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August 2016

# Single-Channel: 6N138M, 6N139M Dual-Channel: HCPL2730M, HCPL2731M 8-Pin DIP Low Input Current High Gain Split Darlington Optocouplers

## Features

- Low Current – 0.5 mA
- Superior CTR – 2000%
- Superior CMR – 10 kV/ $\mu$ s
- CTR Guaranteed 0 to 70°C
- Dual Channel – HCPL2730M, HCPL2731M
- Safety and Regulatory Approvals
  - UL1577, 5,000 VAC<sub>RMS</sub> for 1 Minute
  - DIN EN/IEC60747-5-5

## Applications

- Digital Logic Ground Isolation
- Telephone Ring Detector
- EIA-RS-232C Line Receiver
- High Common Mode Noise Line Receiver
- $\mu$ P Bus Isolation
- Current Loop Receiver

## Description

The single-channel, 6N138M, 6N139M and dual-channel HCPL2730M, HCPL2731M optocouplers consist of an AlGaAs LED optically coupled to a high gain split darlington photodetector.

The split darlington configuration separating the input photodiode and the first stage gain from the output transistor permits lower output saturation voltage and higher speed operation than possible with conventional darlington phototransistor optocoupler. In the dual channel devices, HCPL2730M and HCPL2731M, an integrated emitter-base resistor provides superior stability over temperature.

The combination of a very low input current of 0.5 mA and a high current transfer ratio of 2000% makes this family particularly useful for input interface to MOS, CMOS, LSTTL and EIA RS232C, while output compatibility is ensured to CMOS as well as high fan-out TTL requirements. An internal noise shield provides exceptional common mode rejection of 10 kV/ $\mu$ s.

## Related Resources

- [www.fairchildsemi.com/products/optoelectronics/](http://www.fairchildsemi.com/products/optoelectronics/)
- [www.fairchildsemi.com/pf/HC/HCPL0700.html](http://www.fairchildsemi.com/pf/HC/HCPL0700.html)
- [www.fairchildsemi.com/pf/HC/HCPL0730.html](http://www.fairchildsemi.com/pf/HC/HCPL0730.html)
- [www.fairchildsemi.com/pf/HC/HCPL0731.html](http://www.fairchildsemi.com/pf/HC/HCPL0731.html)

## Schematics

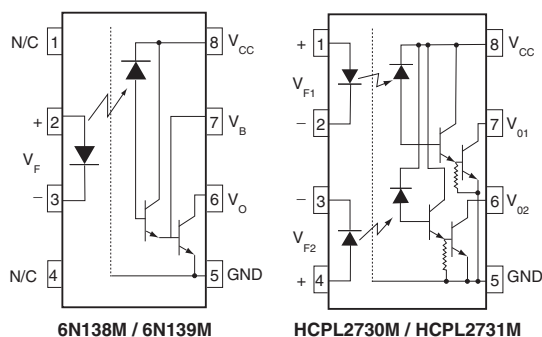


Figure 1. Schematics

## Package Outlines

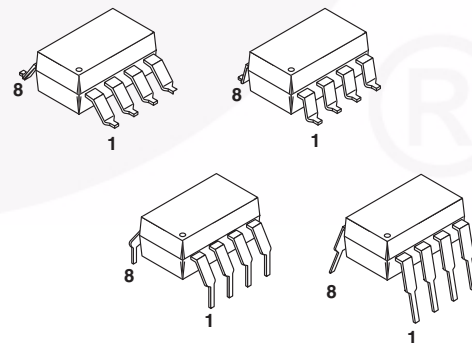


Figure 2. Package Options

## Safety and Insulation Ratings

As per DIN EN/IEC 60747-5-5, this optocoupler is suitable for “safe electrical insulation” only within the safety limit data. Compliance with the safety ratings shall be ensured by means of protective circuits.

Parameter	Characteristics	
Installation Classifications per DIN VDE 0110/1.89 Table 1, For Rated Mains Voltage	< 150 V <sub>RMS</sub>	I-IV
	< 300 V <sub>RMS</sub>	I-IV
	< 450 V <sub>RMS</sub>	I-III
	< 600 V <sub>RMS</sub>	I-III
	< 1,000 V <sub>RMS</sub> (Option T, TS)	I-III
Climatic Classification	40/100/21	
Pollution Degree (DIN VDE 0110/1.89)	2	
Comparative Tracking Index	175	

Symbol	Parameter	Value	Unit
V <sub>PR</sub>	Input-to-Output Test Voltage, Method A, V <sub>IORM</sub> × 1.6 = V <sub>PR</sub> , Type and Sample Test with t <sub>m</sub> = 10 s, Partial Discharge < 5 pC	2,262	V <sub>peak</sub>
	Input-to-Output Test Voltage, Method B, V <sub>IORM</sub> × 1.875 = V <sub>PR</sub> , 100% Production Test with t <sub>m</sub> = 1 s, Partial Discharge < 5 pC	2,651	V <sub>peak</sub>
V <sub>IORM</sub>	Maximum Working Insulation Voltage	1,414	V <sub>peak</sub>
V <sub>IOTM</sub>	Highest Allowable Over-Voltage	6,000	V <sub>peak</sub>
	External Creepage	≥ 8.0	mm
	External Clearance	≥ 7.4	mm
	External Clearance (for Option TV, 0.4" Lead Spacing)	≥ 10.16	mm
DTI	Distance Through Insulation (Insulation Thickness)	≥ 0.5	mm
T <sub>S</sub>	Case Temperature <sup>(1)</sup>	150	°C
I <sub>S,INPUT</sub>	Input Current <sup>(1)</sup>	200	mA
P <sub>S,OUTPUT</sub>	Output Power (Duty Factor ≤ 2.7%) <sup>(1)</sup>	300	mW
R <sub>IO</sub>	Insulation Resistance at T <sub>S</sub> , V <sub>IO</sub> = 500 V <sup>(1)</sup>	> 10 <sup>9</sup>	Ω

### Note:

1. Safety limit value - maximum values allowed in the event of a failure.

## Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only.  $T_A = 25^\circ\text{C}$  unless otherwise specified.

Symbol	Parameter	Value	Unit
$T_{STG}$	Storage Temperature	-40 to +125	$^\circ\text{C}$
$T_{OPR}$	Operating Temperature	-40 to +100	$^\circ\text{C}$
$T_J$	Junction Temperature	-40 to +125	$^\circ\text{C}$
$T_{SOL}$	Lead Solder Temperature	260 for 10 sec	$^\circ\text{C}$

Symbol	Parameter	Device	Value	Unit
<b>EMITTER</b>				
$I_F$ (avg)	DC/Average Forward Input Current Per Channel	All	20	mA
$I_F$ (pk)	Peak Forward Input Current Per Channel (50% duty cycle, 1 ms P.W.)	All	40	mA
$I_F$ (trans)	Peak Transient Input Current Per Channel ( $\leq 1 \mu\text{s}$ P.W., 300 pps)	All	1	A
$V_R$	Reverse Input Voltage Per Channel	All	5	V
$P_D$	Input Power Dissipation Per Channel <sup>(2)</sup>	All	35	mW
<b>DETECTOR</b>				
$I_O$ (avg)	Average Output Current Per Channel	All	60	mA
$V_{ER}$	Emitter-Base Reverse Voltage	6N138M, 6N139M	0.5	V
$V_{CC}, V_O$	Supply Voltage, Output Voltage	6N138M, HCPL2730M	-0.5 to 7.0	V
		6N139M, HCPL2731M	-0.5 to 18.0	
$P_O$	Output Power Dissipation Per Channel	All	100	mW

**Note:**

- No derating required for devices operated within the  $T_{OPR}$  specification (6N138M and 6N139M only).

## Electrical Characteristics

### Individual Component Characteristics

( $V_{CC} = 5.0\text{ V}$ ,  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$  unless otherwise specified. Typical value is measured at  $T_A = 25^\circ\text{C}$ .)

Symbol	Parameter	Device	Test Conditions	Min.	Typ.	Max.	Unit
<b>EMITTER</b>							
$V_F$	Input Forward Voltage	All	$I_F = 1.6\text{ mA}$ , $T_A = 25^\circ\text{C}$		1.30	1.70	V
			$I_F = 1.6\text{ mA}$			1.75	
$BV_R$	Input Reverse Breakdown Voltage	All	$I_R = 10\text{ }\mu\text{A}$ , $T_A = 25^\circ\text{C}$	5.0	19.0		V
$\Delta V_F / \Delta T_A$	Temperature Coefficient of Forward Voltage	All	$I_F = 1.6\text{ mA}$		-1.94		mV/ $^\circ\text{C}$
<b>DETECTOR</b>							
$I_{CCL}$	Logic Low Supply Current	6N138M, 6N139M	$I_F = 1.6\text{ mA}$ , $V_O = \text{Open}$ , $V_{CC} = 18\text{ V}$		0.4	1.5	mA
		HCPL2730M	$V_{CC} = 7\text{ V}$	$I_{F1} = I_{F2} = 1.6\text{ mA}$ , $V_{O1} = V_{O2} = \text{Open}$	1.25	3	
		HCPL2731M	$V_{CC} = 18\text{ V}$				
$I_{CCH}$	Logic High Supply Current	6N138M, 6N139M	$I_F = 0\text{ mA}$ , $V_O = \text{Open}$ , $V_{CC} = 18\text{ V}$		0.0003	10	$\mu\text{A}$
		HCPL2730M	$V_{CC} = 7\text{ V}$	$I_{F1} = I_{F2} = 0\text{ mA}$ , $V_{O1} = V_{O2} = \text{Open}$	0.0003	20	
		HCPL2731M	$V_{CC} = 18\text{ V}$				

### Transfer Characteristics

Symbol	Parameter	Device	Test Conditions	Min.	Typ.	Max.	Unit
<b>COUPLED</b>							
CTR	Current Transfer Ratio <sup>(3)(4)</sup>	6N138M	$I_F = 1.6\text{ mA}$ , $V_O = 0.4\text{ V}$ , $V_{CC} = 4.5\text{ V}$	300	1600		%
		HCPL2730M			2400		
		6N139M	$I_F = 0.5\text{ mA}$ , $V_O = 0.4\text{ V}$ , $V_{CC} = 4.5\text{ V}$	400	2000		
		HCPL2731M			3500		
		6N139M	$I_F = 1.6\text{ mA}$ , $V_O = 0.4\text{ V}$ , $V_{CC} = 4.5\text{ V}$	500	1600		
HCPL2731M	2400						
$I_{OH}$	Logic High Output Current	6N138M	$I_F = 0\text{ mA}$ , $V_O = V_{CC} = 7\text{ V}$		0.001	250	$\mu\text{A}$
		HCPL2730M					
		6N139M	$I_F = 0\text{ mA}$ , $V_O = V_{CC} = 18\text{ V}$		0.0036	100	
		HCPL2731M					
$V_{OL}$	Logic Low Output Voltage <sup>(4)</sup>	6N138M	$I_F = 1.6\text{ mA}$ , $I_O = 4.8\text{ mA}$ , $V_{CC} = 4.5\text{ V}$		0.06	0.4	V
		HCPL2730M			0.05		
		6N139M	$I_F = 0.5\text{ mA}$ , $I_O = 2\text{ mA}$ , $V_{CC} = 4.5\text{ V}$		0.05	0.4	
		6N139M					
		HCPL2731M	0.08				
		6N139M	$I_F = 5\text{ mA}$ , $I_O = 15\text{ mA}$ , $V_{CC} = 4.5\text{ V}$		0.13	0.4	
		HCPL2731M					
		6N139M	$I_F = 12\text{ mA}$ , $I_O = 24\text{ mA}$ , $V_{CC} = 4.5\text{ V}$		0.18	0.4	
HCPL2731M	0.17						

#### Notes:

- Current Transfer Ratio is defined as a ratio of output collector current,  $I_O$ , to the forward LED input current,  $I_F$ , times 100%.
- Pin 7 open. (6N138M and 6N139M only)

**Electrical Characteristics** (Continued) $(V_{CC} = 5.0 \text{ V}, T_A = 0^\circ\text{C to } 70^\circ\text{C unless otherwise specified. Typical value is measured at } T_A = 25^\circ\text{C}.)$ **Switching Characteristics**

Symbol	Parameter	Device	Test Conditions	Min.	Typ.	Max.	Unit
$t_{PHL}$	Propagation Delay Time to Logic LOW <sup>(4)</sup> (Fig. 15)	6N139M	$R_L = 270 \Omega, I_F = 12 \text{ mA}$		0.2	2	$\mu\text{s}$
		HCPL2730M, HCPL2731M	$R_L = 270 \Omega, I_F = 12 \text{ mA}$		0.5	3	
		6N138M	$R_L = 2.2 \text{ k}\Omega, I_F = 1.6 \text{ mA}$		1.0	15	
		HCPL2730M, HCPL2731M	$R_L = 2.2 \text{ k}\Omega, I_F = 1.6 \text{ mA}$		2.5	25	
		6N139M	$R_L = 4.7 \text{ k}\Omega, I_F = 0.5 \text{ mA}$		2.5	30	
		HCPL2731M	$R_L = 4.7 \text{ k}\Omega, I_F = 0.5 \text{ mA}$		8.4	120	
$t_{PLH}$	Propagation Delay Time to Logic HIGH <sup>(4)</sup> (Fig. 15)	6N139M	$R_L = 270 \Omega, I_F = 12 \text{ mA}$		1.3	10	$\mu\text{s}$
		HCPL2730M, HCPL2731M	$R_L = 270 \Omega, I_F = 12 \text{ mA}$		1.0	15	
		6N138M, HCPL2730M, HCPL2731M	$R_L = 2.2 \text{ k}\Omega, I_F = 1.6 \text{ mA}$		7.3	50	
		6N139M, HCPL2731M	$R_L = 4.7 \text{ k}\Omega, I_F = 0.5 \text{ mA}$		13.6	90	
$ CM_H $	Common Mode Transient Immunity at Logic High <sup>(5)</sup> (Fig. 16)	All	$I_F = 0 \text{ mA},  V_{CM}  = 10 \text{ V}_{P-P}$ $R_L = 2.2 \text{ k}\Omega, T_A = 25^\circ\text{C}$	1,000	10,000		$\text{V}/\mu\text{s}$
$ CM_L $	Common Mode Transient Immunity at Logic Low <sup>(5)</sup> (Fig. 16)	All	$I_F = 1.6 \text{ mA},  V_{CM}  = 10 \text{ V}_{P-P}$ $R_L = 2.2 \text{ k}\Omega, T_A = 25^\circ\text{C}$	1,000	10,000		$\text{V}/\mu\text{s}$

**Note:**

5. Common mode transient immunity in logic HIGH level is the maximum tolerable (positive)  $dV_{cm}/dt$  on the leading edge of the common mode pulse signal  $V_{CM}$ , 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 logic LOW level is the maximum tolerable (negative)  $dV_{cm}/dt$  on the trailing edge of the common mode pulse signal,  $V_{CM}$ , to assure that the output will remain in a logic LOW state (i.e.,  $V_O < 0.8 \text{ V}$ ).

**Electrical Characteristics** (Continued)**Isolation Characteristics** ( $T_A = 25^\circ\text{C}$  unless otherwise specified.)

Symbol	Parameter	Device	Test Conditions	Min.	Typ.	Max.	Unit
$V_{\text{ISO}}$	Withstand Insulation Test Voltage <sup>(6)(7)</sup>	All	$RH \leq 50\%$ , $T_A = 25^\circ\text{C}$ , $I_{\text{I-O}} \leq 10 \mu\text{A}$ , $t = 1 \text{ min}$ , $f = 50 \text{ Hz}$	5,000			$\text{VAC}_{\text{RMS}}$
$R_{\text{I-O}}$	Resistance (Input to Output) <sup>(6)</sup>	All	$V_{\text{I-O}} = 500 \text{ V}_{\text{DC}}$		$10^{11}$		$\Omega$
$C_{\text{I-O}}$	Capacitance (Input to Output) <sup>(6)(8)</sup>	All	$f = 1 \text{ MHz}$ , $V_{\text{I-O}} = 0 \text{ V}$		1		pF
$I_{\text{I-I}}$	Input-Input Insulation Leakage Current <sup>(9)</sup>	HCPL2730M, HCPL2731M	$RH \leq 45\%$ , $V_{\text{I-I}} = 500 \text{ V}_{\text{DC}}$ , $t = 5 \text{ sec}$		0.005		$\mu\text{A}$
$R_{\text{I-I}}$	Input-Input Resistance <sup>(9)</sup>	HCPL2730M, HCPL2731M	$V_{\text{I-I}} = 500 \text{ V}_{\text{DC}}$		$10^{11}$		$\Omega$
$C_{\text{I-I}}$	Input-Input Capacitance <sup>(9)</sup>	HCPL2730M, HCPL2731M	$f = 1 \text{ MHz}$		0.03		pF

**Notes:**

- 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.
- 5000  $\text{VAC}_{\text{RMS}}$  for 1 minute duration is equivalent to 6000  $\text{VAC}_{\text{RMS}}$  for 1 second duration.
- For dual channel devices,  $C_{\text{I-O}}$  is measured by shorting pins 1 and 2 or pins 3 and 4 together and pins 5 through 8 shorted together.
- Measured between pins 1 and 2 shorted together, and pins 3 and 4 shorted together.

### Electrical Characteristics (Continued)

T<sub>A</sub> = 25°C unless otherwise specified

Current Limiting Resistor Calculations:

$$R_1 \text{ (Non-Invert)} = \frac{V_{CC1} - V_{DF} - V_{OL1}}{I_F}$$

$$R_1 \text{ (Invert)} = \frac{V_{CC1} - V_{OH1} - V_{DF}}{I_F}$$

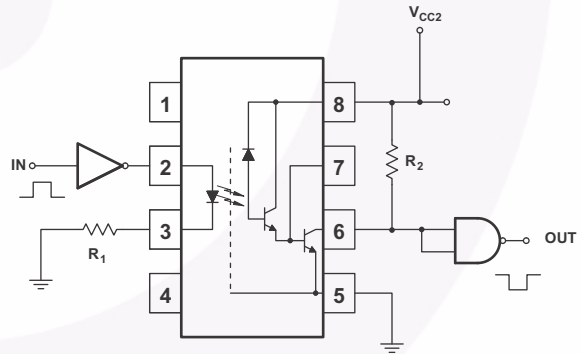
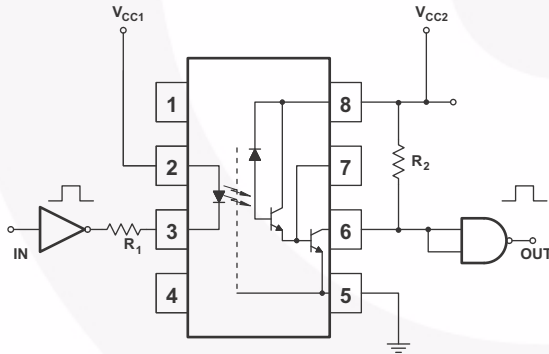
$$R_2 = \frac{V_{CC2} - V_{OLX} (@ I_L - I_2)}{I_L}$$

**Where:**

- V<sub>CC1</sub> = Input Supply Voltage
- V<sub>CC2</sub> = Output Supply Voltage
- V<sub>DF</sub> = Diode Forward Voltage
- V<sub>OL1</sub> = Logic "0" Voltage of Driver
- V<sub>OH1</sub> = Logic "1" Voltage of Driver
- I<sub>F</sub> = Diode Forward Current
- V<sub>OLX</sub> = Saturation Voltage of Output Transistor
- I<sub>L</sub> = Load Current Through Resistor R<sub>2</sub>
- I<sub>2</sub> = Input Current of Output Gate

INPUT CONFIGURATION		R <sub>1</sub> (Ω)	R <sub>2</sub> (Ω) @ OUTPUT CONFIGURATION						
			CMOS @ 5 V	CMOS @ 10 V	74XX	74LXX	74SXX	74LSXX	74HXX
CMOS @ 5 V	NON-INV.	2000	1000	2200	750	1000	1000	1000	560
	INV.	510							
CMOS @ 10 V	NON-INV.	5100							
	INV.	4700							
74XX	NON-INV.	2200							
	INV.	180							
74LXX	NON-INV.	1800							
	INV.	100							
74SXX	NON-INV.	2000							
	INV.	360							
74LSXX	NON-INV.	2000							
	INV.	180							
74HXX	NON-INV.	2000							
	INV.	180							

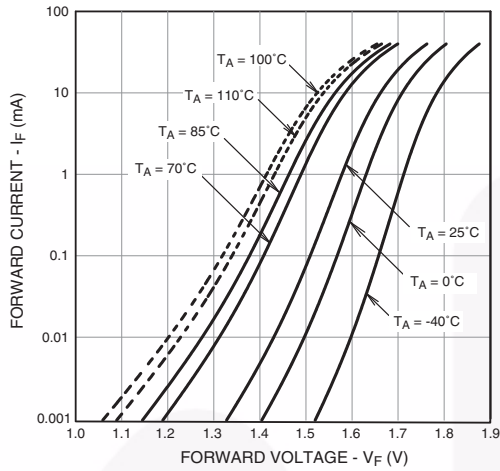
**Fig. 3 Resistor Values for Logic Interface**



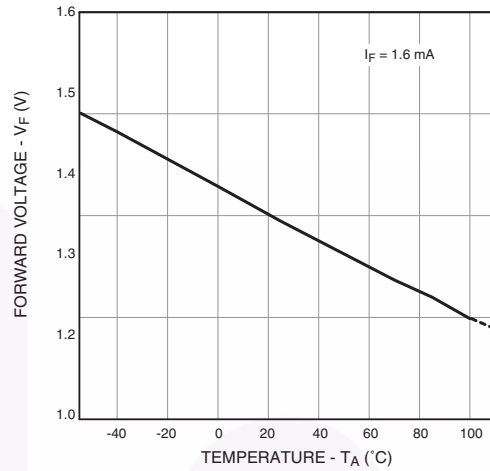
**Fig. 4 Non-Inverting Logic Interface** **Fig. 5 Inverting Logic Interface**



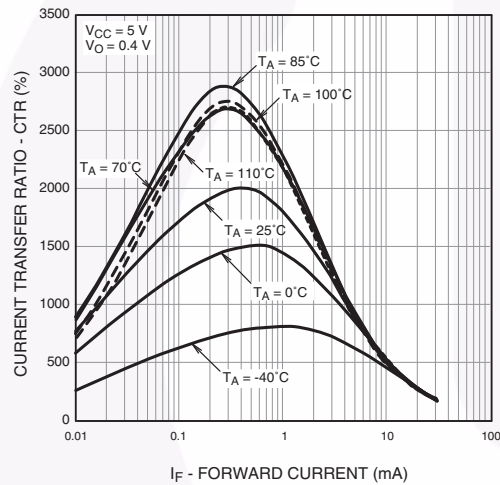
### Typical Performance Curves



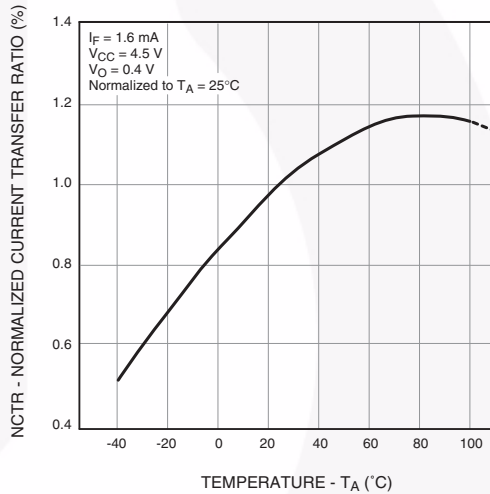
**Fig. 6 LED Forward Current vs. Forward Voltage**



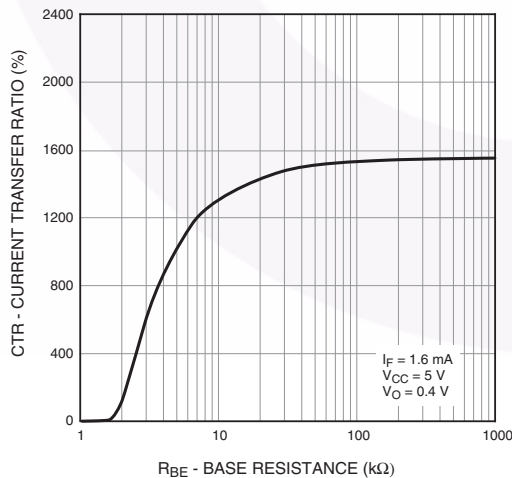
**Fig. 7 LED Forward Voltage vs. Temperature**



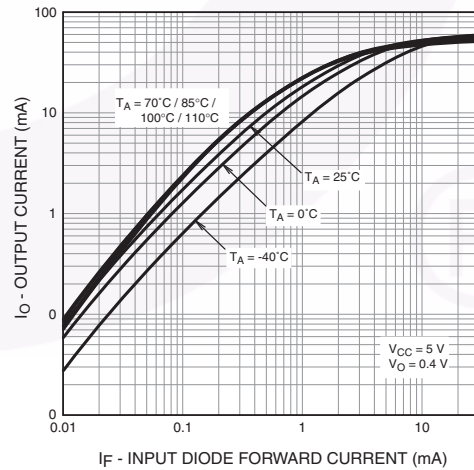
**Fig. 8 Current Transfer Ratio vs. Forward Current (6N138M / 6N139M Only)**



**Fig. 9 Normalized Current Transfer Ratio vs. Ambient Temperature (6N138M / 6N139M Only)**



**Fig. 10 Current Transfer Ratio vs. Base-Emitter Resistance (6N138M / 6N139M Only)**



**Fig. 11 Output Current vs. Input Diode Forward Current (6N138M / 6N139M Only)**

Typical Performance Curves (Continued)

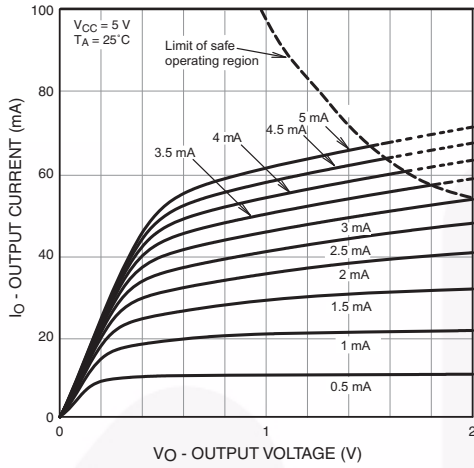


Fig. 12 Output Current vs Output Voltage (6N138M / 6N139M Only)

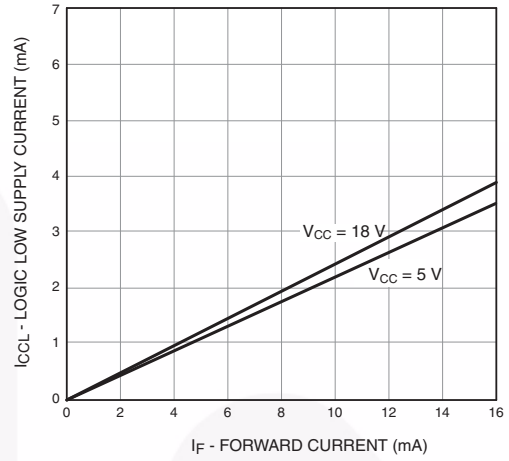


Fig. 13 Logic Low Supply Current vs. Input Diode Forward Current (6N138M / 6N139M Only)

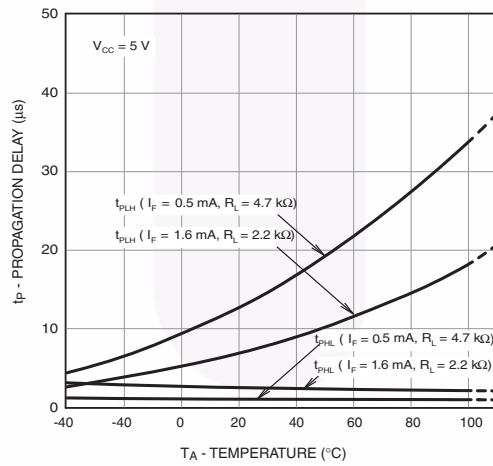
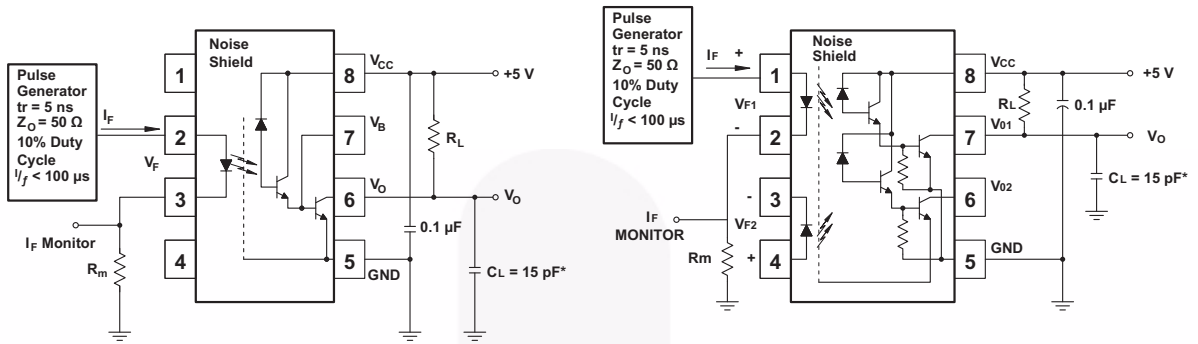


Fig. 14 Propagation Delay vs. Temperature (6N138M / 6N139M Only)

### Test Circuits



Test Circuit for 6N138M, 6N139M

Test Circuit for HCPL2730M and HCPL2731M

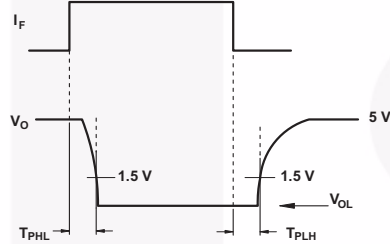
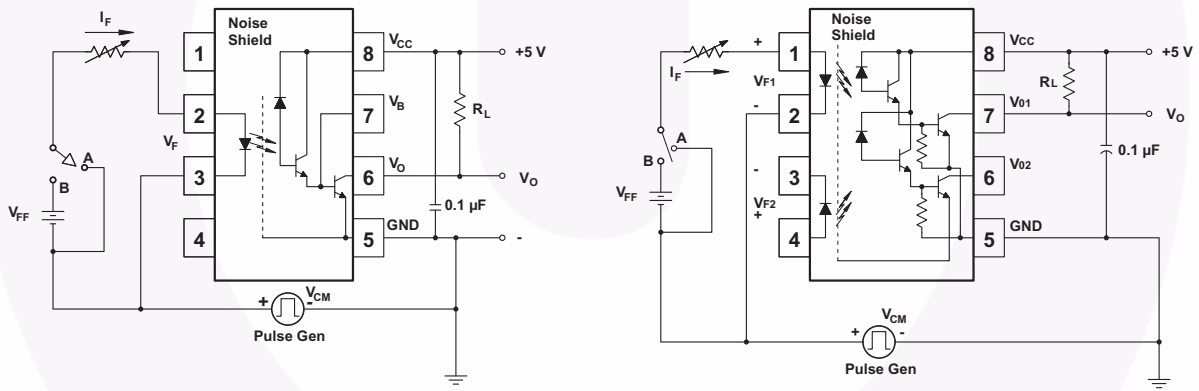


Fig. 15 Switching Time Test Circuit



Test Circuit for 6N138M and 6N139M

Test Circuit for HCPL2730M and HCPL2731M

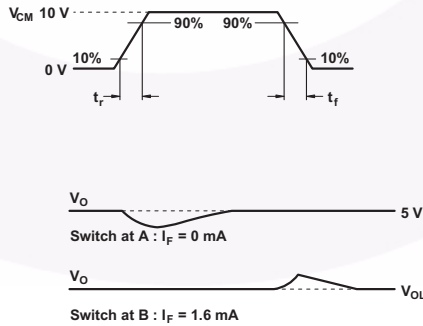
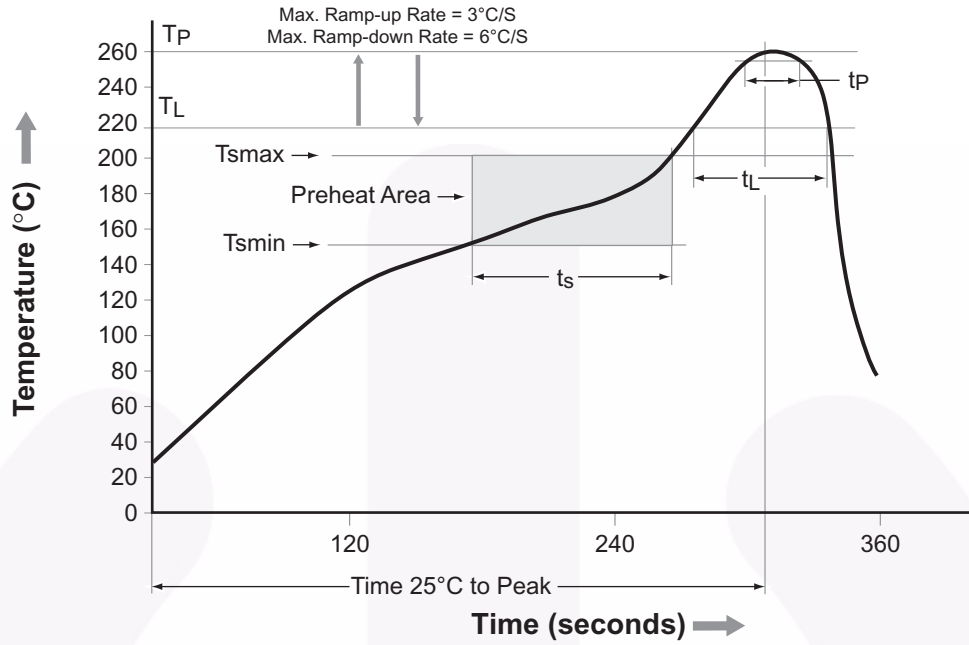


Fig. 16 Common Mode Immunity Test Circuit

### Reflow Profile



Profile Feature	Pb-Free Assembly Profile
Temperature Min. (Tsmín)	150°C
Temperature Max. (Tsmáx)	200°C
Time (ts) from (Tsmín to Tsmáx)	60–120 seconds
Ramp-up Rate (tL to tp)	3°C/second max.
Liquidous Temperature (TL)	217°C
Time (tL) Maintained Above (TL)	60–150 seconds
Peak Body Package Temperature	260°C +0°C / –5°C
Time (tp) within 5°C of 260°C	30 seconds
Ramp-down Rate (TP to TL)	6°C/second max.
Time 25°C to Peak Temperature	8 minutes max.

## Ordering Information

Part Number	Package	Packing Method
6N138M	DIP 8-Pin	Tube (50 units per tube)
6N138SM	SMT 8-Pin (Lead Bend)	Tube (50 units per tube)
6N138SDM	SMT 8-Pin (Lead Bend)	Tape and Reel (1,000 units per reel)
6N138VM	DIP 8-Pin, DIN EN/IEC 60747-5-5 Option	Tube (50 units per tube)
6N138SVM	SMT 8-Pin (Lead Bend), DIN EN/IEC 60747-5-5 Option	Tube (50 units per tube)
6N138SDVM	SMT 8-Pin (Lead Bend), DIN EN/IEC 60747-5-5 Option	Tape and Reel (1,000 units per reel)
6N138TVM	DIP 8-Pin, 0.4" Lead Spacing, DIN EN/IEC 60747-5-5 Option	Tube (50 units per tube)
6N138TSVM	SMT 8-Pin, 0.4" Lead Spacing, DIN EN/IEC 60747-5-5 Option	Tube (50 units per tube)
6N138TSR2VM	SMT 8-Pin, 0.4" Lead Spacing, DIN EN/IEC 60747-5-5 Option	Tape and Reel (1,000 units per reel)

### Note:

The product orderable part number system listed in this table also applies to the 6N139M, HCPL2730M and HCPL2731M product families.

## Marking Information

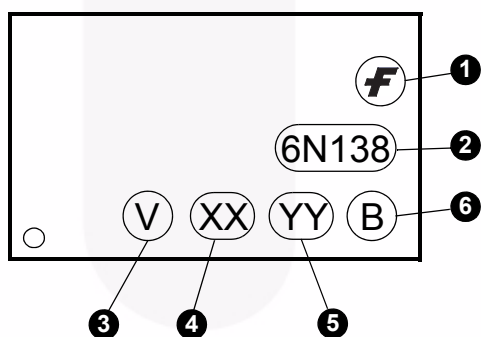
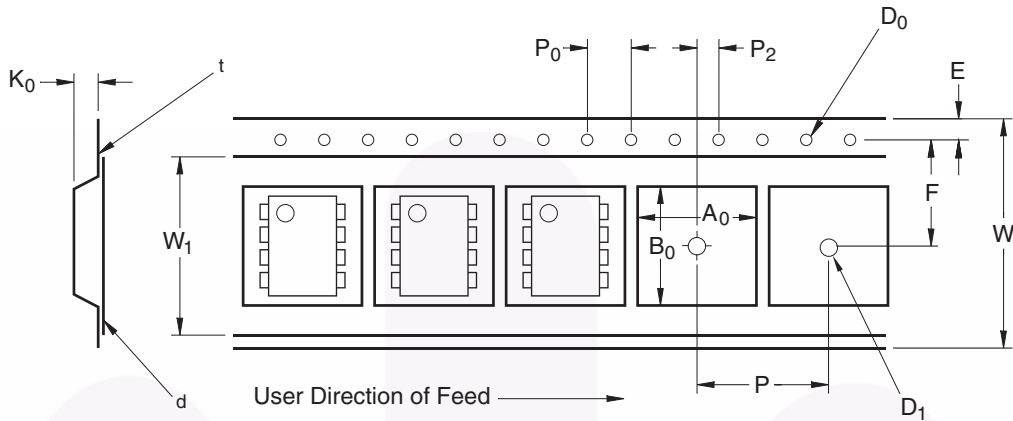


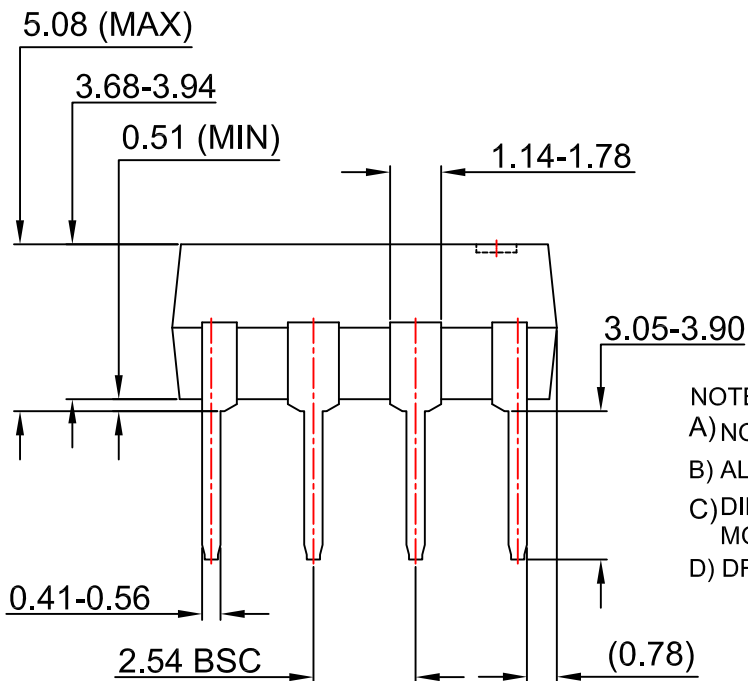
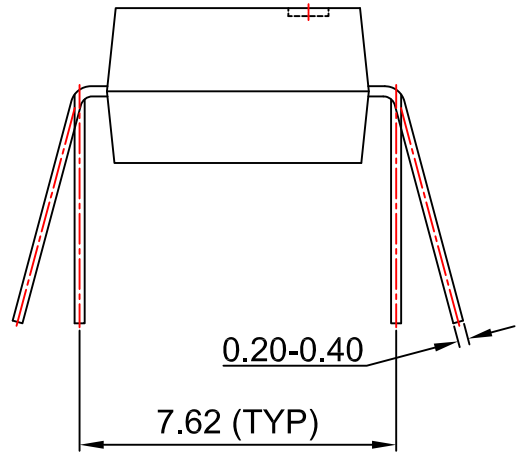
Figure 17. Top Mark

Definitions	
1	Fairchild Logo
2	Device Number
3	DIN EN/IEC60747-5-5 Option (only appears on component ordered with this option)
4	Two Digit Year Code, e.g., '16'
5	Two Digit Work Week Ranging from '01' to '53'
6	Assembly Package Code

### Carrier Tape Specifications (Option SD)



Symbol	Description	Dimension in mm
W	Tape Width	16.0 ± 0.3
t	Tape Thickness	0.30 ± 0.05
P <sub>0</sub>	Sprocket Hole Pitch	4.0 ± 0.1
D <sub>0</sub>	Sprocket Hole Diameter	1.55 ± 0.05
E	Sprocket Hole Location	1.75 ± 0.10
F	Pocket Location	7.5 ± 0.1
P <sub>2</sub>		2.0 ± 0.1
P	Pocket Pitch	12.0 ± 0.1
A <sub>0</sub>	Pocket Dimensions	10.30 ± 0.20
B <sub>0</sub>		10.30 ± 0.20
K <sub>0</sub>		4.90 ± 0.20
W <sub>1</sub>	Cover Tape Width	13.2 ± 0.2
d	Cover Tape Thickness	0.1 max
	Max. Component Rotation or Tilt	10°
R	Min. Bending Radius	30

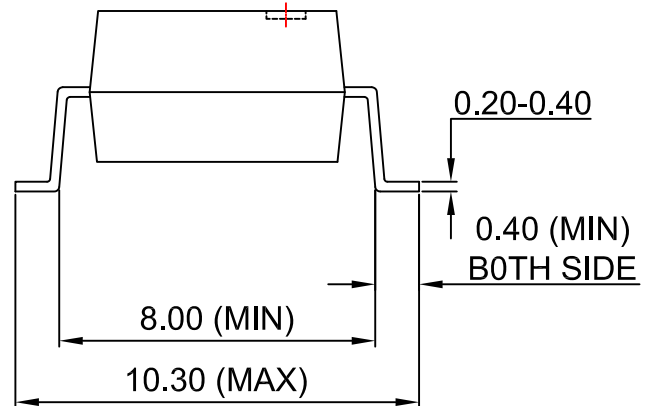


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LAND PATTERN RECOMMENDATION



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PIN 1

15.0° (MAX)

10.16 (TYP)

0.20-0.40



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