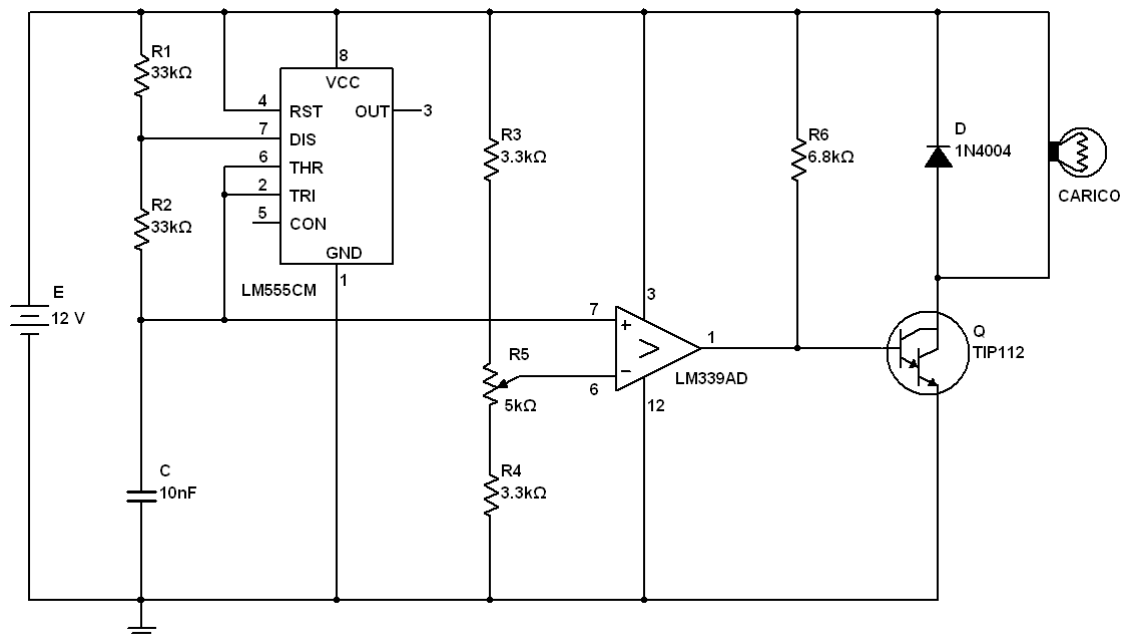


Classe	5 <sup>a</sup> Elettronici
Materia	T.D.P.
Argomento	Controllo di Potenza

## Controllo di potenza in continua con transistor in commutazione pilotato da un segnale PWM

Vogliamo costruire un circuito che ci permetta di controllare la potenza di un carico alimentato da una batteria tramite un transistor fatto funzionare alternativamente in conduzione e interdizione.

Lo schema utilizzato è il seguente:



La parte di controllo è costituita da un oscillatore realizzato con un LM555 in configurazione astabile e da un comparatore LM339 mentre la parte di potenza utilizza il BJT Darlington TIP112.

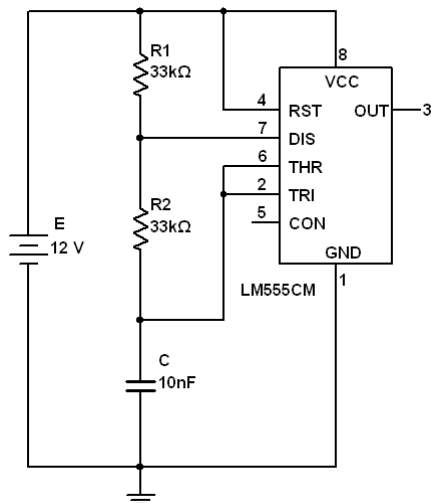
Il timer LM555 nella configurazione indicata oscilla grazie alla carica e scarica del condensatore C in un intervallo di tensione compreso tra:

$$\frac{1}{3}E < V_C(t) < \frac{2}{3}E$$

Nel nostro caso essendo

$$E = 12V$$

si ha



$$4 < V_c(t) < 8 \text{ V}$$

L'LM555 gestisce la carica e scarica del condensatore rilevando la tensione ai suoi capi grazie ai pin 6 e 2 (*threshold* e *trigger*) aprendo e chiudendo alternativamente un interruttore al suo interno che fa capo al pin 7 (*discharge*).

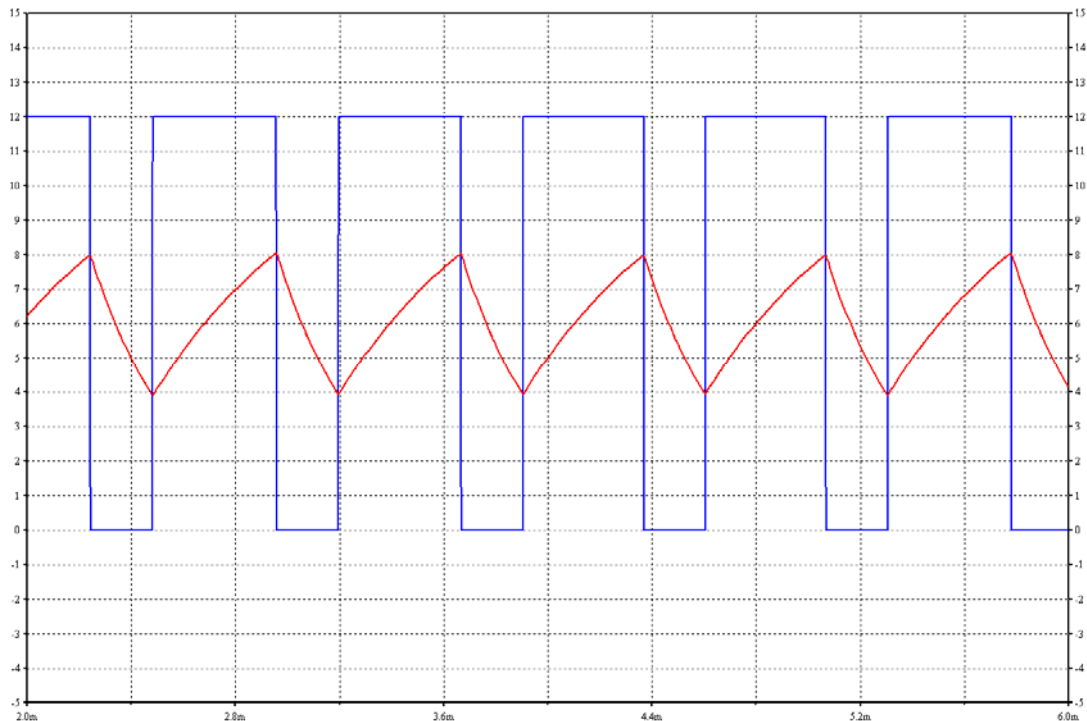
Nel passaggio da 4 V a 8 V il condensatore si carica tramite la batteria attraverso le due resistenze  $R_1$  ed  $R_2$  in un tempo  $T_1$  pari a:

$$T_1 = (R_1 + R_2)C \log_e 2$$

Nel passaggio da 8 V a 4 V il condensatore si scarica attraverso la sola resistenza  $R_2$  sul piedino 7 del LM555 che si porta a massa in un tempo pari a:

$$T_2 = R_2 C \log_e 2$$

Nella fase di carica il pin 3 (*output*) si porta a livello logico alto (12 V) mentre in quella di scarica a livello logico basso ( $\sim 0$  V).



Nel caso in esame sul pin 3 di uscita si ha quindi un'onda rettangolare avente una frequenza:

$$f = \frac{1}{T} = \frac{1}{T_1 + T_2} = \frac{1}{(R_1 + 2R_2)C \log_e 2} = \frac{1}{3 \cdot 33 \cdot 10^3 \cdot 10 \cdot 10^{-9} \cdot \log_e 2} \cong 1457 \text{ Hz}$$

e un duty-cycle:

$$\text{d.c.}_{(\%)} = \frac{T_1}{T} = \frac{T_1}{T_1 + T_2} = \frac{R_1 + R_2}{R_1 + 2R_2} = \frac{2}{3} \cong 66.7\%$$

Il nostro obiettivo è però quello di avere un'onda rettangolare con duty-cycle variabile in un intervallo compreso tra 0 e il 100%.

Per fare questo si usa la tensione ai capi del condensatore e la si confronta con una tensione costante nel comparatore LM339 che in uscita darà il valore alto solo quando la tensione al morsetto positivo supererà quella di riferimento.

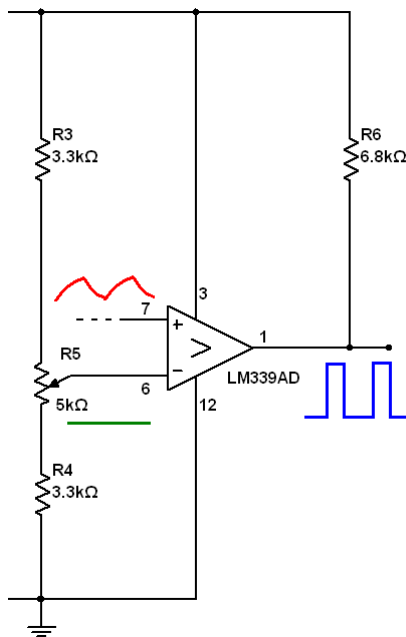
La tensione di confronto all'ingresso negativo del comparatore è ottenuta tramite un partitore costituito dalle resistenze  $R_3$  ed  $R_4$  e dal trimmer  $R_5$ .

Con i valori scelti si ha:

$$V_{-\min} = \frac{R_4}{R_3 + R_4 + R_5} E = \frac{3.3 \cdot 10^3}{(3.3 + 3.3 + 5) \cdot 10^3} E = 12 \frac{3.3}{11.6} \cong 3.41 < 4 = V_{+\min}$$

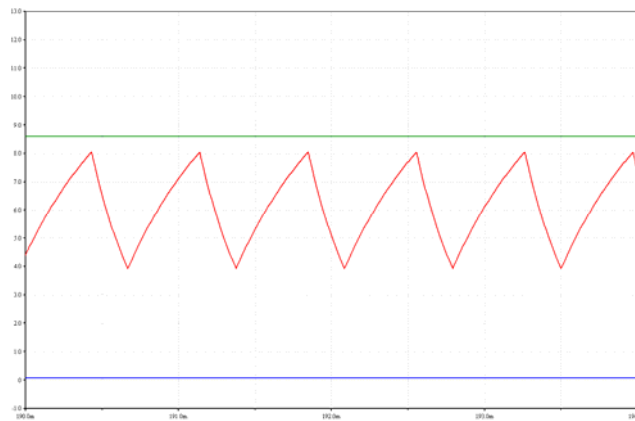
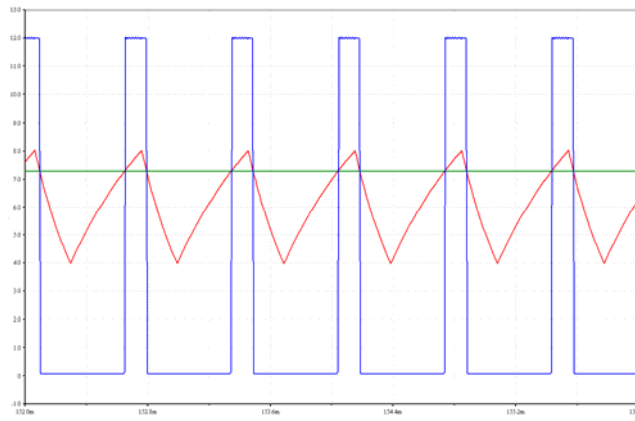
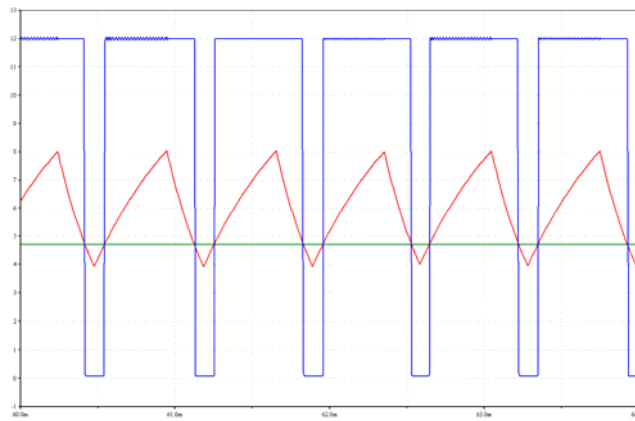
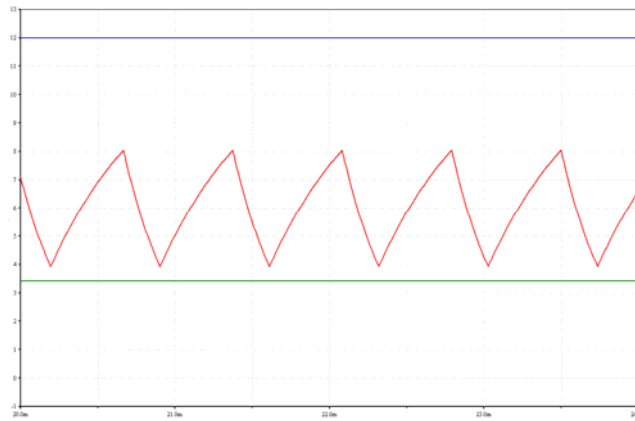
e

$$V_{-\max} = \frac{R_4 + R_5}{R_3 + R_4 + R_5} E = \frac{(3.3 + 5) \cdot 10^3}{(3.3 + 3.3 + 5) \cdot 10^3} E = 12 \frac{8.3}{11.6} \cong 8.59 > 8 = V_{+\max}$$



Pertanto al variare del trimmer, la tensione sull'ingresso negativo varia in un intervallo più ampio rispetto a quella del condensatore che è limitata tra 4 e 8 V.

Le figure successive mostrano l'andamento della tensione a vuoto all'uscita del comparatore per diversi valore di regolazione del trimmer dalla minima alla massima resistenza (L'LM339 ha un'uscita open-collector e richiede una resistenza di pull-up).



Collegata all'uscita del comparatore vi è infine la parte di potenza costituita da un transistor Darlington ad elevato guadagno (valori di  $h_{FE}$  compresi tra 500 e 1000) ed una corrente di collettore  $I_{Cmax}=2$  A.

La resistenza di base del TIP112 è stata calcolata per avere un margine di sicurezza sul dispositivo, infatti quando il comparatore si trova nello stato OFF si ha:

$$I_B = \frac{E - V_{BE0}}{R_6} = \frac{12 - 2.8}{6.8 \cdot 10^3} = 1.35 \text{ mA}$$

pertanto risulta nella peggiore delle ipotesi:

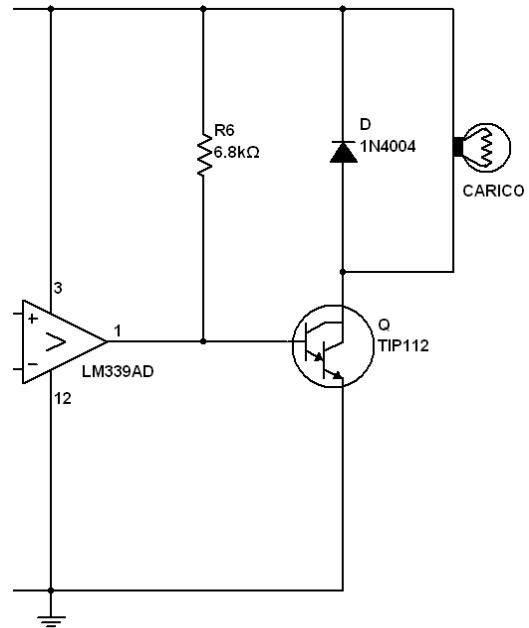
$$I_C = h_{FEmax} I_B = 1000 \cdot 1.35 \cdot 10^{-3} = 1.35 \text{ A}$$

che è minore della massima corrente di collettore ammessa dal BJT.

Per concludere è stato inserito sul collettore del TIP112 il diodo 1N4004 che serve ad utilizzare il circuito anche con carichi induttivi come motori in corrente continua.

Datasheets allegati:

- LM555
- LM339
- TIP112



# LM555/NE555/SA555

## Single Timer

### Features

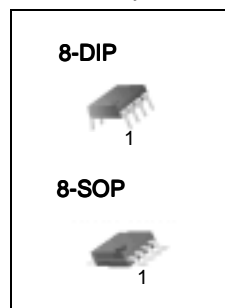
- High Current Drive Capability (200mA)
- Adjustable Duty Cycle
- Temperature Stability of 0.005%/°C
- Timing From  $\mu$ Sec to Hours
- Turn off Time Less Than 2 $\mu$ Sec

### Applications

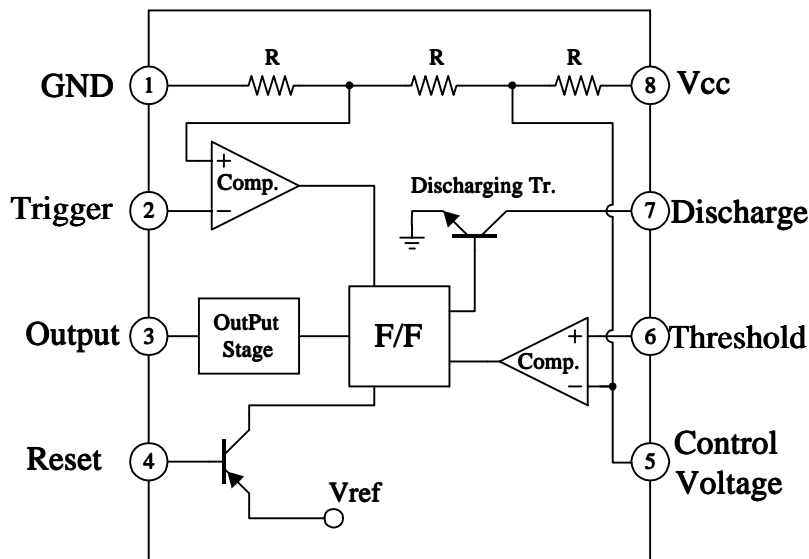
- Precision Timing
- Pulse Generation
- Time Delay Generation
- Sequential Timing

### Description

The LM555/NE555/SA555 is a highly stable controller capable of producing accurate timing pulses. With a monostable operation, the time delay is controlled by one external resistor and one capacitor. With an astable operation, the frequency and duty cycle are accurately controlled by two external resistors and one capacitor.



### Internal Block Diagram



**Absolute Maximum Ratings (T<sub>A</sub> = 25°C)**

Parameter	Symbol	Value	Unit
Supply Voltage	V <sub>CC</sub>	16	V
Lead Temperature (Soldering 10sec)	T <sub>LEAD</sub>	300	°C
Power Dissipation	P <sub>D</sub>	600	mW
Operating Temperature Range LM555/NE555 SA555	T <sub>OPR</sub>	0 ~ +70 -40 ~ +85	°C
Storage Temperature Range	T <sub>STG</sub>	-65 ~ +150	°C

## Electrical Characteristics

( $T_A = 25^\circ\text{C}$ ,  $V_{CC} = 5 \sim 15\text{V}$ , unless otherwise specified)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Supply Voltage	$V_{CC}$	-	4.5	-	16	V
Supply Current (Low Stable) (Note1)	$I_{CC}$	$V_{CC} = 5\text{V}$ , $R_L = \infty$	-	3	6	mA
		$V_{CC} = 15\text{V}$ , $R_L = \infty$	-	7.5	15	mA
Timing Error (Monostable) Initial Accuracy (Note2) Drift with Temperature (Note4) Drift with Supply Voltage (Note4)	$ACCUR$ $\Delta t/\Delta T$ $\Delta t/\Delta V_{CC}$	$R_A = 1\text{k}\Omega$ to $100\text{k}\Omega$ $C = 0.1\mu\text{F}$	-	1.0 50 0.1	3.0 - 0.5	% ppm/ $^\circ\text{C}$ %/V
Timing Error (Astable) Initial Accuracy (Note2) Drift with Temperature (Note4) Drift with Supply Voltage (Note4)	$ACCUR$ $\Delta t/\Delta T$ $\Delta t/\Delta V_{CC}$	$R_A = 1\text{k}\Omega$ to $100\text{k}\Omega$ $C = 0.1\mu\text{F}$	-	2.25 150 0.3	-	% ppm/ $^\circ\text{C}$ %/V
Control Voltage	$V_C$	$V_{CC} = 15\text{V}$	9.0	10.0	11.0	V
		$V_{CC} = 5\text{V}$	2.6	3.33	4.0	V
Threshold Voltage	$V_{TH}$	$V_{CC} = 15\text{V}$	-	10.0	-	V
		$V_{CC} = 5\text{V}$	-	3.33	-	V
Threshold Current (Note3)	$I_{TH}$	-	-	0.1	0.25	$\mu\text{A}$
Trigger Voltage	$V_{TR}$	$V_{CC} = 5\text{V}$	1.1	1.67	2.2	V
		$V_{CC} = 15\text{V}$	4.5	5	5.6	V
Trigger Current	$I_{TR}$	$V_{TR} = 0\text{V}$	-	0.01	2.0	$\mu\text{A}$
Reset Voltage	$V_{RST}$	-	0.4	0.7	1.0	V
Reset Current	$I_{RST}$	-	-	0.1	0.4	mA
Low Output Voltage	$V_{OL}$	$V_{CC} = 15\text{V}$ $I_{SINK} = 10\text{mA}$ $I_{SINK} = 50\text{mA}$	-	0.06 0.3	0.25 0.75	V V
		$V_{CC} = 5\text{V}$ $I_{SINK} = 5\text{mA}$	-	0.05	0.35	V
High Output Voltage	$V_{OH}$	$V_{CC} = 15\text{V}$ $I_{SOURCE} = 200\text{mA}$ $I_{SOURCE} = 100\text{mA}$	12.75	12.5 13.3	-	V V
		$V_{CC} = 5\text{V}$ $I_{SOURCE} = 100\text{mA}$	2.75	3.3	-	V
Rise Time of Output (Note4)	$t_R$	-	-	100	-	ns
Fall Time of Output (Note4)	$t_F$	-	-	100	-	ns
Discharge Leakage Current	$I_{LKG}$	-	-	20	100	nA

### Notes:

- When the output is high, the supply current is typically 1mA less than at  $V_{CC} = 5\text{V}$ .
- Tested at  $V_{CC} = 5.0\text{V}$  and  $V_{CC} = 15\text{V}$ .
- This will determine the maximum value of  $R_A + R_B$  for 15V operation, the max. total  $R = 20\text{M}\Omega$ , and for 5V operation, the max. total  $R = 6.7\text{M}\Omega$ .
- These parameters, although guaranteed, are not 100% tested in production.

# Application Information

Table 1 below is the basic operating table of 555 timer:

Table 1. Basic Operating Table

Threshold Voltage (V <sub>th</sub> )(PIN 6)	Trigger Voltage (V <sub>tr</sub> )(PIN 2)	Reset(PIN 4)	Output(PIN 3)	Discharging Tr. (PIN 7)
Don't care	Don't care	Low	Low	ON
$V_{th} > 2V_{cc} / 3$	$V_{tr} > 2V_{cc} / 3$	High	Low	ON
$V_{cc} / 3 < V_{th} < 2 V_{cc} / 3$	$V_{cc} / 3 < V_{tr} < 2 V_{cc} / 3$	High	-	-
$V_{th} < V_{cc} / 3$	$V_{tr} < V_{cc} / 3$	High	High	OFF

When the low signal input is applied to the reset terminal, the timer output remains low regardless of the threshold voltage or the trigger voltage. Only when the high signal is applied to the reset terminal, the timer's output changes according to threshold voltage and trigger voltage.

When the threshold voltage exceeds 2/3 of the supply voltage while the timer output is high, the timer's internal discharge Tr. turns on, lowering the threshold voltage to below 1/3 of the supply voltage. During this time, the timer output is maintained low. Later, if a low signal is applied to the trigger voltage so that it becomes 1/3 of the supply voltage, the timer's internal discharge Tr. turns off, increasing the threshold voltage and driving the timer output again at high.

## 1. Monostable Operation

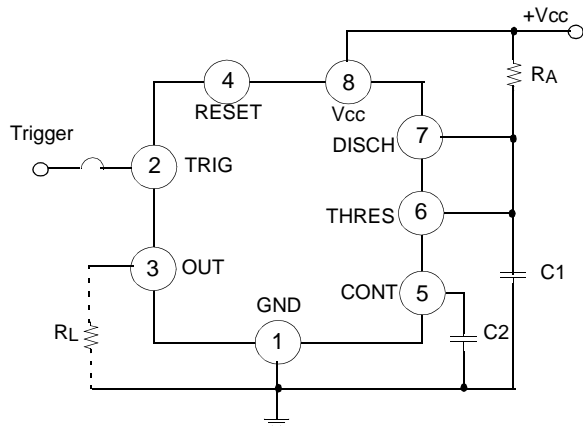


Figure 1. Monoatable Circuit

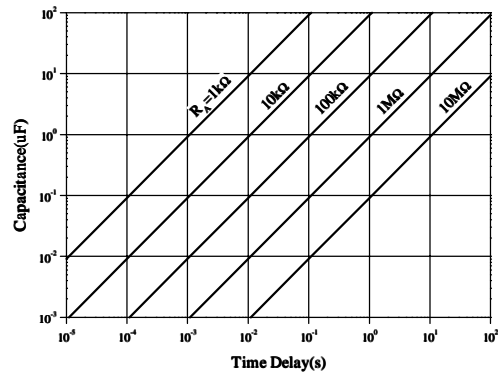


Figure 2. Resistance and Capacitance vs. Time delay( $t_d$ )

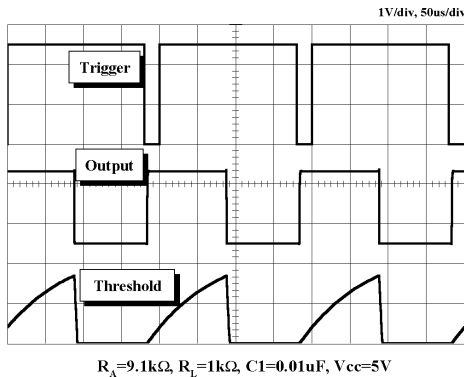


Figure 3. Waveforms of Monostable Operation

Figure 1 illustrates a monostable circuit. In this mode, the timer generates a fixed pulse whenever the trigger voltage falls below  $V_{cc}/3$ . When the trigger pulse voltage applied to the #2 pin falls below  $V_{cc}/3$  while the timer output is low, the timer's internal flip-flop turns the discharging Tr. off and causes the timer output to become high by charging the external capacitor C1 and setting the flip-flop output at the same time.

The voltage across the external capacitor C1,  $V_{C1}$  increases exponentially with the time constant  $\tau = R_A * C$  and reaches  $2V_{cc}/3$  at  $t_d = 1.1R_A * C$ . Hence, capacitor C1 is charged through resistor  $R_A$ . The greater the time constant  $R_A C$ , the longer it takes for the  $V_{C1}$  to reach  $2V_{cc}/3$ . In other words, the time constant  $R_A C$  controls the output pulse width.

When the applied voltage to the capacitor C1 reaches  $2V_{cc}/3$ , the comparator on the trigger terminal resets the flip-flop, turning the discharging Tr. on. At this time, C1 begins to discharge and the timer output converts to low.

In this way, the timer operating in the monostable repeats the above process. Figure 2 shows the time constant relationship based on  $R_A$  and C. Figure 3 shows the general waveforms during the monostable operation.

It must be noted that, for a normal operation, the trigger pulse voltage needs to maintain a minimum of  $V_{cc}/3$  before the timer output turns low. That is, although the output remains unaffected even if a different trigger pulse is applied while the output is high, it may be affected and the waveform does not operate properly if the trigger pulse voltage at the end of the output pulse remains at below  $V_{cc}/3$ . Figure 4 shows such a timer output abnormality.

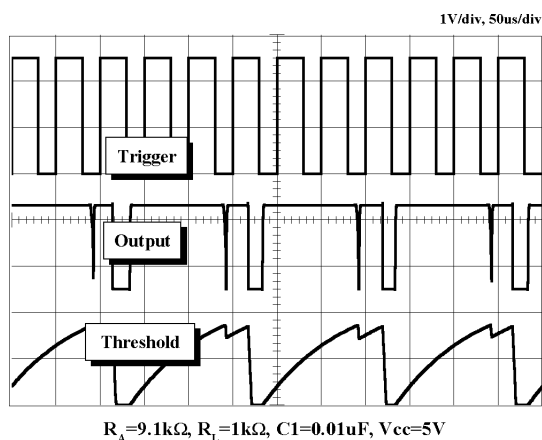


Figure 4. Waveforms of Monostable Operation (abnormal)

## 2. Astable Operation

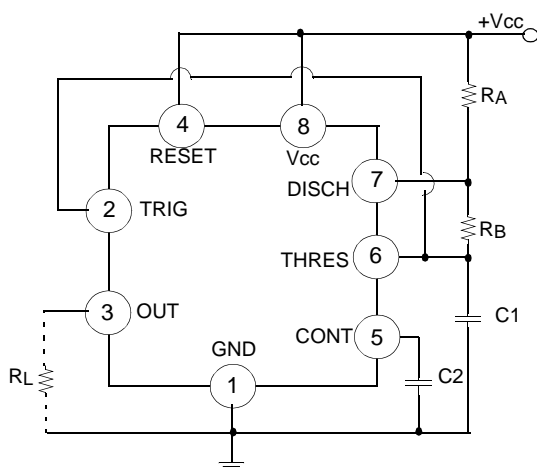


Figure 5. Astable Circuit

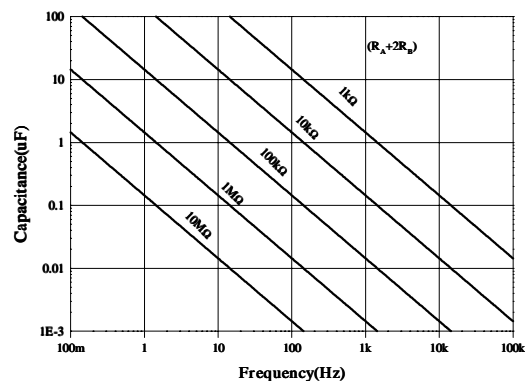
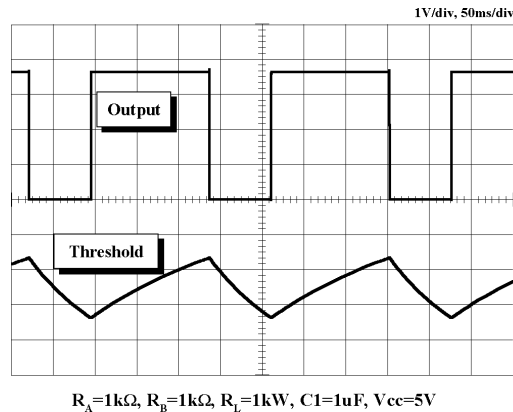


Figure 6. Capacitance and Resistance vs. Frequency

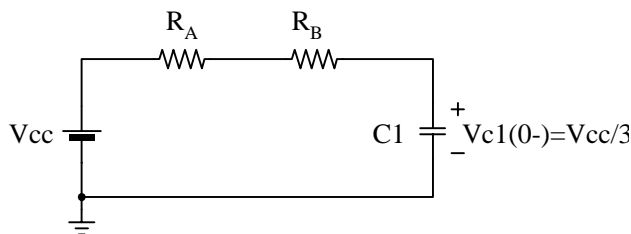


**Figure 7. Waveforms of Astable Operation**

An astable timer operation is achieved by adding resistor  $R_B$  to Figure 1 and configuring as shown on Figure 5. In the astable operation, the trigger terminal and the threshold terminal are connected so that a self-trigger is formed, operating as a multi vibrator. When the timer output is high, its internal discharging  $Tr$  turns off and the  $V_{C1}$  increases by exponential function with the time constant  $(R_A+R_B)*C$ .

When the  $V_{C1}$ , or the threshold voltage, reaches  $2V_{CC}/3$ , the comparator output on the trigger terminal becomes high, resetting the F/F and causing the timer output to become low. This in turn turns on the discharging  $Tr$  and the  $C1$  discharges through the discharging channel formed by  $R_B$  and the discharging  $Tr$ . When the  $V_{C1}$  falls below  $V_{CC}/3$ , the comparator output on the trigger terminal becomes high and the timer output becomes high again. The discharging  $Tr$  turns off and the  $V_{C1}$  rises again.

In the above process, the section where the timer output is high is the time it takes for the  $V_{C1}$  to rise from  $V_{CC}/3$  to  $2V_{CC}/3$ , and the section where the timer output is low is the time it takes for the  $V_{C1}$  to drop from  $2V_{CC}/3$  to  $V_{CC}/3$ . When timer output is high, the equivalent circuit for charging capacitor  $C1$  is as follows:



$$C_1 \frac{dv_{c1}}{dt} = \frac{V_{CC} - V(0-)}{R_A + R_B} \quad (1)$$

$$V_{C1}(0+) = V_{CC}/3 \quad (2)$$

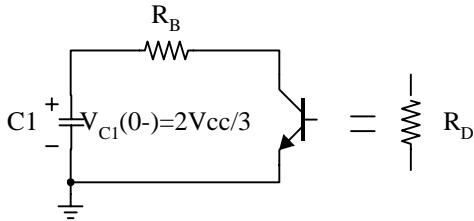
$$V_{C1}(t) = V_{CC} \left( 1 - \frac{2}{3} e^{-\left( \frac{t}{(R_A + R_B)C_1} \right)} \right) \quad (3)$$

Since the duration of the timer output high state( $t_H$ ) is the amount of time it takes for the  $V_{C1}(t)$  to reach  $2V_{CC}/3$ ,

$$V_{C1}(t) = \frac{2}{3}V_{CC} = V_{CC} \left( 1 - \frac{2}{3} e^{-\left(\frac{t_H}{(R_A + R_B)C_1}\right)} \right) \quad (4)$$

$$t_H = C_1(R_A + R_B)\ln 2 = 0.693(R_A + R_B)C_1 \quad (5)$$

The equivalent circuit for discharging capacitor C1, when timer output is low is, as follows:



$$C_1 \frac{dv_{C1}}{dt} + \frac{1}{R_A + R_B} V_{C1} = 0 \quad (6)$$

$$V_{C1}(t) = \frac{2}{3}V_{CC} e^{-\frac{t}{(R_A + R_D)C_1}} \quad (7)$$

Since the duration of the timer output low state( $t_L$ ) is the amount of time it takes for the  $V_{C1}(t)$  to reach  $V_{CC}/3$ ,

$$\frac{1}{3}V_{CC} = \frac{2}{3}V_{CC} e^{-\frac{t_L}{(R_A + R_D)C_1}} \quad (8)$$

$$t_L = C_1(R_B + R_D)\ln 2 = 0.693(R_B + R_D)C_1 \quad (9)$$

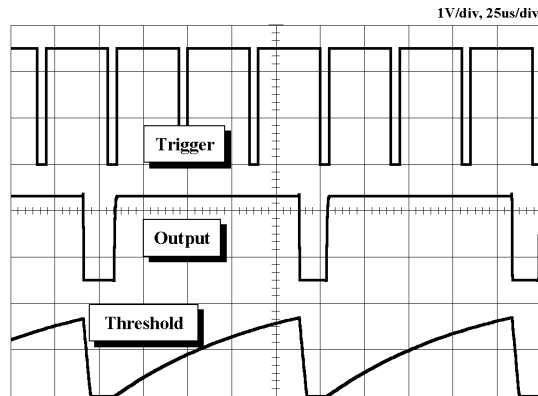
Since  $R_D$  is normally  $R_B \gg R_D$  although related to the size of discharging  $T_r$ ,  
 $t_L = 0.693R_B C_1$  (10)

Consequently, if the timer operates in astable, the period is the same with  
 $T = t_H + t_L = 0.693(R_A + R_B)C_1 + 0.693R_B C_1 = 0.693(R_A + 2R_B)C_1$  because the period is the sum of the charge time and discharge time. And since frequency is the reciprocal of the period, the following applies.

$$\text{frequency, } f = \frac{1}{T} = \frac{1.44}{(R_A + 2R_B)C_1} \quad (11)$$

### 3. Frequency divider

By adjusting the length of the timing cycle, the basic circuit of Figure 1 can be made to operate as a frequency divider. Figure 8. illustrates a divide-by-three circuit that makes use of the fact that retriggering cannot occur during the timing cycle.



$R_A=9.1k\Omega, R_L=1k\Omega, C1=0.01\mu F, V_{cc}=5V$

Figure 8. Waveforms of Frequency Divider Operation

#### 4. Pulse Width Modulation

The timer output waveform may be changed by modulating the control voltage applied to the timer's pin 5 and changing the reference of the timer's internal comparators. Figure 9 illustrates the pulse width modulation circuit.

When the continuous trigger pulse train is applied in the monostable mode, the timer output width is modulated according to the signal applied to the control terminal. Sine wave as well as other waveforms may be applied as a signal to the control terminal. Figure 10 shows the example of pulse width modulation waveform.

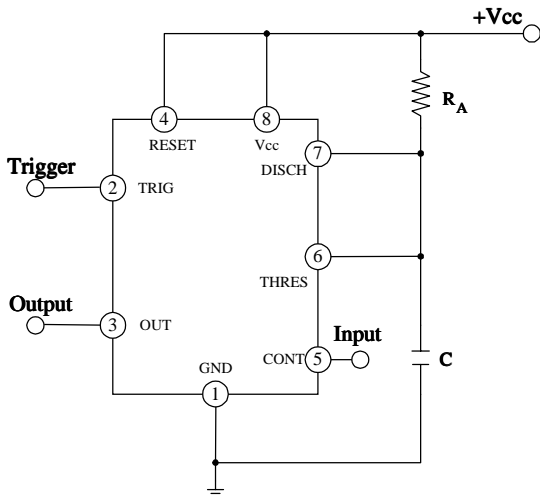
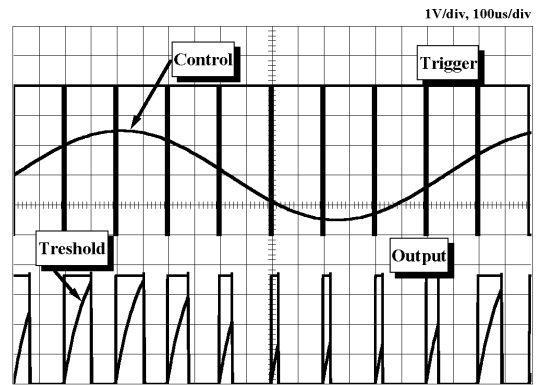


Figure 9. Circuit for Pulse Width Modulation



$R_A=9.1k\Omega, R_L=1k\Omega, C1=0.01\mu F, V_{cc}=5V$

Figure 10. Waveforms of Pulse Width Modulation

#### 5. Pulse Position Modulation

If the modulating signal is applied to the control terminal while the timer is connected for the astable operation as in Figure 11, the timer becomes a pulse position modulator.

In the pulse position modulator, the reference of the timer's internal comparators is modulated which in turn modulates the timer output according to the modulation signal applied to the control terminal.

Figure 12 illustrates a sine wave for modulation signal and the resulting output pulse position modulation : however, any wave shape could be used.

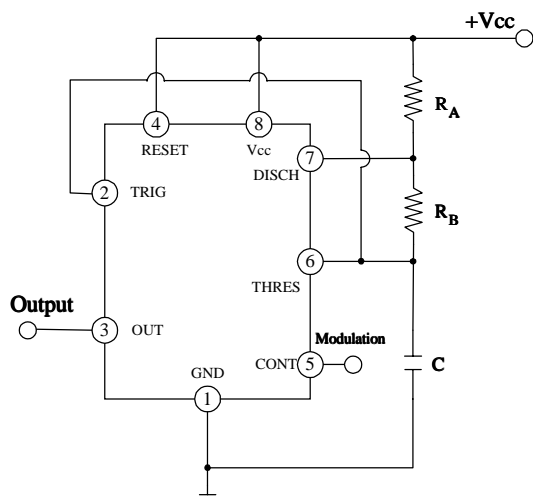


Figure 11. Circuit for Pulse Position Modulation

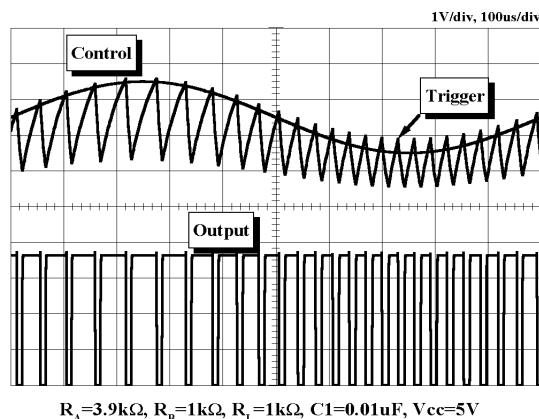


Figure 12. Waveforms of pulse position modulation

## 6. Linear Ramp

When the pull-up resistor  $R_A$  in the monostable circuit shown in Figure 1 is replaced with constant current source, the  $V_C$  increases linearly, generating a linear ramp. Figure 13 shows the linear ramp generating circuit and Figure 14 illustrates the generated linear ramp waveforms.

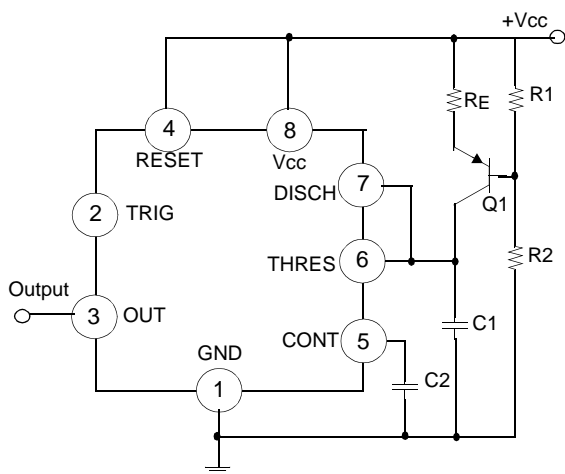


Figure 13. Circuit for Linear Ramp

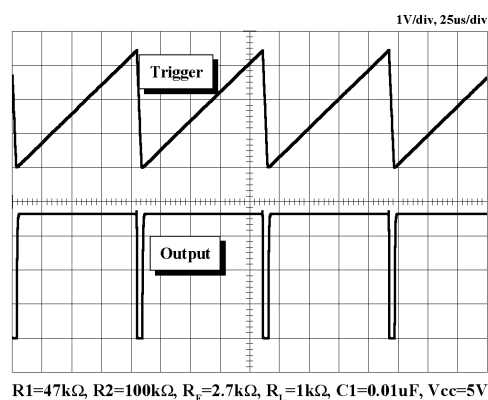


Figure 14. Waveforms of Linear Ramp

In Figure 13, current source is created by PNP transistor  $Q_1$  and resistor  $R_1$ ,  $R_2$ , and  $R_E$ .

$$I_C = \frac{V_{CC} - V_E}{R_E} \quad (12)$$

Here,  $V_E$  is

$$V_E = V_{BE} + \frac{R_2}{R_1 + R_2} V_{CC} \quad (13)$$

For example, if  $V_{CC}=15V$ ,  $R_E=20k\Omega$ ,  $R_1=5k\Omega$ ,  $R_2=10k\Omega$ , and  $V_{BE}=0.7V$ ,  
 $V_E=0.7V+10V=10.7V$

$I_C=(15-10.7)/20k=0.215mA$

When the trigger starts in a timer configured as shown in Figure 13, the current flowing through capacitor C1 becomes a constant current generated by PNP transistor and resistors.

Hence, the VC is a linear ramp function as shown in Figure 14. The gradient S of the linear ramp function is defined as follows:

$$S = \frac{V_{p-p}}{T} \quad (14)$$

Here the  $V_{p-p}$  is the peak-to-peak voltage.

If the electric charge amount accumulated in the capacitor is divided by the capacitance, the VC comes out as follows:

$$V=Q/C \quad (15)$$

The above equation divided on both sides by T gives us

$$\frac{V}{T} = \frac{Q/T}{C} \quad (16)$$

and may be simplified into the following equation.

$$S=I/C \quad (17)$$

In other words, the gradient of the linear ramp function appearing across the capacitor can be obtained by using the constant current flowing through the capacitor.

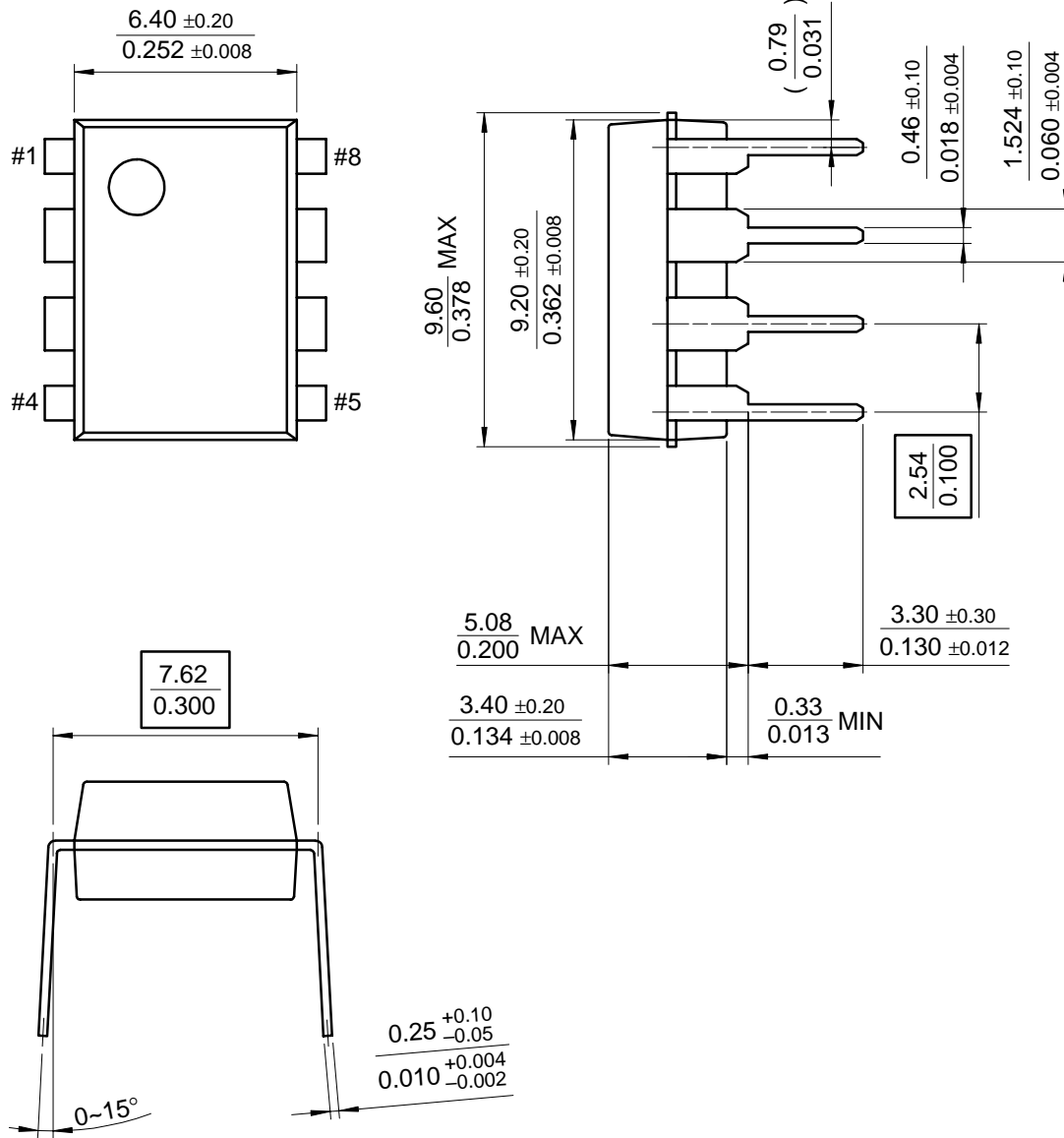
If the constant current flow through the capacitor is 0.215mA and the capacitance is 0.02 $\mu$ F, the gradient of the ramp function at both ends of the capacitor is  $S = 0.215\text{m}/0.022\mu = 9.77\text{V}/\text{ms}$ .

# Mechanical Dimensions

## Package

Dimensions in millimeters

### 8-DIP

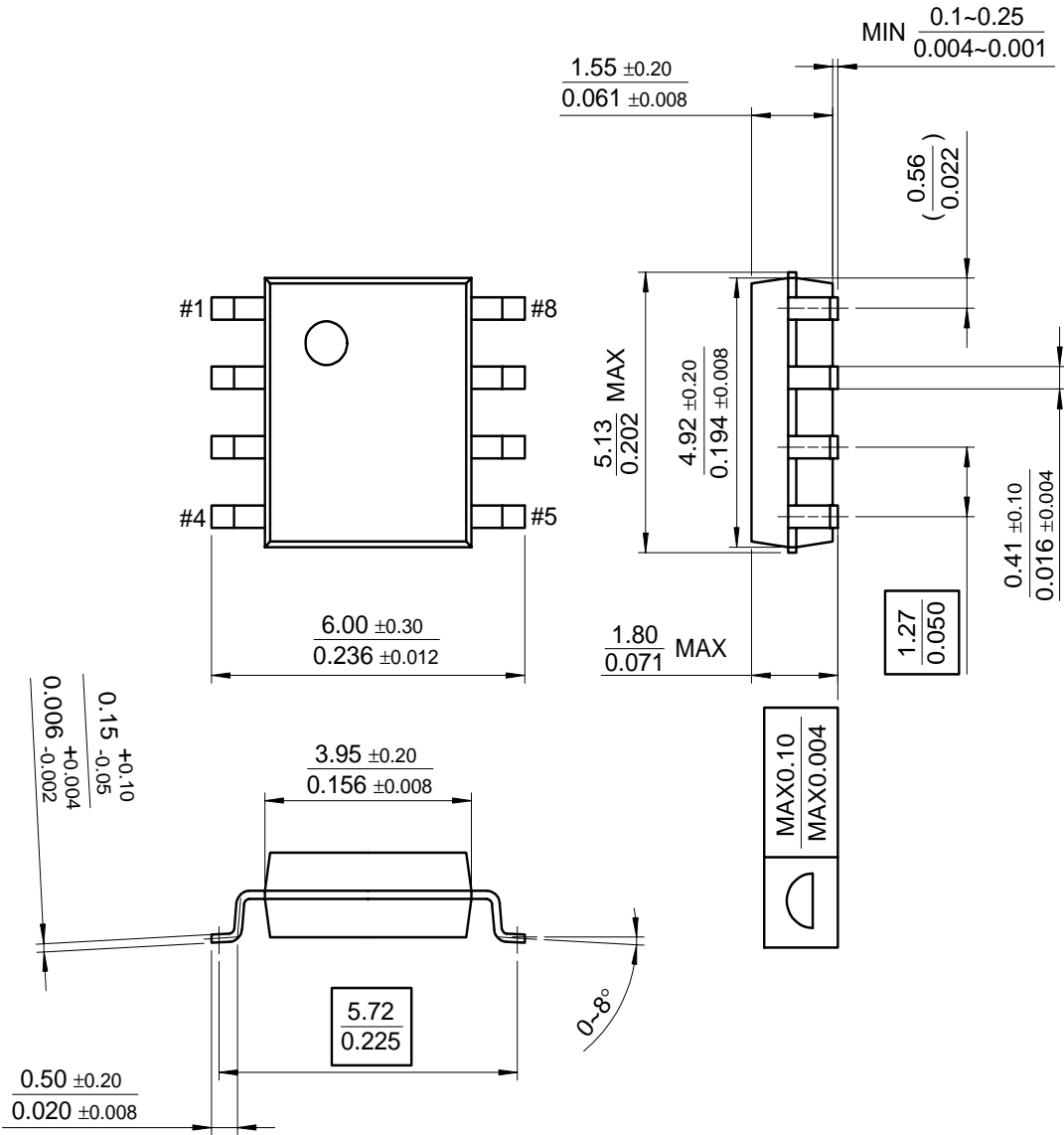


Mechanical Dimensions (Continued)

Package

Dimensions in millimeters

8-SOP



# LM2901, LM339/LM339A, LM3302, LM239/LM239A

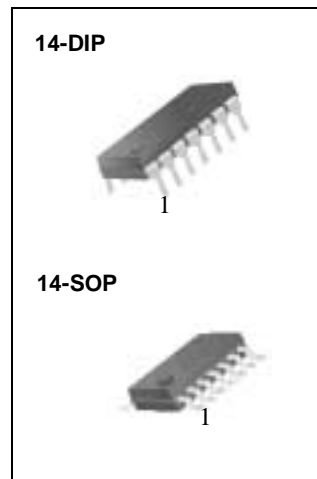
## Quad Comparator

### Features

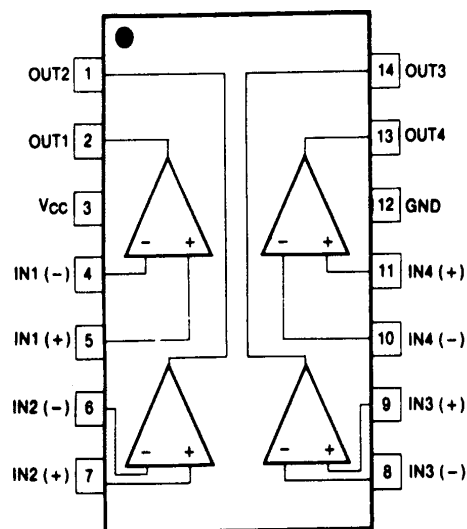
- Single or dual supply operation
- Wide range of supply voltage  
LM2901, LM339/LM339A, LM239/LM239A : 2 ~ 36V (or  $\pm 1 \sim \pm 18V$ )  
LM3302 : 2 ~ 28V (or  $\pm 1 \sim \pm 14V$ )
- Low supply current drain 800 $\mu A$  Typ.
- Open collector outputs for wired and connectors
- Low input bias current 25nA Typ.
- Low Input offset current  $\pm 2.3nA$  Typ.
- Low input offset voltage  $\pm 1.4mV$  Typ.
- Common mode input voltage range includes ground.
- Low output saturation voltage
- Output compatible with TTL, DTL and MOS logic system

### Description

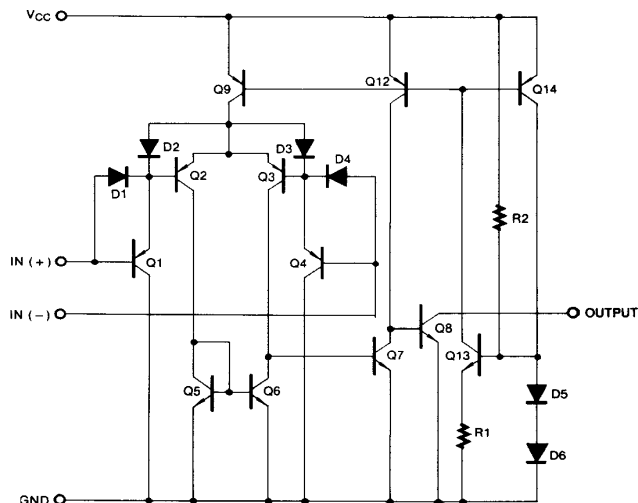
The LM2901, LM339/LM339A, LM239/LM239A, LM3302 consist of four independent voltage comparators designed to operate from single power supply over a wide voltage range.



### Internal Block Diagram



## Schematic Diagram



## Absolute Maximum Ratings

Parameter	Symbol	Value	Unit
Supply Voltage	V <sub>CC</sub>	±18 or 36	V
Supply Voltage only LM3302	V <sub>CC</sub>	±14 or 28	V
Differential Input Voltage	V <sub>I(DIFF)</sub>	36	V
Differential Input Voltage only LM3302	V <sub>I(DIFF)</sub>	28	V
Input Voltage	V <sub>I</sub>	- 0.3 to +36	V
Input Voltage only LM3302	V <sub>I</sub>	- 0.3 to +28	V
Output Short Circuit to GND	-	Continuous	-
Power Dissipation	PD	570	mW
Operating Temperature LM339/LM339A LM2901/LM3302 LM239/LM239A	TOPR	0 ~ + 70 -40 ~ + 85 -25 ~ + 85	°C
Storage Temperature	T <sub>STG</sub>	- 65 ~ + 150	°C

## Electrical Characteristics

(VCC = 5V, TA = 25°C, unless otherwise specified)

Parameter	Symbol	Conditions	LM239A/LM339A			LM239/LM339			Unit	
			Min	Typ	Max	Min	Typ	Max		
Input Offset Voltage	V <sub>IO</sub>	V <sub>O(P)</sub> = 1.4V, R <sub>S</sub> = 0Ω	-	±1	±2	-	±1.4	±5	mV	
		Note 1	-		±4.0	-	-	±9.0		
Input Offset Current	I <sub>IO</sub>		-	±2.3	±50	-	±2.3	±50	nA	
		Note 1	-		±150	-	-	±150		
Input Bias Current	I <sub>BIAS</sub>		-	57	250	-	57	250	nA	
		Note 1	-	-	400	-	-	400		
Input Common Mode Voltage Range	V <sub>I(R)</sub>		0	-	V <sub>CC</sub> -1.5	0	-	V <sub>CC</sub> -1.5	V	
		Note 1	0	-	V <sub>CC</sub> -2	0	-	V <sub>CC</sub> -2		
Supply Current	I <sub>CC</sub>	V <sub>CC</sub> = 5V R <sub>L</sub> = ∞	-	1.1	2.0	-	1.1	2.0	mA	
Voltage Gain	G <sub>V</sub>	V <sub>CC</sub> = 15V, R <sub>L</sub> ≥ 15KΩ (for large swing)	50	200	-	50	200	-	V/mV	
Large Signal Response Time	T <sub>LRES</sub>	V <sub>I</sub> = TTL Logic Swing V <sub>REF</sub> = 1.4V, V <sub>RL</sub> = 5V, R <sub>L</sub> = 5.1KΩ	-	350	-	-	350	-	ns	
Response Time	T <sub>RES</sub>	V <sub>RL</sub> = 5V, R <sub>L</sub> = 5.1KΩ	-	1.4	-	-	1.4	-	μs	
Output Sink Current	I <sub>SINK</sub>	V <sub>I(-)</sub> ≥ 1V, V <sub>I(+)</sub> = 0V, V <sub>O(P)</sub> ≤ 1.5V	6	18	-	6	18	-	mA	
Output Saturation Voltage	V <sub>SAT</sub>	V <sub>I(-)</sub> ≥ 1V, V <sub>I(+)</sub> = 0V	-	140	400	-	140	400	mV	
		I <sub>SINK</sub> = 4mA	Note 1	-		700	-			700
Output Leakage Current	I <sub>o(LKG)</sub>	V <sub>I(-)</sub> = 0V V <sub>I(+)</sub> = 1V	V <sub>O(P)</sub> = 5V	-	0.1	-	-	0.1	-	nA
			V <sub>O(P)</sub> = 30V	-	-	1.0	-	-	1.0	μA
Differential Voltage	V <sub>I(DIFF)</sub>	Note 1	-	-	36	-	-	36	V	

### Note 1.

LM339/LM339A : 0 ≤ T<sub>A</sub> ≤ +70°C

LM2901/LM3302 : -40 ≤ T<sub>A</sub> ≤ +85°C

LM239/LM239A : -25 ≤ T<sub>A</sub> ≤ +85°C

**Electrical Characteristics (Continued)**

(VCC = 5V, TA = 25°C, unless otherwise specified)

Parameter	Symbol	Conditions	LM2901			LM3302			Unit
			Min	Typ	Max.	Min	Typ	Max.	
Input Offset Voltage	V <sub>IO</sub>	V <sub>O(P)</sub> = 1.4V, R <sub>S</sub> = 0Ω	-	2	7	-	2	20	mV
		Note 1	-	9	15	-	-	40	
Input Offset Current	I <sub>IO</sub>		-	2.3	50	-	3	100	nA
		Note 1	-	50	200	-	-	300	
Input Bias Current	I <sub>BIAS</sub>		-	57	250	-	57	250	nA
		Note 1	-	200	500	-	-	1000	
Input Common Mode Voltage Range	V <sub>I(R)</sub>		0	-	V <sub>CC</sub> -1.5	0	-	V <sub>CC</sub> -1.5	V
		Note 1	0	-	V <sub>CC</sub> -2	0	-	V <sub>CC</sub> -2	
Supply Current	I <sub>CC</sub>	R <sub>L</sub> = ∞, V <sub>CC</sub> = 5V	-	1.1	2.0	-	1.1	2.0	mA
		R <sub>L</sub> = ∞, V <sub>CC</sub> = 30V	-	1.6	2.5	-	-	-	
Voltage Gain	G <sub>V</sub>	V <sub>CC</sub> = 15V, R <sub>L</sub> ≥ 15KΩ (for large swing)	25	100	-	2	30	-	V/ mV
Large Signal Response Time	T <sub>LR</sub>	V <sub>I</sub> = TTL Logic Swing V <sub>REF</sub> = 1.4V, V <sub>RL</sub> = 5V, R <sub>L</sub> = 5.1KΩ	-	350	-	-	350	-	ns
Response Time	T <sub>RES</sub>	V <sub>RL</sub> = 5V, R <sub>L</sub> = 5.1KΩ	-	1.4	-	-	1.4	-	μs
Output Sink Current	I <sub>SINK</sub>	V <sub>I(-)</sub> ≥ 1V, V <sub>I(+)</sub> = 0V, V <sub>O(P)</sub> ≤ 1.5V	6	18	-	6	18	-	mA
Output Saturation Voltage	V <sub>SAT</sub>	V <sub>I(-)</sub> ≥ 1V, V <sub>I(+)</sub> = 0V	-	140	400	-	140	400	mV
		I <sub>SINK</sub> = 4mA	-	-	700	-	-	700	
Output Leakage Current	I <sub>O(LKG)</sub>	V <sub>I(-)</sub> = 0V	-	0.1	-	-	0.1	-	nA
		V <sub>I(+)</sub> = 1V	-	-	1.0	-	-	1.0	μA
Differential Voltage	V <sub>I(DIFF)</sub>	Note 1	-	-	36	-	-	36	V

**Note 1.**

LM339/LM339A : 0 ≤ TA ≤ +70°C

LM2901/LM3302 : -40 ≤ TA ≤ +85°C

LM239/LM239A : -25 ≤ TA ≤ +85°C

## Typical Performance Characteristics

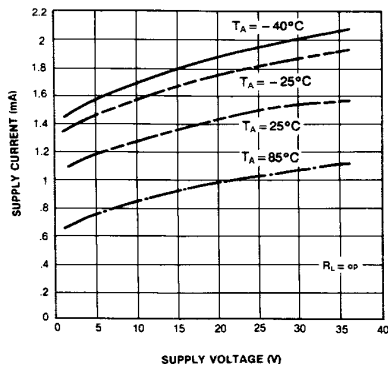


Figure 1. Supply Current vs Supply Voltage

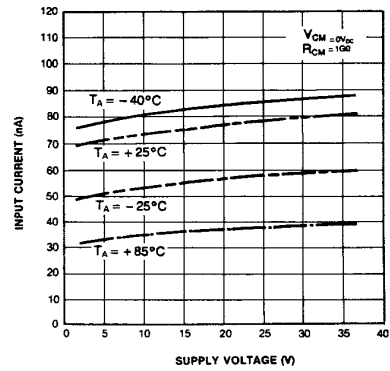


Figure 2. Input Current vs Supply Voltage

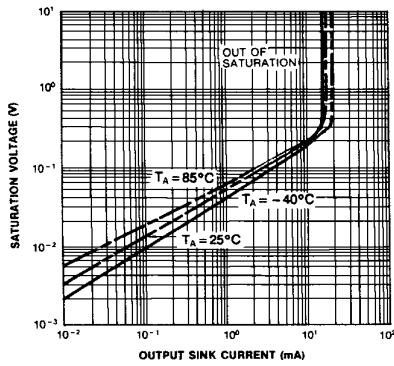


Figure 3. Output Saturation Voltage vs sink Current

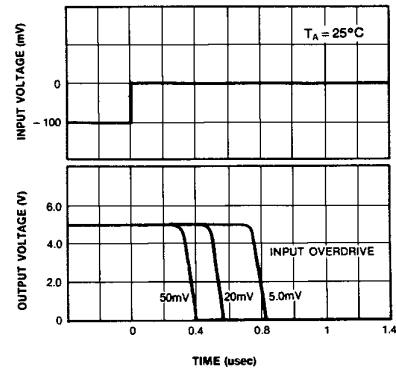


Figure 4. Response Time for Various Input Overdrive-Negative Transition

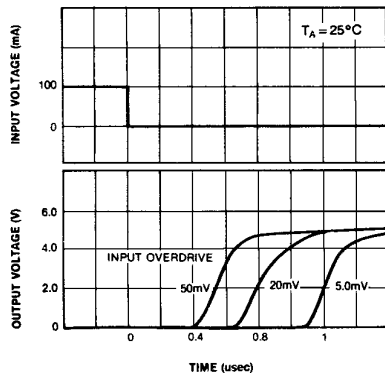
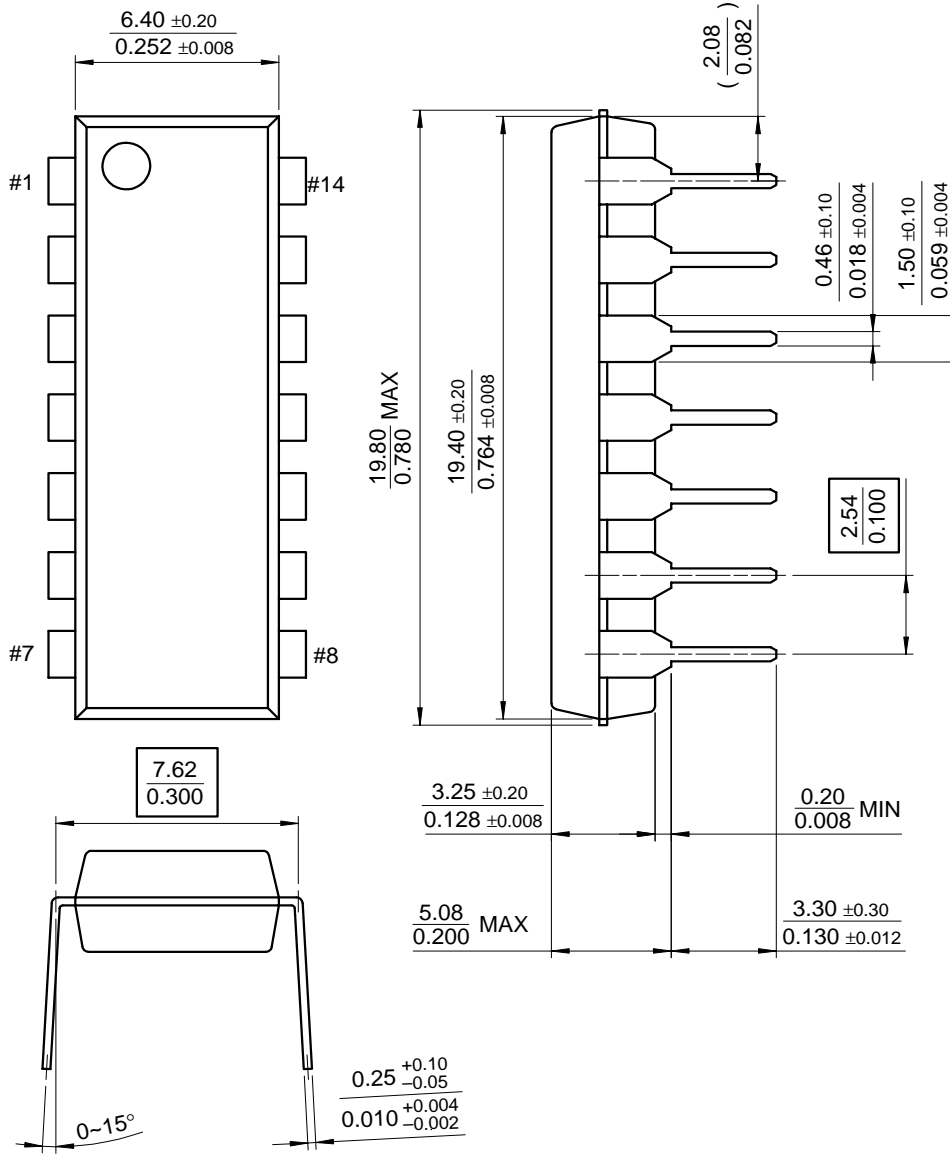


Figure 5. Response Time for Various Input Overdrive-Positive Transition

# Mechanical Dimensions

## Package

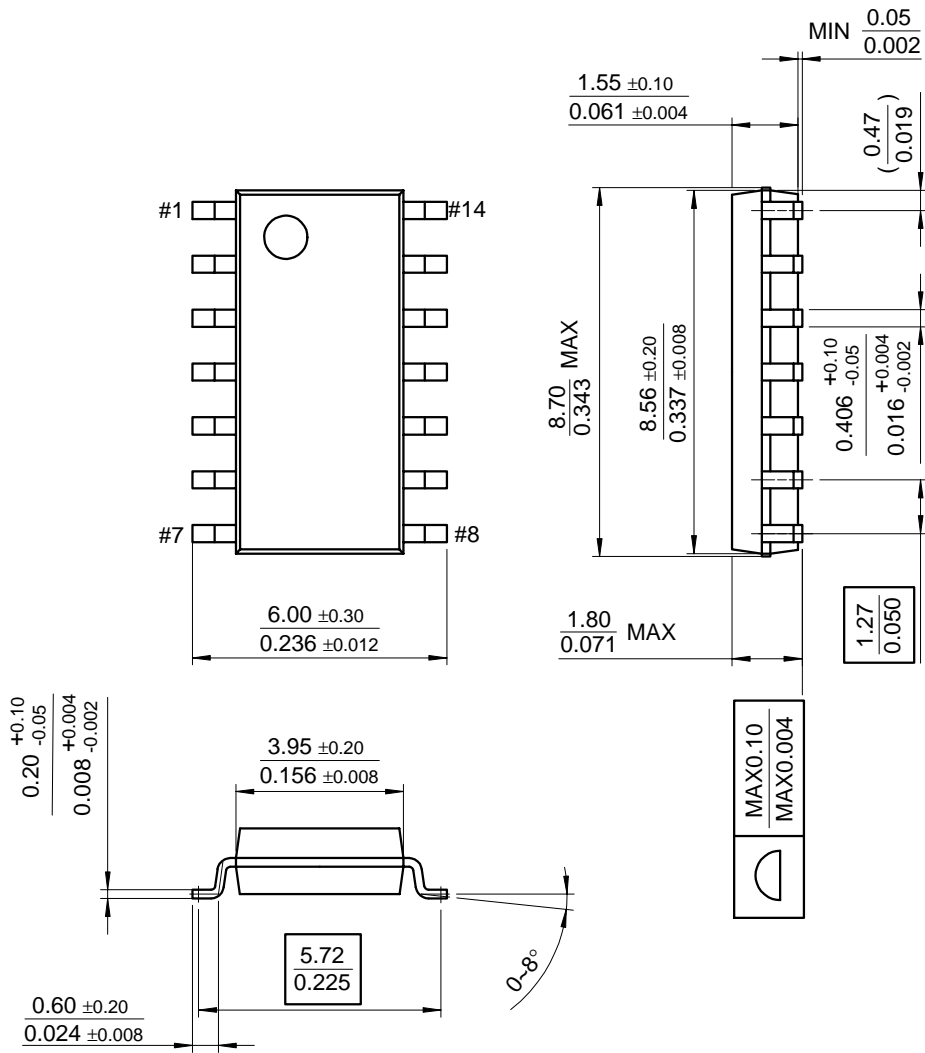
### 14-DIP



# Mechanica Dimensions (Continued)

## Package

### 14-SOP





# TIP110/112 TIP115/117

## COMPLEMENTARY SILICON POWER DARLINGTON TRANSISTORS

- STMicroelectronics PREFERRED SALESTYPES
- COMPLEMENTARY PNP - NPN DEVICES
- MONOLITHIC DARLINGTON CONFIGURATION
- INTEGRATED ANTIPARALLEL COLLECTOR-EMITTER DIODE

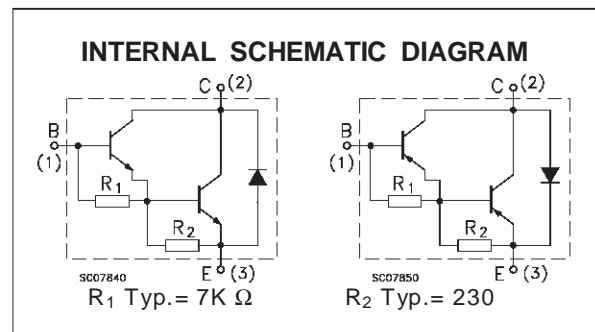
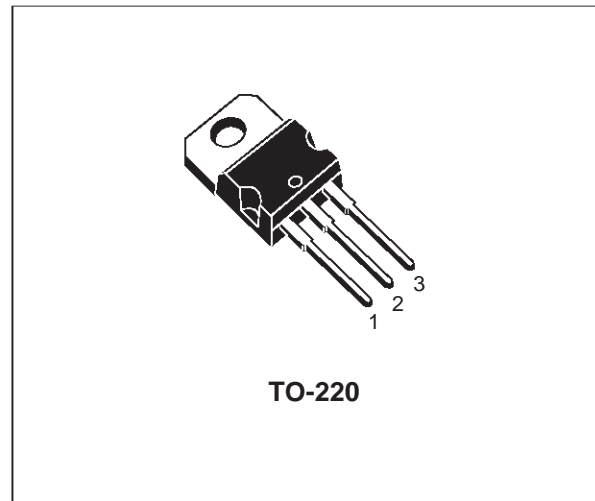
### APPLICATIONS

- LINEAR AND SWITCHING INDUSTRIAL EQUIPMENT

### DESCRIPTION

The TIP110 and TIP112 are silicon Epitaxial-Base NPN transistors in monolithic Darlington configuration mounted in Jedec TO-220 plastic package. They are intended for use in medium power linear and switching applications.

The complementary PNP types are TIP115 and TIP117.



### ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value		Unit	
		NPN	TIP110		TIP112
		PNP	TIP115		TIP117
V <sub>CBO</sub>	Collector-Base Voltage (I <sub>E</sub> = 0)		60	100	V
V <sub>CEO</sub>	Collector-Emitter Voltage (I <sub>B</sub> = 0)		60	100	V
V <sub>EBO</sub>	Emitter-Base Voltage (I <sub>C</sub> = 0)		5		V
I <sub>C</sub>	Collector Current		2		A
I <sub>CM</sub>	Collector Peak Current		4		A
I <sub>B</sub>	Base Current		50		mA
P <sub>tot</sub>	Total Dissipation at T <sub>case</sub> ≤ 25 °C T <sub>amb</sub> ≤ 25 °C		50		W
			2		W
T <sub>stg</sub>	Storage Temperature		-65 to 150		°C
T <sub>j</sub>	Max. Operating Junction Temperature		150		°C

\* For PNP types voltage and current values are negative

# TIP110/TIP112/TIP115/TIP117

## THERMAL DATA

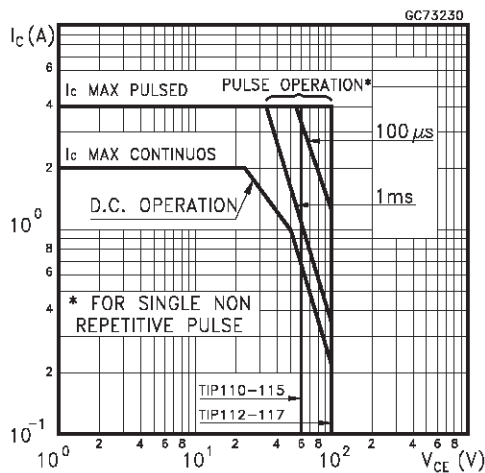
R <sub>thj-case</sub>	Thermal Resistance Junction-case	Max	2.5	°C/W
R <sub>thj-amb</sub>	Thermal Resistance Junction-ambient	Max	62.5	°C/W

## ELECTRICAL CHARACTERISTICS (T<sub>case</sub> = 25 °C unless otherwise specified)

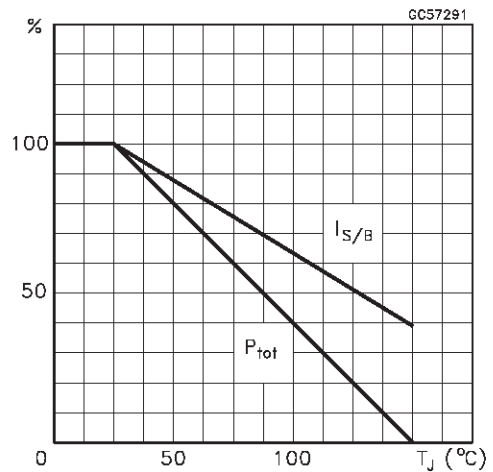
Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
I <sub>CEO</sub>	Collector Cut-off Current (I <sub>B</sub> = 0)	V <sub>CE</sub> = Half Rated V <sub>CEO</sub>			2	mA
I <sub>CBO</sub>	Collector Cut-off Current (I <sub>E</sub> = 0)	V <sub>CB</sub> = Rated V <sub>CBO</sub>			1	mA
I <sub>EBO</sub>	Emitter Cut-off Current (I <sub>C</sub> = 0)	V <sub>EB</sub> = 5 V			2	mA
V <sub>CEO(sus)*</sub>	Collector-Emitter Sustaining Voltage (I <sub>B</sub> = 0)	I <sub>C</sub> = 30 mA for <b>TIP110/115</b> for <b>TIP112/117</b>	60 100			V V
V <sub>CE(sat)*</sub>	Collector-Emitter Saturation Voltage	I <sub>C</sub> = 2 A    I <sub>B</sub> = 8 mA			2.5	V
V <sub>BE*</sub>	Base-Emitter Voltage	I <sub>C</sub> = 2 A    V <sub>CE</sub> = 4 V			2.8	V
h <sub>FE*</sub>	DC Current Gain	I <sub>C</sub> = 1 A    V <sub>CE</sub> = 4 V I <sub>C</sub> = 2 A    V <sub>CE</sub> = 4 V	1000 500			

\* Pulsed: Pulse duration = 300 μs, duty cycle 1.5 %  
For PNP types voltage and current values are negative.

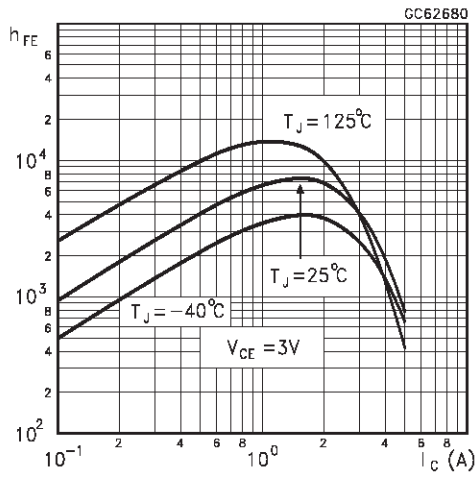
### Safe Operating Areas



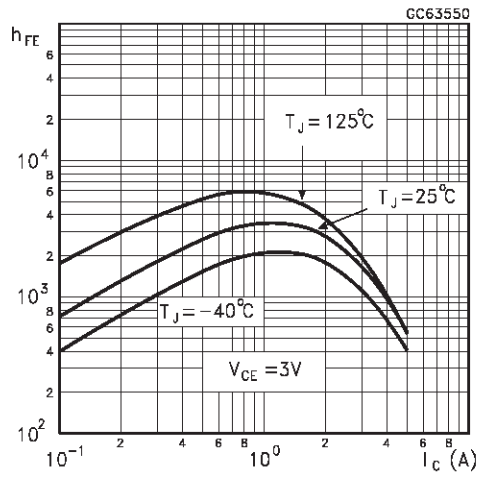
### Derating Curve



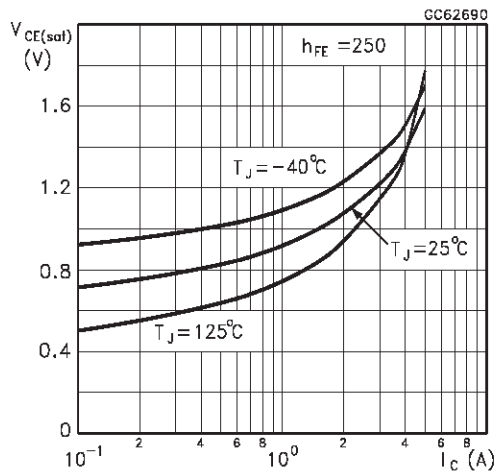
DC Current Gain (NPN type)



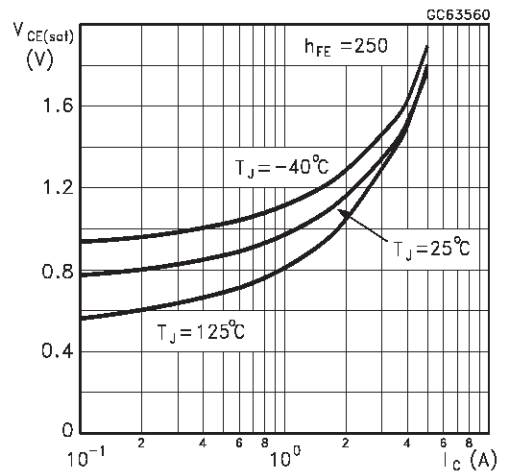
DC Current Gain (PNP type)



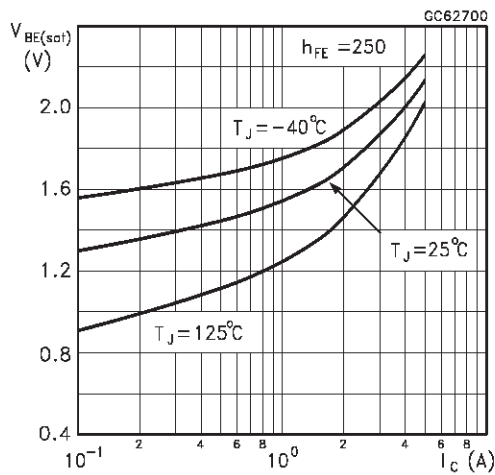
Collector-Emitter Saturation Voltage (NPN type)



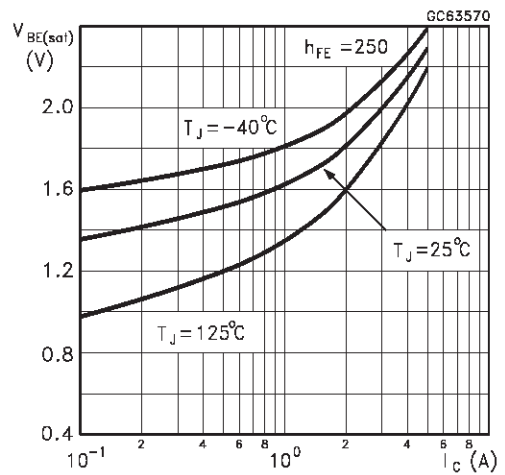
Collector-Emitter Saturation Voltage (PNP type)



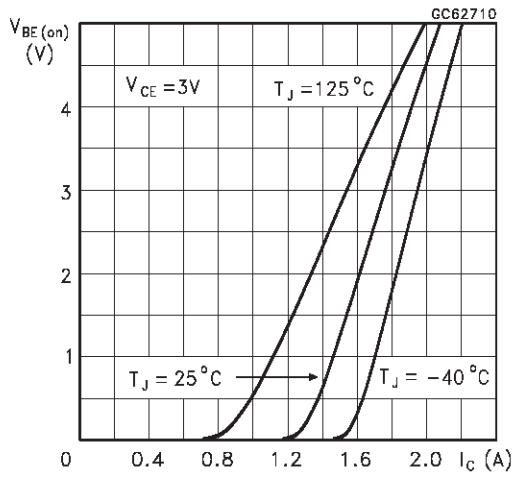
Base-Emitter Saturation Voltage (NPN type)



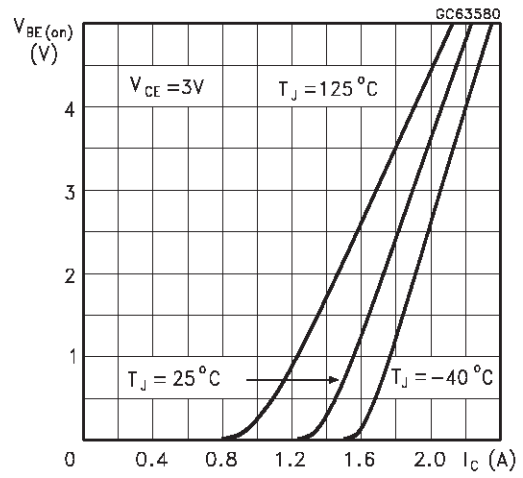
Base-Emitter Saturation Voltage (PNP type)



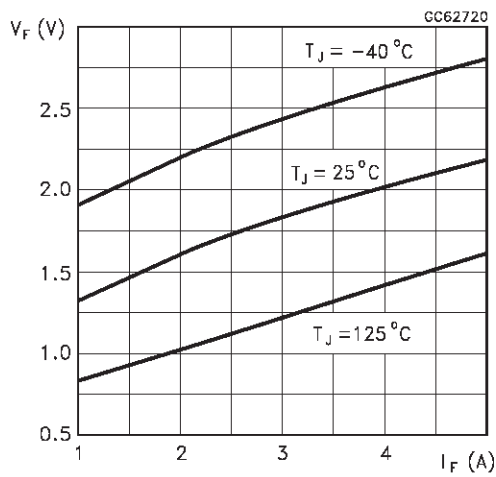
Base-Emitter On Voltage (NPN type)



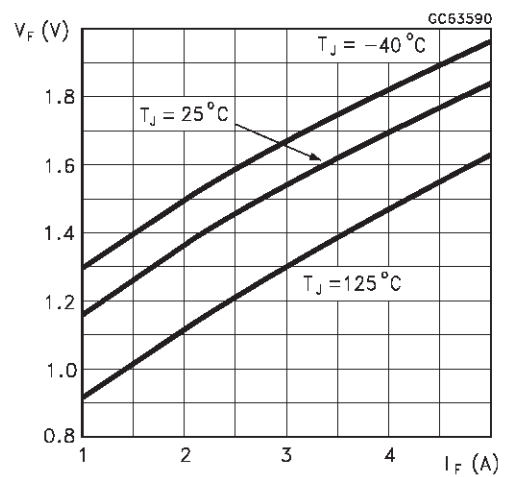
Base-Emitter On Voltage (PNP type)



Freewheel Diode Forward Voltage (NPN types)

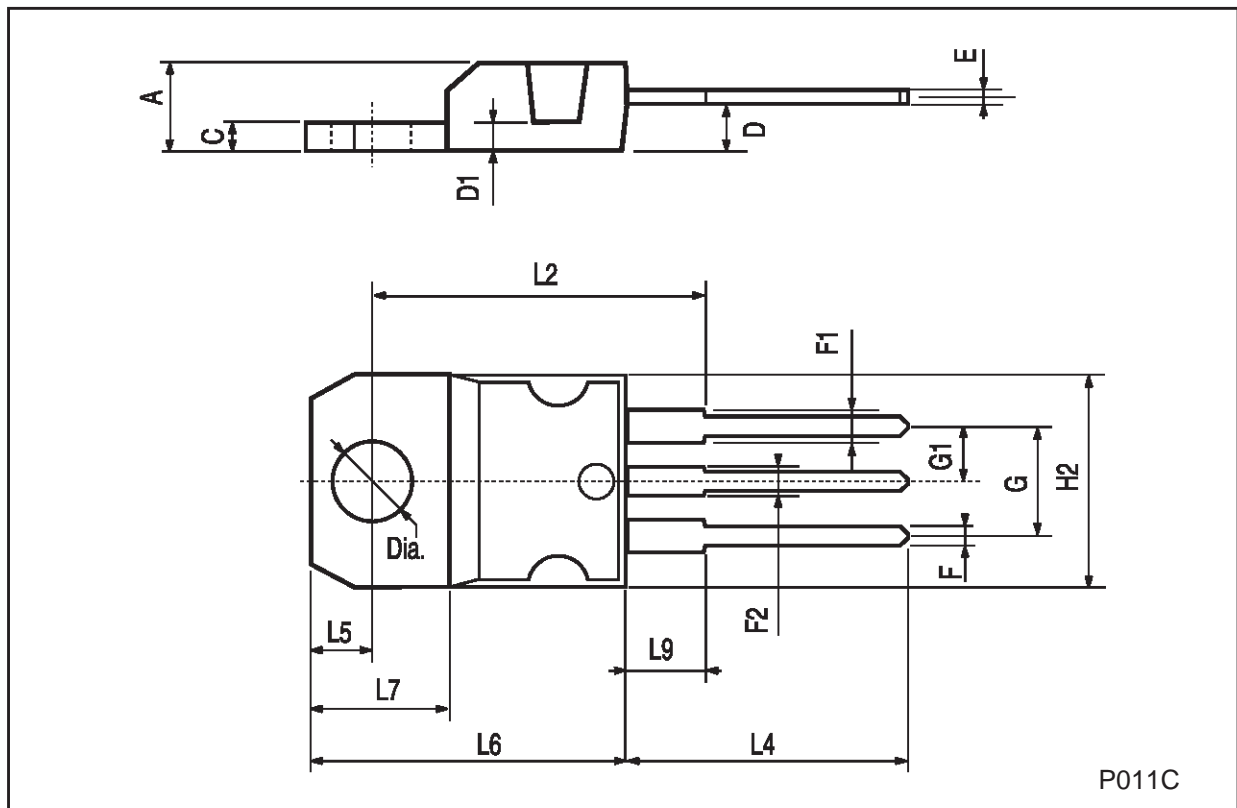


Freewheel Diode Forward Voltage (PNP types)



**TO-220 MECHANICAL DATA**

DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A	4.40		4.60	0.173		0.181
C	1.23		1.32	0.048		0.051
D	2.40		2.72	0.094		0.107
D1		1.27			0.050	
E	0.49		0.70	0.019		0.027
F	0.61		0.88	0.024		0.034
F1	1.14		1.70	0.044		0.067
F2	1.14		1.70	0.044		0.067
G	4.95		5.15	0.194		0.203
G1	2.4		2.7	0.094		0.106
H2	10.0		10.40	0.393		0.409
L2		16.4			0.645	
L4	13.0		14.0	0.511		0.551
L5	2.65		2.95	0.104		0.116
L6	15.25		15.75	0.600		0.620
L7	6.2		6.6	0.244		0.260
L9	3.5		3.93	0.137		0.154
DIA.	3.75		3.85	0.147		0.151



P011C