °C.
2. Please refer to Thermal Model-E that is simulated with three dies.

Thermal Model-D for a Dual-Channel Plastic-Package Optocoupler

Definitions

θ_1, θ_2, θ_3, θ_4, θ_5, θ_6, θ_7, θ_8, θ_9, θ_{10}: Thermal impedances between nodes as shown in Figure 4.

Ambient Temperature: Measured approximately 1.25 cm above the optocoupler HCPLl-2430 with no forced air and 2.54cm around the optocoupler HCPL-0738 with no forced air.

Description

HCPL-2430 thermal model assumes that an 8-pin dual-channel plastic package optocoupler is soldered into an 8.5 cm x 8.1 cm printed circuit board (PCB). HCPL-0738 thermal model assumes that a SO-8 plastic package optocoupler is soldered into a 7.62 cm x 7.62 cm low K board. These optocouplers are hybrid devices with four die: two LEDs and two detectors. The temperature at the LED and the detector of the optocoupler can be calculated by using the equations below.

$\Delta T_{E1A} = A_{11}P_{E1} + A_{12}P_{E2} + A_{13}P_{D1} + A_{14}P_{D2}$

$\Delta T_{E2A} = A_{21}P_{E1} + A_{22}P_{E2} + A_{23}P_{D1} + A_{24}P_{D2}$

$\Delta T_{D1A} = A_{31}P_{E1} + A_{32}P_{E2} + A_{33}P_{D1} + A_{34}P_{D2}$

$\Delta T_{D2A} = A_{41}P_{E1} + A_{42}P_{E2} + A_{43}P_{D1} + A_{44}P_{D2}$

where:

ΔT_{E1A} = Temperature difference between ambient and LED 1
ΔT_{E2A} = Temperature difference between ambient and LED 2
ΔT_{D1A} = Temperature difference between ambient and detector 1
ΔT_{D2A} = Temperature difference between ambient and detector 2
P_{E1} = Power dissipation from LED 1;
P_{E2} = Power dissipation from LED 2;
P_{D1} = Power dissipation from detector 1;
P_{D2} = Power dissipation from detector 2
A_{XY} thermal coefficient (units in °C/W) is a function of thermal impedances θ_1 through θ_{10}.

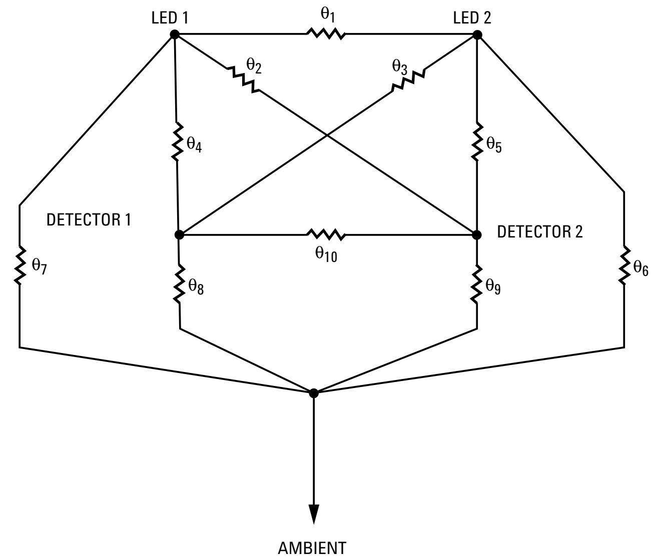

Figure 4. Thermal Model-D Diagram

Table 3 Thermal Model-D Coefficient Data (units in °C/W).

Part Number	A_{11}, A_{22}	A_{12}, A_{21}	A_{13}, A_{31}	A_{14}, A_{41}	A_{23}, A_{32}	A_{24}, A_{42}	A_{33}, A_{44}	A_{34}, A_{43}
HCPL-2430	308	92	101	91	91	101	162	112
HCPL-0738	383	188	179	196	193	178	249	200

Note: Maximum junction temperature for above part: 125 °C.

Thermal Model-E for a Single-Channel Optocoupler with Input Buffer Circuit

Definitions

θ_1, θ_2, θ_3, θ_4, θ_5, θ_6: Thermal impedances between nodes as shown in Figure 5.

Ambient Temperature: Measured approximately 1.25 cm above the optocoupler HCPL-7100/01 with no forced air and 2.54cm around the optocoupler HCPL-0370 with no forced air.

Description

HCPL-7100/1 thermal model assumes that the optocoupler is soldered into an 8.5 cm x 8.1 cm printed circuit board (PCB). HCPL-0370 thermal model assumes that the optocoupler is soldered into a 7.62 cm x 7.62 cm low K board. These couplers are hybrid devices with three die: an input IC that drives the LED, an LED, and the detector IC. The temperature at the input IC, LED, and detector of this optocoupler can be calculated be using the equations below.

$\Delta T_{IA} = A_{11}P_I + A_{12}P_E + A_{13}P_D$

$\Delta T_{EA} = A_{21}P_I + A_{22}P_E + A_{23}P_D$

$\Delta T_{DA} = A_{31}P_I + A_{32}P_E + A_{33}P_D$

where:

ΔT_{IA} = Temperature difference between ambient and input IC
ΔT_{EA} = Temperature difference between ambient and LED
ΔT_{DA} =Temperature difference between ambient and detector
P_I = Power dissipation from input IC (Typical: 25 mW)
P_E = Power dissipation from LED (Typical: 10 mW when input Logic Low; less than 0.01 mW when input Logic High)
P_D = Power dissipation from detector (Typical 30 mW)
A_{11} through A_{33} thermal coefficients (units in °C/W) are functions of thermal impedances θ_1, θ_2, θ_3, θ_4, θ_5, θ_6.

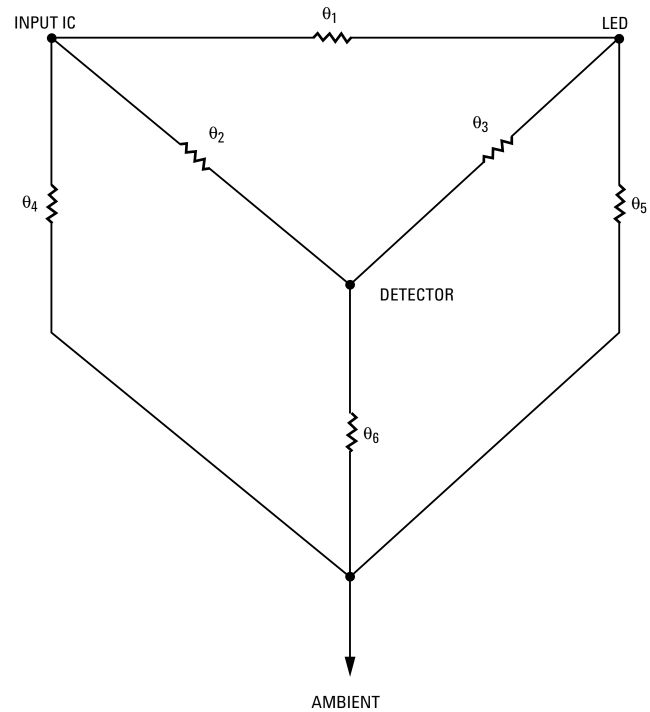

Figure 5. Thermal Model-E Diagram

Table 4 Thermal Model-E Coefficient Data (units in °C/W).

Part Number	A_{11}	A_{12}	A_{13}	A_{21}	A_{22}	A_{23}	A_{31}	A_{32}	A_{33}
HCPL-7100/1	206	133	103	133	299	115	103	115	193
HCPL-0370	240	191	141	205	328	167	165	173	255

Note: Maximum junction temperature for above part: 125 °C.

Thermal Model-F for a Single-Channel SO-5 Plastic-Package Optocoupler

Definitions

θ_1: Thermal impedance from LED junction to ambient

θ_2: Thermal impedance from LED to detector (output IC)

θ_3: Thermal impedance from detector (output IC) junction to ambient

Ambient Temperature: Measured approximately 2.54 cm around the optocoupler with no forced air.

Description

This thermal model assumes that a 5-pin single-channel plastic package optocoupler is soldered into a 7.62 cm x 7.62 cm low K printed circuit board (PCB). The temperature at the LED and Detector junctions of the optocoupler can be calculated using the equations below.

$\Delta T_{EA} = A_{11}P_E + A_{12}P_D$

$\Delta T_{DA} = A_{21}P_E + A_{22}P_D$

where:

ΔT_{EA} = Temperature difference between ambient and LED
ΔT_{DA} = Temperature difference between ambient and detector
P_E = Power dissipation from LED
P_D = Power dissipation from detector
A_{11}, A_{12}, A_{21}, A_{22} thermal coefficients (units in °C/W) are functions of the thermal impedances θ_1, θ_2, θ_3 (See Note 2).

Table 5 Thermal Model-F Coefficient Data (units in °C/W).

Part Number	A_{11}	A_{12}, A_{21}	A_{22}
HCPL-M601/M611	399	223	282

Notes:
1. Maximum junction temperature for above parts: 125 °C.
2. $A_{11} = q_1 \,||\, (q_2 + q_3)$; $A_{12} = A_{21} = (q_1 q_2) / (q_1 + q_2 + q_3)$; $A_{22} = q_3 \,||\, (q_2 + q_3)$.

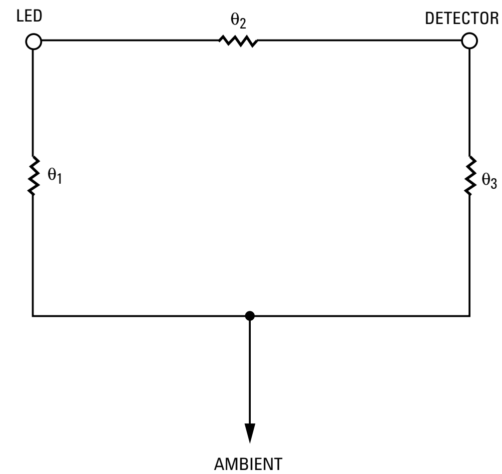

Figure 6. Thermal Model-F Diagram

Thermal Model-G for a Dual-Channel SO-16 Plastic-Package Optocoupler

Definitions

θ_1, θ_2, θ_3, θ_4, θ_5, θ_6, θ_7, θ_8, θ_9, θ_{10}: Thermal impedances between nodes as shown in Figure 7.

Ambient Temperature: Measured 1.25 cm above the optocoupler with no forced air.

Description

This thermal model assumes that a 16-pin dual-channel plastic package optocoupler is soldered into an 8.5 cm x 8.1 cm printed circuit board. These optocouplers are hybrid devices with four die: two LEDs and two detectors. The temperature at the LED and the detector of the optocoupler can be calculated by using the equations below.

$\Delta T_{E1A} = A_{11}P_{E1} + A_{12}P_{E2} + A_{13}P_{D1} + A_{14}P_{D2}$

$\Delta T_{E2A} = A_{21}P_{E1} + A_{22}P_{E2} + A_{23}P_{D1} + A_{24}P_{D2}$

$\Delta T_{D1A} = A_{31}P_{E1} + A_{32}P_{E2} + A_{33}P_{D1} + A_{34}P_{D2}$

$\Delta T_{D2A} = A_{41}P_{E1} + A_{42}P_{E2} + A_{43}P_{D1} + A_{44}P_{D2}$

Where:

ΔT_{E1A} = Temperature difference between ambient and LED 1
ΔT_{E2A} = Temperature difference between ambient and LED 2
ΔT_{D1A} = Temperature difference between ambient and detector 1
ΔT_{D2A} = Temperature difference between ambient and detector 2
P_{E1} = Power dissipation from LED 1;
P_{E2} = Power dissipation from LED 2;
P_{D1} = Power dissipation from detector 1;
P_{D2} = Power dissipation from detector 2
A_{XY} thermal coefficient (units in °C/W) is a function of thermal impedances θ_1 through θ_{10}.

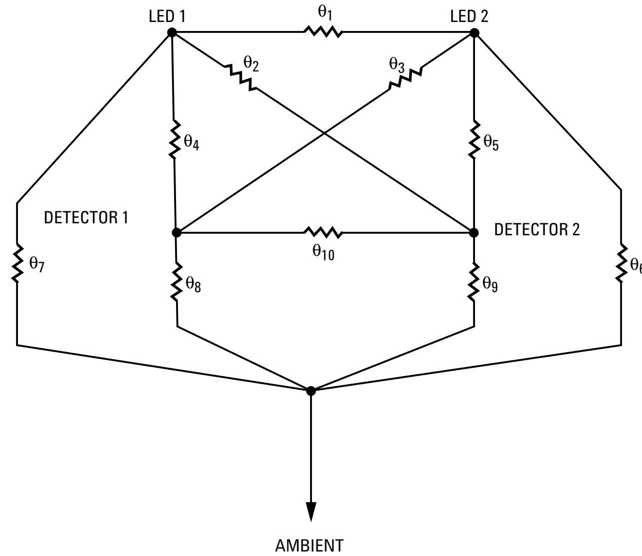

Figure 7. Thermal Model-G Diagram

Table 6 Thermal Model-D Coefficient Data (units in °C/W).

Part Number	A_{11}, A_{22}	A_{12}, A_{21}	A_{13}, A_{31}	A_{14}, A_{41}	A_{23}, A_{32}	A_{24}, A_{42}	A_{33}, A_{44}	A_{34}, A_{43}
HCPL-315J	198	64	62	83	90	64	137	69

Note: Maximum junction temperature for above part: 125 °C.

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Data subject to change.

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