## หนังสืออ้างอิง


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2. John D. Harnden, Jr. and Forset B. Golden, Power semiconductor Application Volume 2, (IEEE, 1972).
3. D.R. Grafham and J.C., SCR Manual fifth edition. (General Electric Company., 1972.)
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6. A.E. Fitzgerald and Charles Kingsley, Jr. and Alexander, L Kusko, Electric Machinery, (McGraw-Hill Book Company, Tokyo, 1971.)
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# Industrial/Automotive/Functional Blocks

## LM555/LM555C timer

### general description

The LM555 is a highly stable device for generating accurate time delays or oscillation. Additional terminals are provided for triggering or resetting if desired. In the time delay mode of operation, the time is precisely controlled by one external resistor and capacitor. For astable operation as an oscillator, the free running frequency and duty cycle are accurately controlled with two external resistors and one capacitor. The circuit may be triggered and reset on falling waveforms, and the output circuit can source or sink up to 200 mA or drive TTL circuits.

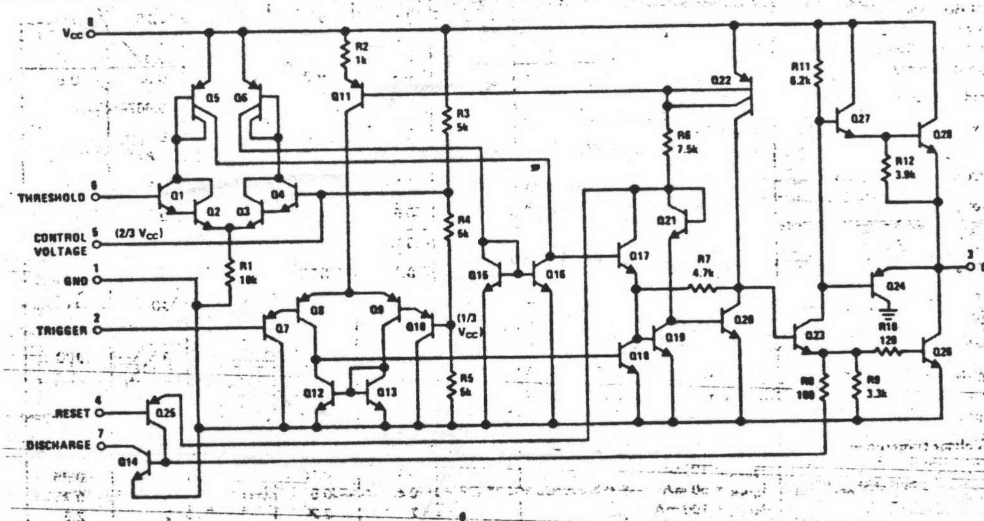
### features

- Direct replacement for SE555/NE555
- Timing from microseconds through hours
- Operates in both astable and monostable modes
- Adjustable duty cycle
- Output can source or sink 200 mA
- Output and supply TTL compatible
- Temperature stability better than 0.005% per °C
- Normally on and normally off output

### applications

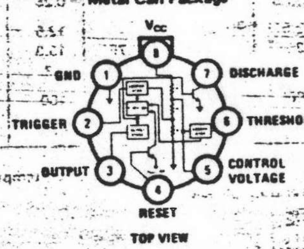
- Precision timing
- Pulse generation
- Sequential timing
- Time delay generation
- Pulse width modulation
- Pulse position modulation
- Linear ramp generator

### schematic diagram



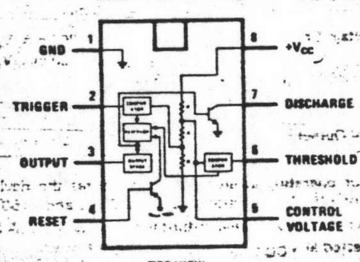

### connection diagrams

**Metal Can Package**




**Order Number LM555H or LM555CH**
**See Package 11**

**Dual-In-Line Package**




**Order Number LM555CN**
**See Package 20**

## absolute maximum ratings

| | |
|---|---|
| Supply Voltage | +18V |
| Power Dissipation (Note 1) | 600 mW |
| Operating Temperature Ranges | |
| LM555C | 0°C to +70°C |
| LM555 | −55°C to +125°C |
| Storage Temperature Range | −65°C to +150°C |
| Lead Temperature (Soldering, 10 seconds) | 300°C |

## electrical characteristics ($T_A$ = 25°C, $V_{CC}$ = +5V to +15V, unless otherwise specified)

| PARAMETER | CONDITIONS | LIMITS | | | | | | UNITS |
|---|---|---|---|---|---|---|---|---|
| | | LM555 | | | LM555C | | | |
| | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Supply Voltage | | 4.5 | | 18 | 4.5 | | 16 | V |
| Supply Current | $V_{CC}$ = 5V, $R_L$ = ∞ | | 3 | 5 | | 3 | 6 | mA |
| | $V_{CC}$ = 15V, $R_L$ = ∞ (Low State) (Note 2) | | 10 | 12 | | 10 | 15 | mA |
| Timing Error, Monostable | | | | | | | | |
| Initial Accuracy | | | 0.5 | 2 | | 1 | | % |
| Drift with Temperature | $R_A$, $R_B$ = 1k to 100 k, C = 0.1μF, (Note 3) | | 30 | | | 50 | | ppm/°C |
| Accuracy over Temperature | | | 1.5 | 3.0 | | 1.5 | | % |
| Drift with Supply | | | 0.05 | 0.2 | | 0.1 | | %/V |
| Timing Error, Astable | | | | | | | | |
| Initial Accuracy | | | 1.5 | 5 | | 2.25 | 7 | % |
| Drift with Temperature | | | 90 | | | 150 | | ppm/°C |
| Accuracy over Temperature | | | 2.5 | | | 3.0 | | % |
| Drift with Supply | | | 0.15 | 0.2 | | 0.30 | 0.5 | %/V |
| Threshold Voltage | | | 0.667 | | | 0.667 | | x $V_{CC}$ |
| Trigger Voltage | $V_{CC}$ = 15V | 4.8 | 5 | 5.2 | | 5 | | V |
| | $V_{CC}$ = 5V | 1.45 | 1.67 | 1.9 | | 1.67 | | V |
| Trigger Current | | | 0.01 | 0.5 | | 0.5 | 0.9 | μA |
| Reset Voltage | | 0.4 | 0.5 | 1 | 0.4 | 0.5 | 1 | V |
| Reset Current | | | 0.1 | 0.4 | | 0.1 | 0.4 | mA |
| Threshold Current | (Note 4) | | 0.1 | 0.25 | | 0.1 | 0.25 | μA |
| Control Voltage Level | $V_{CC}$ = 15V | 9.6 | 10 | 10.4 | 9 | 10 | 11 | V |
| | $V_{CC}$ = 5V | 2.9 | 3.33 | 3.8 | 2.6 | 3.33 | 4 | V |
| Pin 7 Leakage Output High | | | 1 | 100 | | 1 | 100 | nA |
| Pin 7 Sat (Note 5) | | | | | | | | |
| Output Low | $V_{CC}$ = 15V, $I_7$ = 15 mA | | 150 | | | 180 | | mV |
| Output Low | $V_{CC}$ = 4.5V, $I_7$ = 4.5 mA | | 70 | 100 | | 80 | 200 | mV |
| Output Voltage Drop (Low) | $V_{CC}$ = 15V | | | | | | | |
| | $I_{SINK}$ = 10 mA | | 0.1 | 0.15 | | 0.1 | 0.25 | V |
| | $I_{SINK}$ = 50 mA | | 0.4 | 0.5 | | 0.4 | 0.75 | V |
| | $I_{SINK}$ = 100 mA | | 2 | 2.2 | | 2 | 2.5 | V |
| | $I_{SINK}$ = 200 mA | | 2.5 | | | 2.5 | | V |
| | $V_{CC}$ = 5V | | | | | | | |
| | $I_{SINK}$ = 8 mA | | 0.1 | 0.25 | | | | V |
| | $I_{SINK}$ = 5 mA | | | | | 0.25 | 0.35 | V |
| Output Voltage Drop (High) | $I_{SOURCE}$ = 200 mA, $V_{CC}$ = 15V | | 12.5 | | | 12.5 | | V |
| | $I_{SOURCE}$ = 100 mA, $V_{CC}$ = 15V | 13 | 13.3 | | 12.75 | 13.3 | | V |
| | $V_{CC}$ = 5V | 3 | 3.3 | | 2.75 | 3.3 | | V |
| Rise Time of Output | | | 100 | | | 100 | | ns |
| Fall Time of Output | | | 100 | | | 100 | | ns |

**Note 1:** For operating at elevated temperatures the device must be derated based on a +150°C maximum junction temperature and a thermal resistance of +45°C/W junction to case for TO-5 and +150°C/W junction to ambient for both packages.

**Note 2:** Supply current when output high typically 1 mA less at $V_{CC}$ = 5V.

**Note 3:** Tested at $V_{CC}$ = 5V and $V_{CC}$ = 15V.

**Note 4:** This will determine the maximum value of $R_A + R_B$ for 15V operation. The maximum total $(R_A + R_B)$ is 20 MΩ.

**Note 5:** No protection against excessive pin 7 current is necessary providing the package dissipation rating will not be exceeded.

## applications information (con't)

The frequency of oscillation is:

$$f = \frac{1}{T} = \frac{1.44}{(R_A + 2R_B)\,C}$$

*Figure 6* may be used for quick determination of these RC values.

The duty cycle is: $$D = \frac{R_B}{R_A + 2R_B}$$

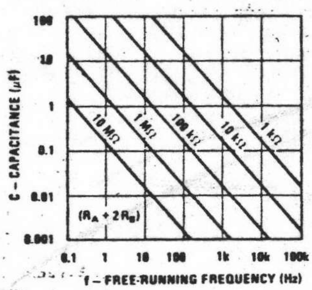



**FIGURE 6. Free Running Frequency**

### FREQUENCY DIVIDER

The monostable circuit of *Figure 1* can be used as a frequency divider by adjusting the length of the timing cycle. *Figure 7* shows the waveforms generated in a divide by three circuit.

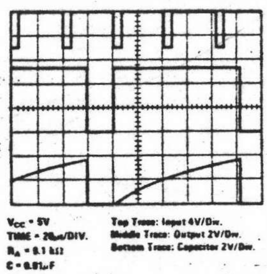



**FIGURE 7. Frequency Divider**

### PULSE WIDTH MODULATOR

When the timer is connected in the monostable mode and triggered with a continuous pulse train, the output pulse width can be modulated by a signal applied to pin 5. *Figure 8* shows the circuit, and in *Figure 9* are some waveform examples.

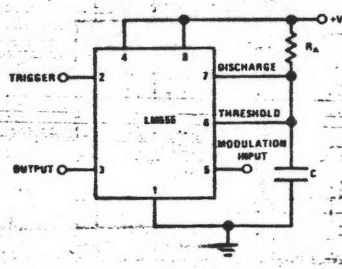



**FIGURE 8. Pulse Width Modulator**

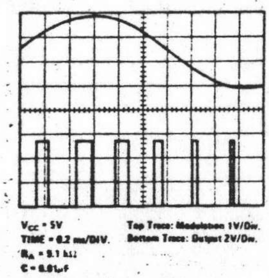



**FIGURE 9. Pulse Width Modulator**

### PULSE POSITION MODULATOR

This application uses the timer connected for astable operation, as in *Figure 10*, with a modulating signal again applied to the control voltage terminal. The pulse position varies with the modulating signal, since the threshold voltage and hence the time delay is varied. *Figure 11* shows the waveforms generated for a triangle wave modulation signal.

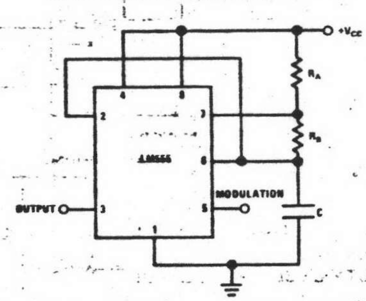



**FIGURE 10. Pulse Position Modulator**

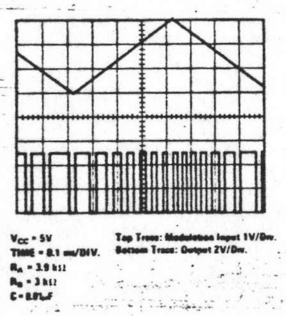



**FIGURE 11. Pulse Position Modulator**

### LINEAR RAMP

When the pullup resistor, $R_A$, in the monostable circuit is replaced by a constant current source, a linear ramp is

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MM54C73/MM74C73, MM54C76/MM74C76, MM54C107/MM74C107

National Semiconductor

# MM54C73/MM74C73 Dual J-K Flip-Flops with Clear
# MM54C76/MM74C76 Dual J-K Flip-Flops with Clear and Preset
# MM54C107/MM74C107 Dual J-K Flip-Flops with Clear

## general description

These dual J-K flip-flops are monolithic complementary MOS (CMOS) integrated circuits constructed with N- and P-channel enhancement transistors. Each flip-flop has independent J, K, clock and clear inputs and Q and $\overline{Q}$ outputs. The MM54C76/MM74C76 flip flops also include preset inputs and are supplied in 16 pin packages. These flip flops are edge sensitive to the clock input and change state on the negative going transition of the clock pulses. Clear or preset is independent of the clock and is accomplished by a low level on the respective input.

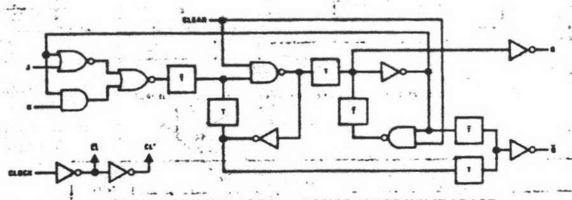
## features

- Supply voltage range — 3V to 15V
- Tenth power TTL compatible — drive 2 LPTTL loads
- High noise immunity — $0.45\ V_{CC}$ (typ)
- Low power — 50 nW (typ)
- Medium speed operation — 10 MHz (typ) with 10V supply

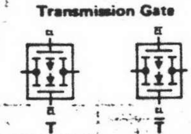
## applications

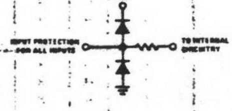
- Automotive
- Data terminals
- Instrumentation
- Medical electronics
- Alarm systems
- Industrial electronics
- Remote metering
- Computers

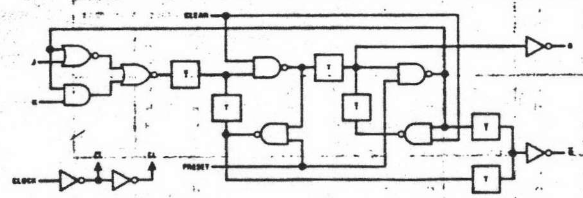
## logic and connection diagrams



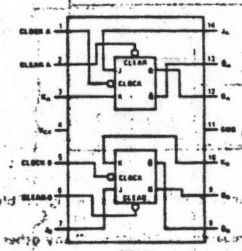
MM54C73/MM74C73 and MM54C107/MM74C107



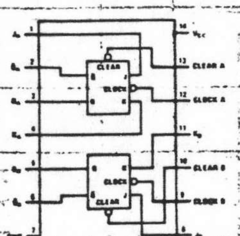



MM54C76/MM74C76



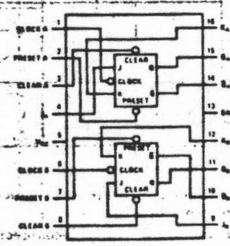
Note: A logic "0" on clear sets Q to logic "0."

MM54C73/MM74C73



Note: A logic "0" on clear sets Q to logic "0."

MM54C107/MM74C107



Note 1: A logic "0" on clear sets Q to a logic "0."
Note 2: A logic "0" on preset sets Q to a logic "1."

MM54C76/MM74C76

## absolute maximum ratings

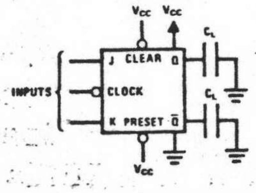
| | |
|---|---|
| Voltage at any pin (Note 1) | $-0.3V$ to $V_{CC}$ $+0.3V$ |
| Operating Temperature MM54CXX | $-55°C$ to $125°C$ |
| MM74CXX | $-40°C$ to $+85°C$ |
| Storage Temperature | $-65°C$ to $150°C$ |
| Maximum $V_{CC}$ Voltage | 18V |
| Package Dissipation | 500 mW |
| Lead Temperature (Soldering, 10 sec) | 300°C |
| Operating $V_{CC}$ Range | +3V to 15V |

## electrical characteristics

| PARAMETERS | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|
| **CMOS TO CMOS** | | | | | |
| Logical "1" Input Voltage $V_{IN(1)}$ | $V_{CC}$ = 5.0V | 3.5 | | | V |
| | $V_{CC}$ = 10.0V | 8 | | | V |
| Logical "0" Input Voltage $V_{IN(0)}$ | $V_{CC}$ = 5.0V | | | 1.5 | V |
| | $V_{CC}$ = 10.0V | | | 2.0 | V |
| Logical "1" Output Voltage $V_{OUT(1)}$ | $V_{CC}$ = 5.0V | 4.5 | | | V |
| | $V_{CC}$ = 10.0V | 9.0 | | | V |
| Logical "0" Output Voltage $V_{OUT(0)}$ | $V_{CC}$ = 5.0V | | | 0.5 | V |
| | $V_{CC}$ = 10.0V | | | 1.0 | V |
| Logical "1" Input Current $I_{IN(1)}$ | $V_{CC}$ = 15.0V | | | 1.0 | μA |
| Logical "0" Input Current $I_{IN(0)}$ | $V_{CC}$ = 15.0V | -1.0 | | | μA |
| Supply Current $I_{CC}$ | $V_{CC}$ = 15.0V | | 0.050 | 60 | μA |
| Input Capacitance | Any Input | | 5 | | pF |
| Propagation Delay Time to a Logical "0" $t_{pd0}$ or Logical "1" $t_{pd1}$ From Clock to Q or $\overline{Q}$ | $V_{CC}$ = 5.0V, $C_L$ = 50 pF, $T_A$ = 25°C | | 180 | 300 | ns |
| | $V_{CC}$ = 10.0V, $C_L$ = 50 pF, $T_A$ = 25°C | | 70 | 110 | ns |
| Propagation Delay Time to a Logical "0" From Preset or Clear | $V_{CC}$ = 5.0V, $C_L$ = 50 pF, $T_A$ = 25°C | | 200 | 300 | ns |
| | $V_{CC}$ = 10.0V, $C_L$ = 50 pF, $T_A$ = 25°C | | 80 | 130 | ns |
| Propagation Delay Time to a Logical "1" From Preset or Clear | $V_{CC}$ = 5.0V, $C_L$ = 50 pF, $T_A$ = 25°C | | 200 | 300 | ns |
| | $V_{CC}$ = 10.V, $C_L$ = 50 pF, $T_A$ = 25°C | | 80 | 130 | ns |
| Time Prior to Clock Pulse That Data Must be Present, $t_{SETUP}$ | $V_{CC}$ = 5.0V, $C_L$ = 50 pF, $T_A$ = 25°C | | 110 | 175 | ns |
| | $V_{CC}$ = 10V, $C_L$ = 50 pF, $T_A$ = 25°C | | 45 | 70 | ns |
| Time After Clock Pulse That J and K Must be Held | $V_{CC}$ = 5.0V, $C_L$ = 50 pF, $T_A$ = 25°C | | -40 | 0 | ns |
| | $V_{CC}$ = 10.0V, $C_L$ = 50 pF, $T_A$ = 25°C | | -20 | 0 | ns |
| Minimum Clock Pulse Width $t_{WL}$ = $t_{WH}$ | $V_{CC}$ = 5.0V, $C_L$ = 50 pF, $T_A$ = 25°C | | 120 | 190 | ns |
| | $V_{CC}$ = 10.0V, $C_L$ = 50 pF, $T_A$ = 25°C | | 50 | 80 | ns |
| Minimum Preset and Clear Pulse Width | $V_{CC}$ = 5.0V, $C_L$ = 50 pF, $T_A$ = 25°C | | 90 | 130 | ns |
| | $V_{CC}$ = 10.0V, $C_L$ = 50 pF, $T_A$ = 25°C | | 40 | 60 | ns |
| Maximum Toggle Frequency | $V_{CC}$ = 5.0V, $C_L$ = 50 pF, $T_A$ = 25°C | 2.5 | 4.0 | | MHz |
| | $V_{CC}$ = 10.0V, $C_L$ = 50 pF, $T_A$ = 25°C | 7.0 | 11.0 | | MHz |
| Clock Pulse Rise and Fall Time | $V_{CC}$ = 5.0V, $C_L$ = 50 pF, $T_A$ = 25°C | | | 15 | μs |
| | $V_{CC}$ = 10.0V, $C_L$ = 50 pF, $T_A$ = 25°C | | | 5 | μs |
| **LOW POWER TTL TO CMOS INTERFACE** | | | | | |
| Logical "1" Input Voltage $V_{IN(1)}$ | 54C, $V_{CC}$ = 4.5V; 74C, $V_{CC}$ = 4.75V | $V_{CC}$−1.5 | | | V |
| Logical "0" Input Votlage $V_{IN(0)}$ | 54C, $V_{CC}$ = 4.5V; 74C, $V_{CC}$ = 4.75V | | | 0.8 | V |
| Logical "1" Output Voltage $V_{OUT(1)}$ | 54C, $V_{CC}$ = 4.5V, $I_O$ = −360μA; 74C, $V_{CC}$ = 4.75V, $I_O$ = −360μA | 2.4 | | | V |
| Logical "0" Output Voltage $V_{OUT(0)}$ | 54C, $V_{CC}$ = 4.5V, $I_O$ = 360μA; 74C, $V_{CC}$ = 4.75V, $I_O$ = 360μA | | | 0.4 | V |
| **OUTPUT DRIVE (See 54C/74C Family Characteristics Data Sheet)** | | | | | |
| Output Source Current ($I_{SOURCE}$) | $V_{CC}$ = 5.0V, $V_{IN(0)}$ = 0V, $T_A$ = 25°C, $V_{OUT}$ = 0V | -1.75 | | | mA |
| Output Source Current ($I_{SOURCE}$) | $V_{CC}$ = 10V, $V_{IN(0)}$ = 0V, $T_A$ = 25°C, $V_{OUT}$ = 0V | -8.0 | | | mA |
| Output Sink Current ($I_{SINK}$) | $V_{CC}$ = 5.0V, $V_{IN(1)}$ = 5.0V, $T_A$ = 25°C, $V_{OUT}$ = $V_{CC}$ | 1.75 | | | mA |
| Output Sink Current ($I_{SINK}$) | $V_{CC}$ = 10V, $V_{IN(1)}$ = 10V, $T_A$ = 25°C, $V_{OUT}$ = $V_{CC}$ | 8.0 | | | mA |

**Note 1: This device should not be connected to circuits with the power on because high transient voltages may cause permanent damage.**

## ac test circuit




## truth table

| $t_n$ | | $t_{n+1}$ |
|---|---|---|
| J | K | Q |
| 0 | 0 | $Q_n$ |
| 0 | 1 | 0 |
| 1 | 0 | 1 |
| 1 | 1 | $\bar{Q}_n$ |

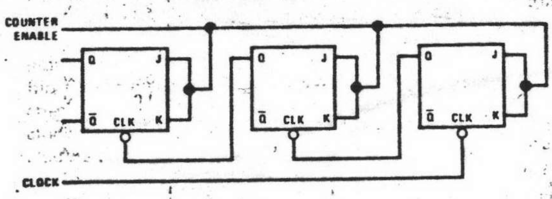
$t_n$ = bit time before clock pulse.
$t_{n+1}$ = bit time after clock pulse.

| Preset | Clear | $Q_n$ | $\bar{Q}_n$ |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 |
| 1 | 0 | 0 | 1 |
| 1 | 1 | *$Q_n$ | *$\bar{Q}_n$ |

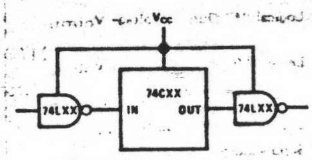
*No change in output from previous state.

## typical applications

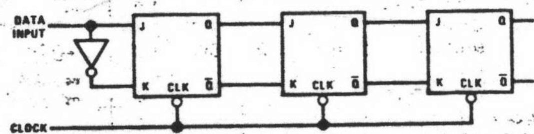
**Ripple Binary Counters**



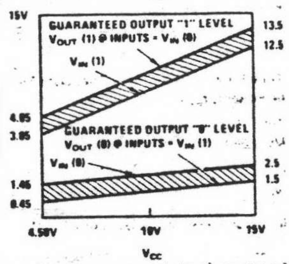

**74C Compatibility**




**Shift Registers**

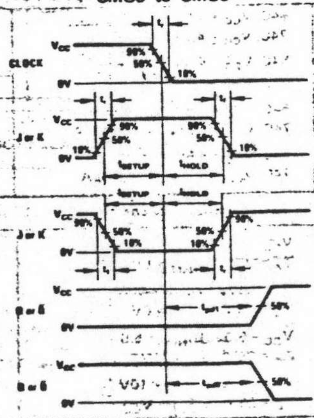



**Guaranteed Noise Margin as a Function of $V_{CC}$**




## switching time waveforms

**CMOS to CMOS**

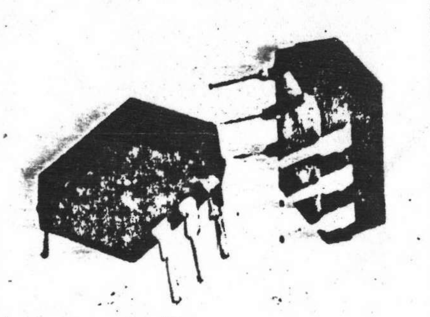



$C_L$ = $t_f$ = 20 ns

**litronix** ภาคผนวก ค.

# Iso-Lit 15
# Iso-Lit 16

## PHOTOTRANSISTOR OPTO-ISOLATOR



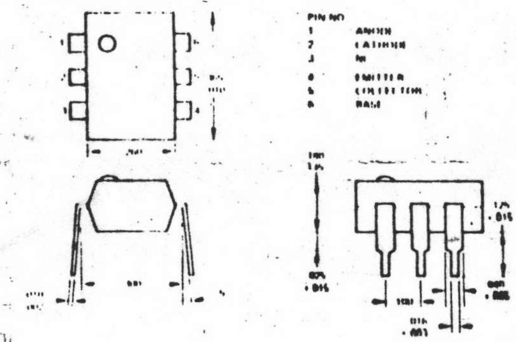
### FEATURES

- 1500 Volt Breakdown Voltage
- 14% Typical Current Transfer Ratio
- IL-16 Maximum 30% Transfer Ratio (Equivalent to MCT-26)
- .5 pF Typical Coupling Capacitance
- Standard Dual-In-Line Package

### DESCRIPTION

IL-15/IL-16 is an optically coupled pair employing a Gallium Arsenide infrared LED and a silicon NPN phototransistor. Signal information, including a DC level, can be transmitted by the device while maintaining a high degree of electrical isolation between input and output. The IL-15/IL-16 can be used to replace relays and transformers in many digital interface applications, as well as analog applications such as CRT modulation.

### Package Dimensions (in inches)



### Maximum Ratings

**Gallium Arsenide LED**

| | |
|---|---|
| Power Dissipation @ 25°C | 200 mW |
| Derate Linearly from 25°C | 2.6 mW/°C |
| Continuous Forward Current | 60 mA |
| Peak Inverse Voltage | 3.0V |

**Detector (Silicon Phototransistor)**

| | |
|---|---|
| Power Dissipation at 25°C | 200 mW |
| Derate Linearly from 25°C | 2.6 mW/°C |
| Collector-Emitter Breakdown Voltage ($BV_{CEO}$) | 30V |
| Emitter-Collector Breakdown Voltage ($BV_{ECO}$) | 7V |
| Collector-Base Breakdown Voltage ($BV_{CBO}$) | 30V |

**Package**

| | |
|---|---|
| Total Package Dissipation at 25°C Ambient (LED Plus Detector) | 250 mW |
| Derate Linearly From 25°C | 3.3 mW/°C |
| Storage Temperature | −55°C to +150°C |
| Operating Temperature | −55°C to +100°C |
| Lead Soldering Time @ 260 C | 7.0 sec |

### Electrical Characteristics (at 25°C Ambient)

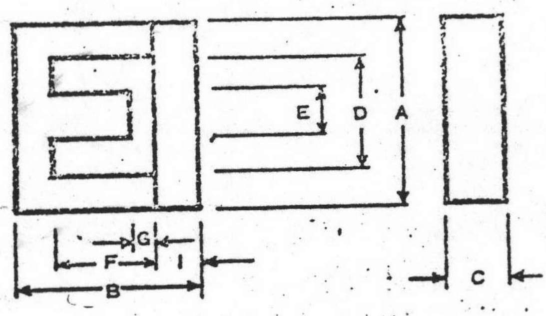
| Parameter | Min | Typ | Max | Unit | Test Condition |
|---|---|---|---|---|---|
| **Gallium Arsenide LED** | | | | | |
| Forward Voltage | | 1.25 | 1.5 | V | $I_F$ = 60 mA |
| Reverse Current | | .15 | 10 | μA | $V_R$ = 3.0 |
| Capacitance | | 100 | | pF | $V_R$ = 0 |
| **Phototransistor Detector** | | | | | |
| $H_{FE}$ | | 150 | | | $V_{CE}$ = 5.0V, $I_C$ = 100 μA |
| $BV_{CEO}$ | 30 | 75 | | V | $I_C$ = 1 mA |
| $BV_{ECO}$ | 7 | 12 | | V | $I_E$ = 100 μA |
| $I_{CEO}$ (dark) | | 5 | 100 | nA | $V_{CE}$ = 5V, $I_F$ = 0 |
| Collector Emitter Capacitance | | 2 | | pF | $V_{CE}$ = 0 |
| **Coupled Characteristics** | | | | | |
| DC Current Transfer Ratio IL 15 | .06 | .20 | | | $I_F$ = 10mA, $V_{CE}$ = 10V |
| IL 16 | .06 | .14 | 0.3 | | $I_F$ = 10mA, $V_{CE}$ = 10V |
| Capacitance, Input to Output | | .5 | 2.0 | pF | |
| Breakdown Voltage | 1500 | | | V | D.C. |
| Resistance, Input to Output | | 100 | | GΩ | |
| Output Rise and Fall Times | | 2 | | μs | $I_F$ = 10 mA, $V_{CE}$ = 10V |
| Collector-Emitter Saturation Voltage $V_{CE(sat)}$ | | | 0.5V | | $I_F$ = 50 mA, $I_C$ = 2 mA |

# ภาคผนวก ง.

## ◦ STANDARD CHARACTERISTICS

| MATERIAL | | 2C3 |
|---|---|---|
| $\mu iac$ | | 2000 ±20% |
| $\tan\delta / \mu iac$ 0.01MHz | $10^{-6}$ | 6 |
| $\Delta\mu iac / \mu iac^2$ /℃ (−30℃ ~ 20 ~ +60℃) | $10^{-6}$ | 1 ~ 5 |
| Tc | ℃ | 110 |
| FREQUENCY | MHz | <0.2 |
| D. F. (1 ~ 10min.) | $10^{-6}$ | < 4 |
| d | g/cm³ | 4.9 |
| B 15 | G | 3.700 |
| Hcms | Oe | 0.2 |
| $\rho$ | Ωcm | 130 |

## EXAMPLE OF DEMENTIONS




UNIT mm

| Name | A Size | A Tolerance | B Size | B Tolerance | C、E Size | C、E Tolerance | D Size | D Tolerance | F Size | F Tolerance | I Size | I Tolerance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E I 1-60 | 60.0 | ±0.6 | 44.0 | ±0.6 | 16.0 | 0 / −0.6 | 44.5 | ±0.5 | 23.0 | ±0.5 | 8.0 | ±0.1 |
| E I 2-60 | | ±0.9 | | ±0.6 | | 0 / −0.8 | | ±0.7 | | ±0.5 | | ±0.3 |
| E I 1-50 | 50.0 | ±0.5 | 42.0 | ±0.4 | 14.0 | 0 / −0.6 | 35.0 | ±0.4 | 25.0 | ±0.4 | 8.5 | ±0.1 |
| E I 2-50 | | ±0.8 | | ±0.6 | | 0 / −0.6 | | ±0.6 | | ±0.4 | | ±0.3 |
| E I 1-40 | 40.0 | ±0.4 | 34.0 | ±0.4 | 11.0 | 0 / −0.4 | 28.0 | ±0.3 | 21.0 | ±0.4 | 6.5 | ±0.1 |
| E I 2-40 | | ±0.6 | | ±0.6 | | 0 / −0.6 | | ±0.5 | | ±0.4 | | ±0.3 |
| E I 1-30 | 30.0 | ±0.3 | 26.0 | ±0.4 | 10.0 | 0 / −0.4 | 20.0 | ±0.3 | 16.0 | ±0.3 | 5.5 | ±0.1 |
| E I 2-30 | | ±0.5 | | ±0.4 | | 0 / −0.6 | | ±0.4 | | ±0.3 | | ±0.2 |
| E I 1-22 | 22.0 | ±0.3 | 18.6 | ±0.3 | 6.0 | 0 / −0.4 | 14.0 | ±0.2 | 10.6 | ±0.2 | 4.0 | ±0.1 |
| E I 2-22 | | ±0.4 | | ±0.4 | | 0 / −0.5 | | ±0.3 | | ±0.3 | | ±0.2 |
| E I 1-19 | 19.0 | ±0.2 | 15.8 | ±0.3 | 4.7 | 0 / −0.4 | 14.5 | ±0.2 | 11.0 | ±0.2 | 2.4 | ±0.1 |
| E I 2-19 | | ±0.3 | | ±0.4 | | 0 / −0.3 | | ±0.3 | | ±0.3 | | ±0.2 |
| E I 1-16 | 16.0 | ±0.2 | 14.0 | ±0.3 | 4.0 | 0 / −0.3 | 12.0 | ±0.2 | 10.0 | ±0.2 | 2.0 | ±0.1 |
| E I 2-16 | | ±0.3 | | ±0.4 | | 0 / −0.4 | | ±0.3 | | ±0.3 | | ±0.2 |
| E I 1-12 | 12.0 | ±0.2 | 9.6 | ±0.2 | 3.0 | 0 / −0.2 | 8.0 | ±0.2 | 5.6 | ±0.2 | 2.0 | ±0.1 |
| E I 2-12 | | ±0.3 | | ±0.3 | | 0 / −0.4 | | ±0.3 | | ±0.3 | | ±0.1 |

# ภาคผนวก จ.

| Gauge | | | | Diameter | | Sectional area | | | Copper wire weight | |
|---|---|---|---|---|---|---|---|---|---|---|
| B.W.G. | A.W.G. | S.W.G. | mm.G. | mil | mm | cir. mil | in² | mm² | lb/1,000ft | kg/km |
| 11 | - | - | - | 120 | 3.048 | 14,400 | .01131 | 7.297 | 43.59 | 64.87 |
| - | - | 11 | - | 116 | 2.946 | 13,456 | .01057 | 6.818 | 40.74 | 60.61 |
| - | 9 | - | - | 114.4 | 2.906 | 13,087 | .01028 | 6.632 | 39.62 | 58.96 |
| - | - | - | 2.9 | 114.2 | 2.900 | 13,042 | .01024 | 6.605 | 39.47 | 58.72 |
| 12 | - | - | - | 109 | 2.769 | 11,880 | .009331 | 6.020 | 35.96 | 53.52 |
| - | - | 12 | - | 104 | 2.642 | 10,816 | .008495 | 5.481 | 32.74 | 48.73 |
| - | - | - | 2.6 | 102.4 | 2.600 | 10,486 | .008246 | 5.309 | 31.78 | 47.29 |
| - | 10 | - | - | 101.9 | 2.588 | 10,384 | .008156 | 5.262 | 31.43 | 46.78 |
| 13 | - | - | - | 95 | 2.413 | 9,025 | .007088 | 4.573 | 27.32 | 40.65 |
| - | - | 13 | - | 92 | 2.337 | 8,464 | .006648 | 4.289 | 25.62 | 38.13 |
| - | 11 | - | - | 90.75 | 2.305 | 8,234 | .006467 | 4.172 | 24.92 | 37.09 |
| - | - | - | 2.3 | 90.54 | 2.300 | 8,199 | .006439 | 4.155 | 24.82 | 36.94 |
| 14 | - | - | - | 83 | 2.108 | 6,889 | .005411 | 3.491 | 20.85 | 31.04 |
| - | 12 | - | - | 80.81 | 2.053 | 6,530 | .005129 | 3.309 | 19.77 | 29.42 |
| - | - | 14 | - | 80 | 2.032 | 6,400 | .005027 | 3.243 | 19.37 | 28.83 |
| - | - | - | 2.0 | 78.74 | 2.000 | 6,200 | .004869 | 3.142 | 18.77 | 27.93 |
| 15 | - | 15 | - | 72 | 1.829 | 5,184 | .004072 | 2.627 | 18.77 | 27.93 |
| - | 13 | - | - | 71.96 | 1.828 | 5,178 | .004067 | 2.624 | 15.67 | 23.33 |
| - | - | - | 1.8 | 70.87 | 1.800 | 5,023 | .003945 | 2.545 | 15.20 | 22.63 |
| 16 | - | - | - | 65 | 1.651 | 4,225 | .003318 | 2.141 | 12.79 | 19.03 |
| - | 14 | - | - | 64.08 | 1.628 | 4,106 | .003225 | 2.081 | 12.43 | 18.50 |
| - | - | 16 | - | 64 | 1.626 | 4,096 | .003217 | 2.075 | 12.40 | 18.45 |
| - | - | - | 1.6 | 62.99 | 1.600 | 3,968 | .003116 | 2.011 | 12.01 | 17.83 |
| 17 | - | - | - | 58 | 1.473 | 3,364 | .002642 | 1.705 | 10.18 | 15.16 |
| - | 15 | - | - | 57.07 | 1.450 | 3,257 | .002558 | 1.650 | 9.859 | 14.67 |
| - | - | 17 | - | 56 | 1.422 | 3,136 | .002463 | 1.589 | 9.493 | 14.13 |
| - | - | - | 1.4 | 55.12 | 1.400 | 3,036 | .002386 | 1.539 | 9.196 | 13.68 |
| - | 16 | - | - | 50.82 | 1.291 | 2,583 | .002029 | 1.309 | 7.820 | 11.64 |
| 18 | - | - | - | 49 | 1.245 | 2,401 | .001886 | 1.217 | 7.269 | 10.82 |
| - | - | 18 | - | 48 | 1.219 | 2,304 | .001810 | 1.167 | 6.976 | 10.38 |
| - | - | - | 1.2 | 47.24 | 1.200 | 2,232 | .001753 | 1.131 | 6.756 | 10.06 |
| - | 17 | - | - | 45.26 | 1.150 | 2,048 | .001608 | 1.037 | 6.197 | 9.219 |
| 19 | - | - | - | 42 | 1.067 | 1,764 | .001385 | 0.8938 | 5.388 | 7.946 |
| - | 18 | - | - | 40.30 | 1.024 | 1,624 | .075 | 0.8226 | 4.914 | 7.313 |
| - | - | 19 | - | 40 | 1.016 | 1,600 | .001257 | 0.8107 | 4.845 | 7.207 |
| - | - | - | 1.0 | 39.37 | 1.000 | 1,550 | .001217 | 0.7854 | 4.690 | 6.982 |
| - | - | 20 | - | 36 | 0.9144 | 1,296 | .001018 | 0.6576 | 3.923 | 5.838 |
| - | 19 | - | - | 35.89 | 0.9116 | 1,288 | .001012 | 0.6529 | 3.900 | 5.804 |
| - | - | - | 9.0 | 35.43 | 0.9000 | 1,255 | .0009857 | 0.6362 | 3.799 | 5.656 |
| 20 | - | - | - | 35 | 0.8890 | 1,225 | .0009621 | 0.6207 | 3.708 | 5.518 |
| 21 | - | 21 | - | 32 | 0.8128 | 1,024 | .0008042 | 0.5189 | 3.099 | 4.613 |
| - | 20 | - | - | 31.96 | 0.8118 | 1,021 | .0008019 | 0.5174 | 3.091 | 4.600 |
| - | - | - | 8.0 | 31.50 | 0.8000 | 992.3 | .0007794 | 0.5027 | 3.004 | 4.469 |
| - | 21 | - | - | 28.46 | 0.7229 | 810 | .0006362 | 0.4105 | 2.452 | 3.649 |
| 22 | - | 22 | - | 28 | 0.7112 | 784 | .0006158 | 0.3973 | 2.373 | 3.532 |
| - | - | - | 7.0 | 27.56 | 0.7000 | 759.6 | .0005966 | 0.3848 | 2.299 | 3.421 |
| - | - | - | 6.5 | 25.59 | 0.6500 | 654.8 | .0005143 | 0.3318 | 1.982 | 2.950 |
| - | 22 | - | - | 25.35 | 0.6438 | 642.6 | .0005047 | 0.3256 | 1.945 | 2.895 |
| 23 | - | - | - | 25 | 0.6350 | 625 | .0004909 | 0.3167 | 1.892 | 2.816 |
| - | - | 23 | - | 24 | 0.6096 | 576 | .0004524 | 0.2919 | 1.744 | 2.595 |
| - | - | - | 6.0 | 23.62 | 0.6000 | 557.9 | .0004382 | 0.2827 | 1.689 | 2.513 |
| - | 23 | - | - | 22.57 | 0.5733 | 509.4 | .0004001 | 0.2581 | 1.542 | 2.295 |
| 24 | - | 24 | - | 22 | 0.5583 | 484 | .0003801 | 0.2452 | 1.465 | 2.180 |
| - | - | - | 5.5 | 21.65 | 0.5500 | 468.7 | .0003681 | 0.2376 | 1.419 | 2.112 |
| - | 24 | - | - | 20.10 | 0.5105 | 404 | .0003173 | 0.2047 | 1.223 | 1.820 |

# ประวัติผู้ทำการวิจัย

นาย มานะ ภัทรกุลพงษ์ เกิดวันที่ 17 เมษายน พ.ศ. 2494 อำเภอ เมือง จังหวัด สงขลา วุฒิการศึกษา วิศวกรรมศาสตร์บัณฑิต สาขา วิศวกรรมไฟฟ้า จากจุฬาลงกรณมหาวิทยาลัย ปี พ.ศ. 2517 มีประสบการณ์ทำงานที่การไฟฟ้าส่วนภูมิภาค 2ปี และเป็นอาจารย์ตรีแผนกวิชาการสื่อสารมวลชน คณะนิเทศศาสตร์ จุฬาลงกรณมหาวิทยาลัย เป็นเวลา 3 ปี