

# MC34063A, MC33063A

## DC-to-DC Converter Control Circuits

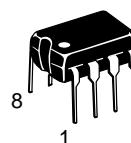
The MC34063A Series is a monolithic control circuit containing the primary functions required for DC-to-DC converters. These devices consist of an internal temperature compensated reference, comparator, controlled duty cycle oscillator with an active current limit circuit, driver and high current output switch. This series was specifically designed to be incorporated in Step-Down and Step-Up and Voltage-Inverting applications with a minimum number of external components. Refer to Application Notes AN920A/D and AN954/D for additional design information.

- Operation from 3.0 V to 40 V Input
- Low Standby Current
- Current Limiting
- Output Switch Current to 1.5 A
- Output Voltage Adjustable
- Frequency Operation to 100 kHz
- Precision 2% Reference



**ON Semiconductor**

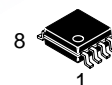
<http://onsemi.com>



PDIP-8  
P, P1 SUFFIX  
CASE 626



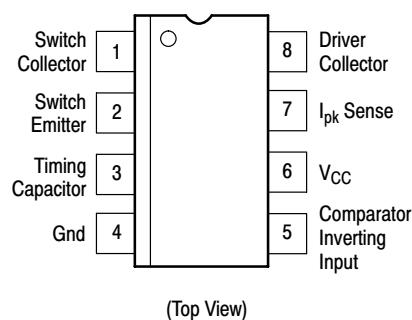
SO-8  
D SUFFIX  
CASE 751



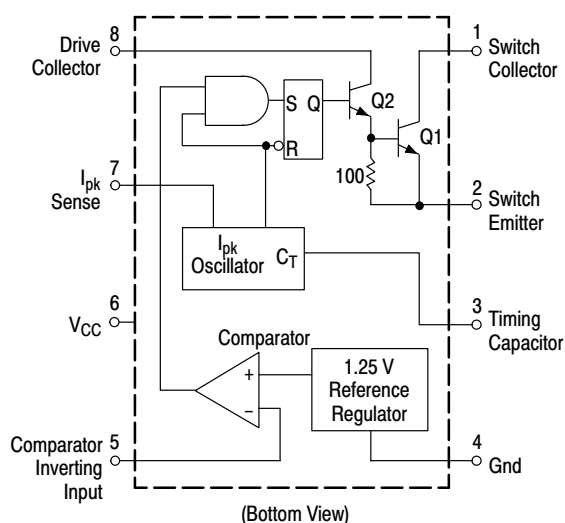
SOEIAJ-8  
M SUFFIX  
CASE 968

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### PIN CONNECTIONS



### Representative Schematic Diagram



This device contains 51 active transistors.

### ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 11 of this data sheet.

### DEVICE MARKING INFORMATION

See general marking information in the device marking section on page 11 of this data sheet.

## MC34063A, MC33063A

### MAXIMUM RATINGS

| Rating   | Symbol                  | Value       | Unit               |
|--|-------------------------|-------------|--------------------|
| Power Supply Voltage                                     | $V_{CC}$                | 40          | Vdc                |
| Comparator Input Voltage Range                           | $V_{IR}$                | -0.3 to +40 | Vdc                |
| Switch Collector Voltage                                 | $V_{C(\text{switch})}$  | 40          | Vdc                |
| Switch Emitter Voltage ( $V_{P_{in\ 1}} = 40\text{ V}$ ) | $V_{E(\text{switch})}$  | 40          | Vdc                |
| Switch Collector to Emitter Voltage                      | $V_{CE(\text{switch})}$ | 40          | Vdc                |
| Driver Collector Voltage                                 | $V_{C(\text{driver})}$  | 40          | Vdc                |
| Driver Collector Current (Note 1.)                       | $I_{C(\text{driver})}$  | 100         | mA                 |
| Switch Current   | $I_{SW}$                | 1.5         | A                  |
| Power Dissipation and Thermal Characteristics            |                         |             |                    |
| Plastic Package, P, P1 Suffix                            |                         |             |                    |
| $T_A = 25^\circ\text{C}$                                 | $P_D$                   | 1.25        | W                  |
| Thermal Resistance                                       | $R_{\theta JA}$         | 100         | $^\circ\text{C/W}$ |
| SOIC Package, D Suffix                                   |                         |             |                    |
| $T_A = 25^\circ\text{C}$                                 | $P_D$                   | 625         | W                  |
| Thermal Resistance                                       | $R_{\theta JA}$         | 160         | $^\circ\text{C/W}$ |
| Operating Junction Temperature                           | $T_J$                   | +150        | $^\circ\text{C}$   |
| Operating Ambient Temperature Range                      | $T_A$                   |             | $^\circ\text{C}$   |
| MC34063A   |                         | 0 to +70    |                    |
| MC33063AV  |                         | -40 to +125 |                    |
| MC33063A   |                         | -40 to +85  |                    |
| Storage Temperature Range                                | $T_{stg}$               | -65 to +150 | $^\circ\text{C}$   |

1. Maximum package power dissipation limits must be observed.
2. ESD data available upon request.

## MC34063A, MC33063A

### ELECTRICAL CHARACTERISTICS ( $V_{CC} = 5.0\text{ V}$ , $T_A = T_{low}$ to $T_{high}$ [Note 3.], unless otherwise specified.)

| Characteristics  | Symbol               | Min | Typ | Max | Unit          |
|--|----------------------|-----|-----|-----|---------------|
| <b>OSCILLATOR</b>  |                      |     |     |     |               |
| Frequency ( $V_{Pin\ 5} = 0\text{ V}$ , $C_T = 1.0\text{ nF}$ , $T_A = 25^\circ\text{C}$ ) | $f_{osc}$            | 24  | 33  | 42  | kHz           |
| Charge Current ( $V_{CC} = 5.0\text{ V to }40\text{ V}$ , $T_A = 25^\circ\text{C}$ )       | $I_{chg}$            | 24  | 35  | 42  | $\mu\text{A}$ |
| Discharge Current ( $V_{CC} = 5.0\text{ V to }40\text{ V}$ , $T_A = 25^\circ\text{C}$ )    | $I_{dischg}$         | 140 | 220 | 260 | $\mu\text{A}$ |
| Discharge to Charge Current Ratio (Pin 7 to $V_{CC}$ , $T_A = 25^\circ\text{C}$ )          | $I_{dischg}/I_{chg}$ | 5.2 | 6.5 | 7.5 | –             |
| Current Limit Sense Voltage ( $I_{chg} = I_{dischg}$ , $T_A = 25^\circ\text{C}$ )          | $V_{ipk(sense)}$     | 250 | 300 | 350 | mV            |

### OUTPUT SWITCH (Note 4.)

|   |               |    |      |     |               |
|---|---------------|----|------|-----|---------------|
| Saturation Voltage, Darlington Connection<br>( $I_{SW} = 1.0\text{ A}$ , Pins 1, 8 connected)                                   | $V_{CE(sat)}$ | –  | 1.0  | 1.3 | V             |
| Saturation Voltage (Note 5.)<br>( $I_{SW} = 1.0\text{ A}$ , $R_{Pin\ 8} = 82\ \Omega$ to $V_{CC}$ , Forced $\beta \approx 20$ ) | $V_{CE(sat)}$ | –  | 0.45 | 0.7 | V             |
| DC Current Gain ( $I_{SW} = 1.0\text{ A}$ , $V_{CE} = 5.0\text{ V}$ , $T_A = 25^\circ\text{C}$ )                                | $h_{FE}$      | 50 | 75   | –   | –             |
| Collector Off–State Current ( $V_{CE} = 40\text{ V}$ )  | $I_{C(off)}$  | –  | 0.01 | 100 | $\mu\text{A}$ |

### COMPARATOR

|   |              |               |            |               |    |
|---|--------------|---------------|------------|---------------|----|
| Threshold Voltage<br>$T_A = 25^\circ\text{C}$<br>$T_A = T_{low}$ to $T_{high}$                                  | $V_{th}$     | 1.225<br>1.21 | 1.25<br>–  | 1.275<br>1.29 | V  |
| Threshold Voltage Line Regulation ( $V_{CC} = 3.0\text{ V to }40\text{ V}$ )<br>MC33063A, MC34063A<br>MC33363AV | $Reg_{line}$ | –<br>–        | 1.4<br>1.4 | 5.0<br>6.0    | mV |
| Input Bias Current ( $V_{in} = 0\text{ V}$ )  | $I_{IB}$     | –             | –20        | –400          | nA |

### TOTAL DEVICE

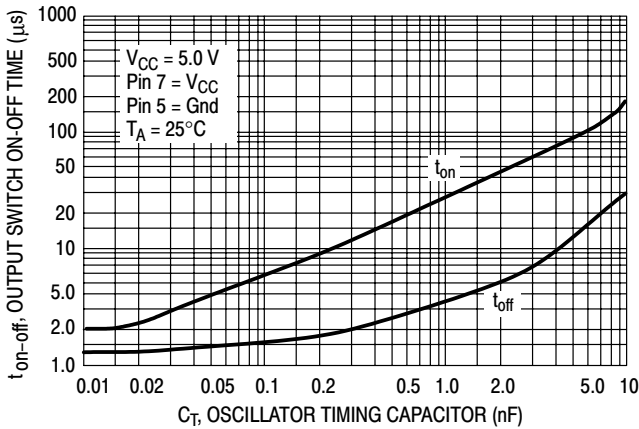
|  |          |   |   |     |    |
|--|----------|---|---|-----|----|
| Supply Current ( $V_{CC} = 5.0\text{ V to }40\text{ V}$ , $C_T = 1.0\text{ nF}$ , Pin 7 = $V_{CC}$ , $V_{Pin\ 5} > V_{th}$ , Pin 2 = Gnd, remaining pins open) | $I_{CC}$ | – | – | 4.0 | mA |
|--|----------|---|---|-----|----|

3.  $T_{low} = 0^\circ\text{C}$  for MC34063A,  $-40^\circ\text{C}$  for MC33063A, AV  $T_{high} = +70^\circ\text{C}$  for MC34063A,  $+85^\circ\text{C}$  for MC33063A,  $+125^\circ\text{C}$  for MC33063AV
4. Low duty cycle pulse techniques are used during test to maintain junction temperature as close to ambient temperature as possible.
5. If the output switch is driven into hard saturation (non–Darlington configuration) at low switch currents ( $\leq 300\text{ mA}$ ) and high driver currents ( $\geq 30\text{ mA}$ ), it may take up to  $2.0\ \mu\text{s}$  for it to come out of saturation. This condition will shorten the off time at frequencies  $\geq 30\text{ kHz}$ , and is magnified at high temperatures. This condition does not occur with a Darlington configuration, since the output switch cannot saturate. If a non–Darlington configuration is used, the following output drive condition is recommended:

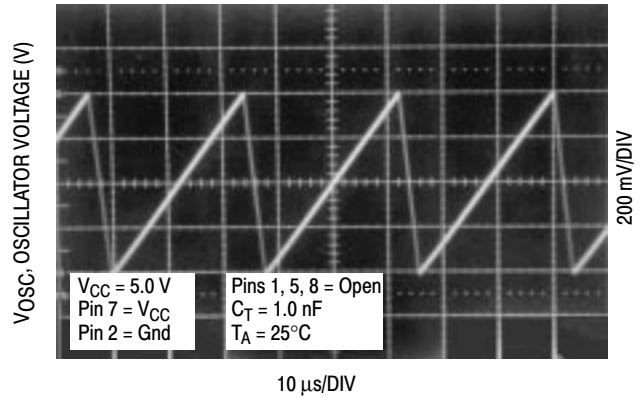
$$\text{Forced } \beta \text{ of output switch : } \frac{I_{C\ \text{output}}}{I_{C\ \text{driver}} - 7.0\text{ mA}} \geq 10$$

\* The  $100\ \Omega$  resistor in the emitter of the driver device requires about  $7.0\text{ mA}$  before the output switch conducts.

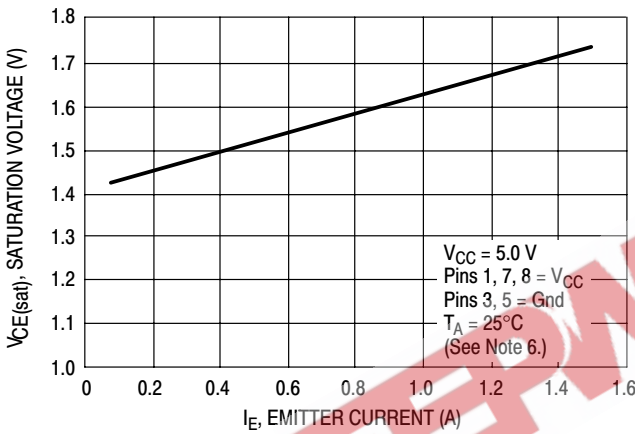
# MC34063A, MC33063A



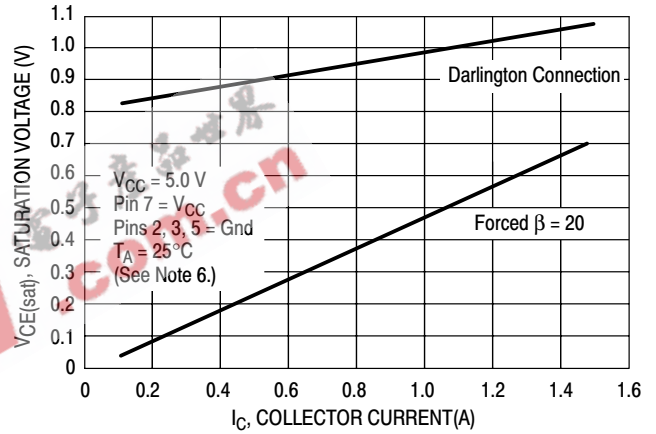
**Figure 1. Output Switch On-Off Time versus Oscillator Timing Capacitor**



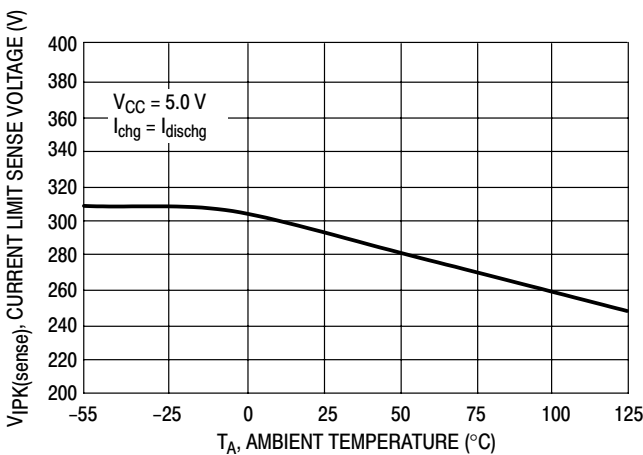
**Figure 2. Timing Capacitor Waveform**



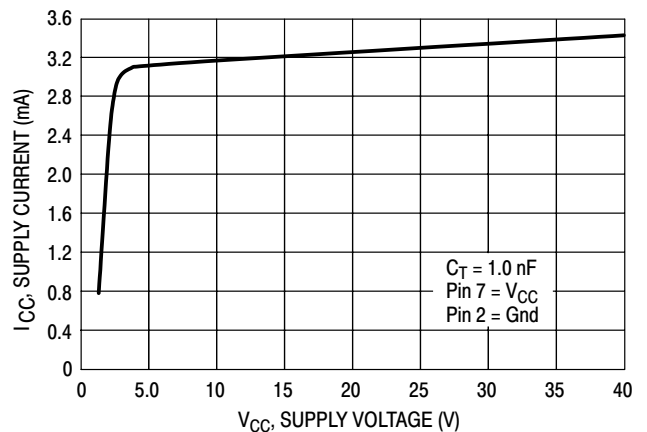
**Figure 3. Emitter Follower Configuration Output Saturation Voltage versus Emitter Current**



**Figure 4. Common Emitter Configuration Output Switch Saturation Voltage versus Collector Current**



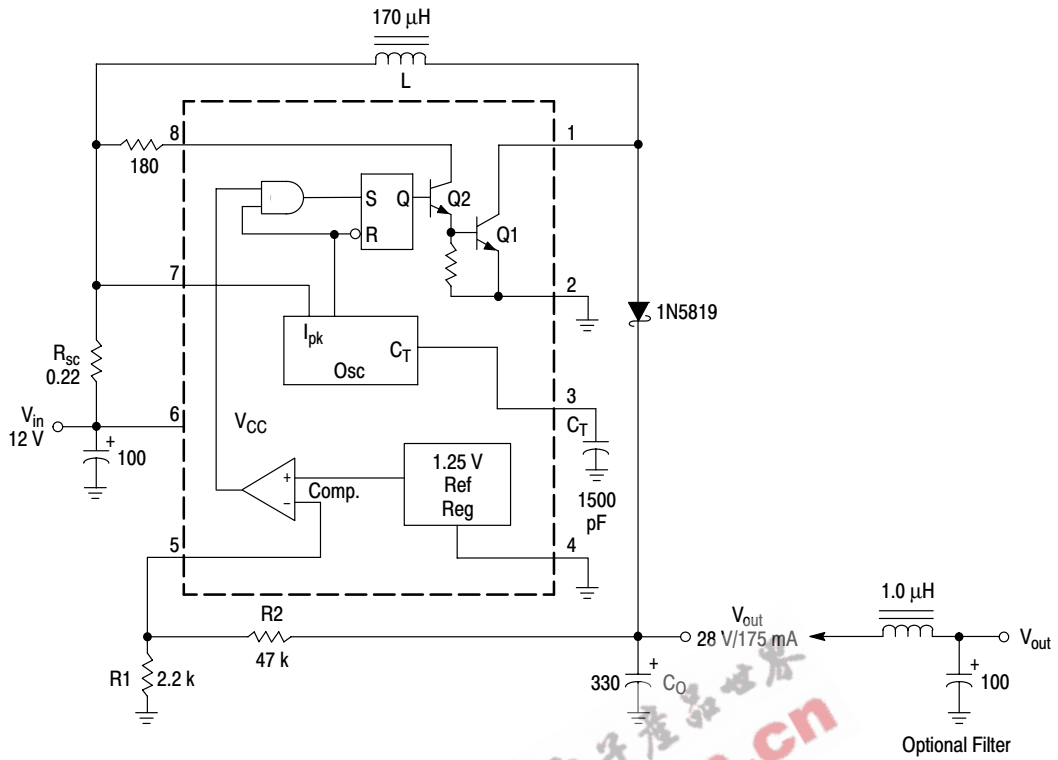
**Figure 5. Current Limit Sense Voltage versus Temperature**



**Figure 6. Standby Supply Current versus Supply Voltage**

6. Low duty cycle pulse techniques are used during test to maintain junction temperature as close to ambient temperature as possible.

## MC34063A, MC33063A



| Test                               | Conditions  | Results                      |
|------------------------------------|---|------------------------------|
| Line Regulation                    | $V_{in} = 8.0\text{ V to }16\text{ V}, I_O = 175\text{ mA}$ | $30\text{ mV} = \pm 0.05\%$  |
| Load Regulation                    | $V_{in} = 12\text{ V}, I_O = 75\text{ mA to }175\text{ mA}$ | $10\text{ mV} = \pm 0.017\%$ |
| Output Ripple                      | $V_{in} = 12\text{ V}, I_O = 175\text{ mA}$                 | $400\text{ mVpp}$            |
| Efficiency                         | $V_{in} = 12\text{ V}, I_O = 175\text{ mA}$                 | $87.7\%$                     |
| Output Ripple With Optional Filter | $V_{in} = 12\text{ V}, I_O = 175\text{ mA}$                 | $40\text{ mVpp}$             |

**Figure 7. Step-Up Converter**

## MC34063A, MC33063A

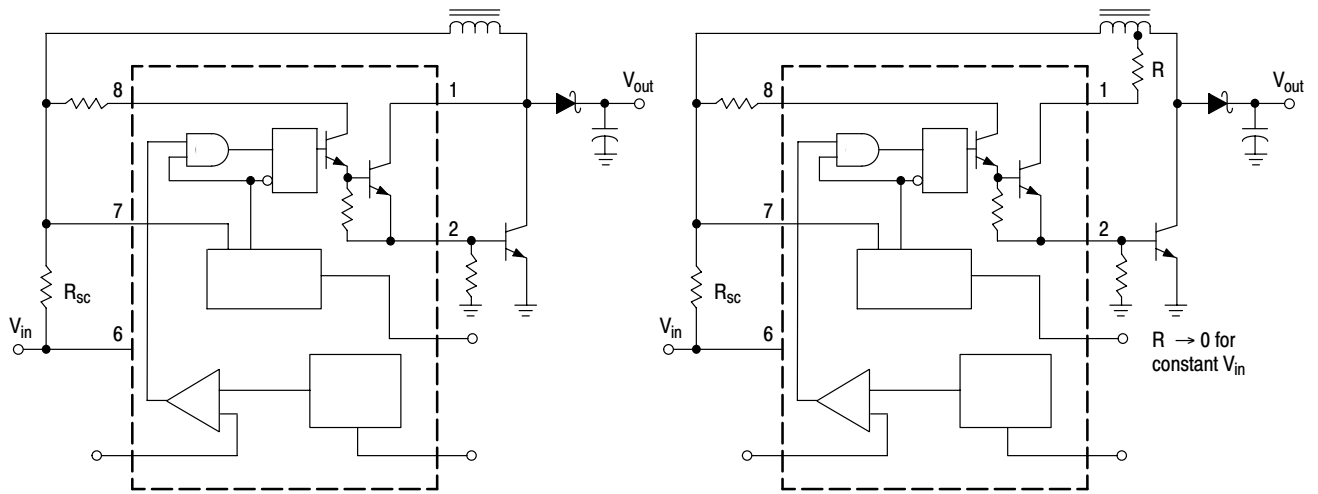


Figure 8. External Current Boost Connections for  $I_C$  Peak Greater than 1.5 A

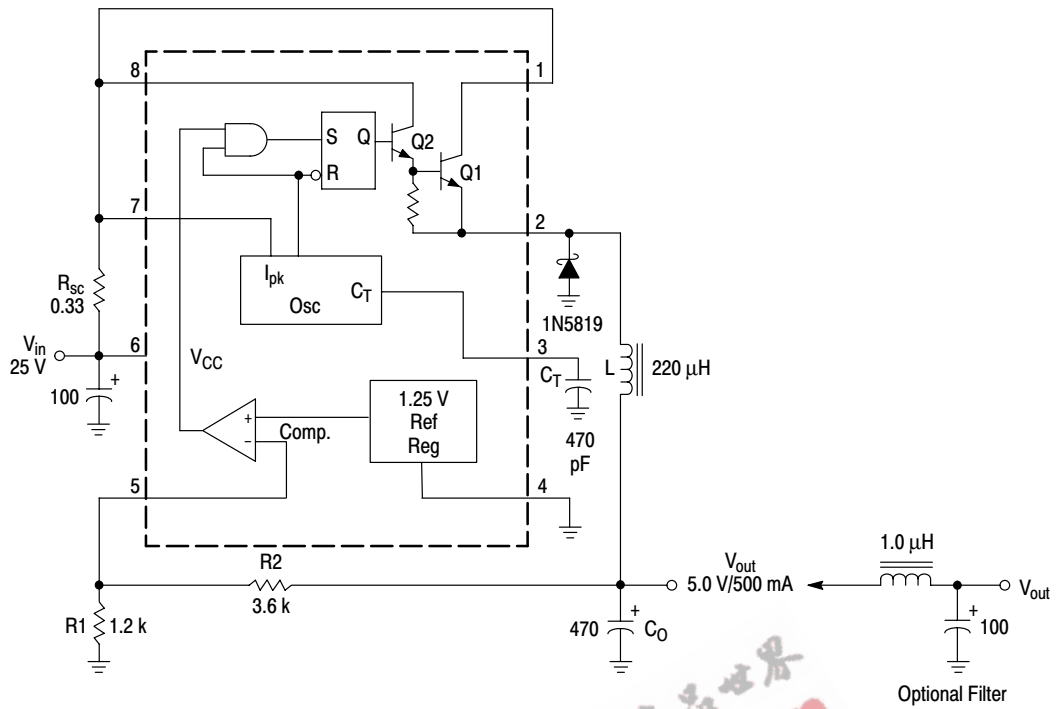
### 8a. External NPN Switch

### 8b. External NPN Saturated Switch

(See Note 7.)

7. If the output switch is driven into hard saturation (non-Darlington configuration) at low switch currents ( $\leq 300$  mA) and high driver currents ( $\geq 30$  mA), it may take up to  $2.0 \mu\text{s}$  to come out of saturation. This condition will shorten the off time at frequencies  $\geq 30$  kHz, and is magnified at high temperatures. This condition does not occur with a Darlington configuration, since the output switch cannot saturate. If a non-Darlington configuration is used, the following output drive condition is recommended.

## MC34063A, MC33063A



| Test                               | Conditions   | Results                      |
|------------------------------------|--|------------------------------|
| Line Regulation                    | $V_{in} = 15\text{ V to } 25\text{ V}, I_O = 500\text{ mA}$  | $12\text{ mV} = \pm 0.12\%$  |
| Load Regulation                    | $V_{in} = 25\text{ V}, I_O = 50\text{ mA to } 500\text{ mA}$ | $3.0\text{ mV} = \pm 0.03\%$ |
| Output Ripple                      | $V_{in} = 25\text{ V}, I_O = 500\text{ mA}$                  | $120\text{ mVpp}$            |
| Short Circuit Current              | $V_{in} = 25\text{ V}, R_L = 0.1\ \Omega$                    | $1.1\text{ A}$               |
| Efficiency                         | $V_{in} = 25\text{ V}, I_O = 500\text{ mA}$                  | $83.7\%$                     |
| Output Ripple With Optional Filter | $V_{in} = 25\text{ V}, I_O = 500\text{ mA}$                  | $40\text{ mVpp}$             |

Figure 9. Step-Down Converter

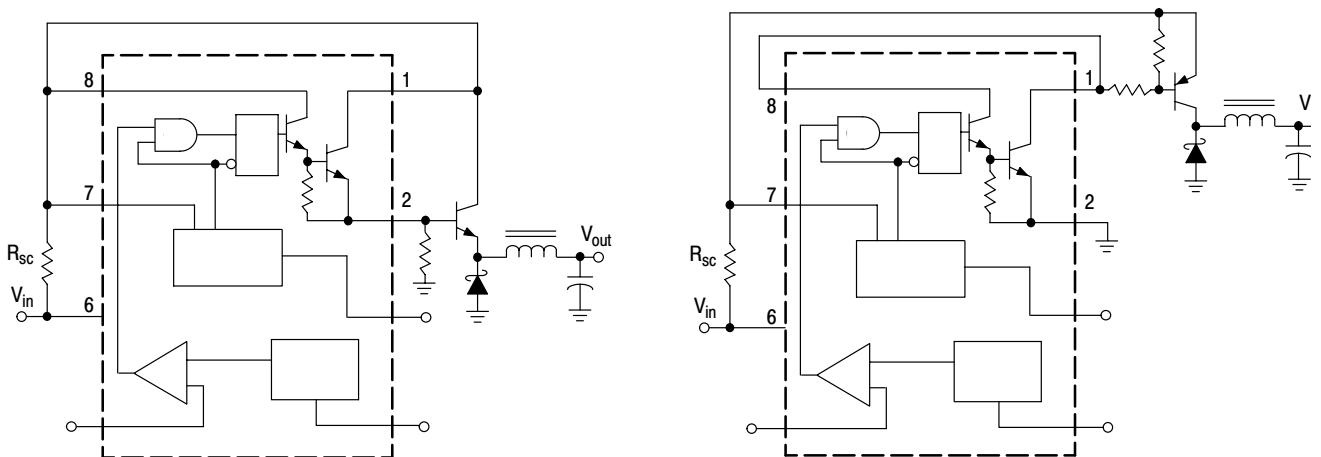
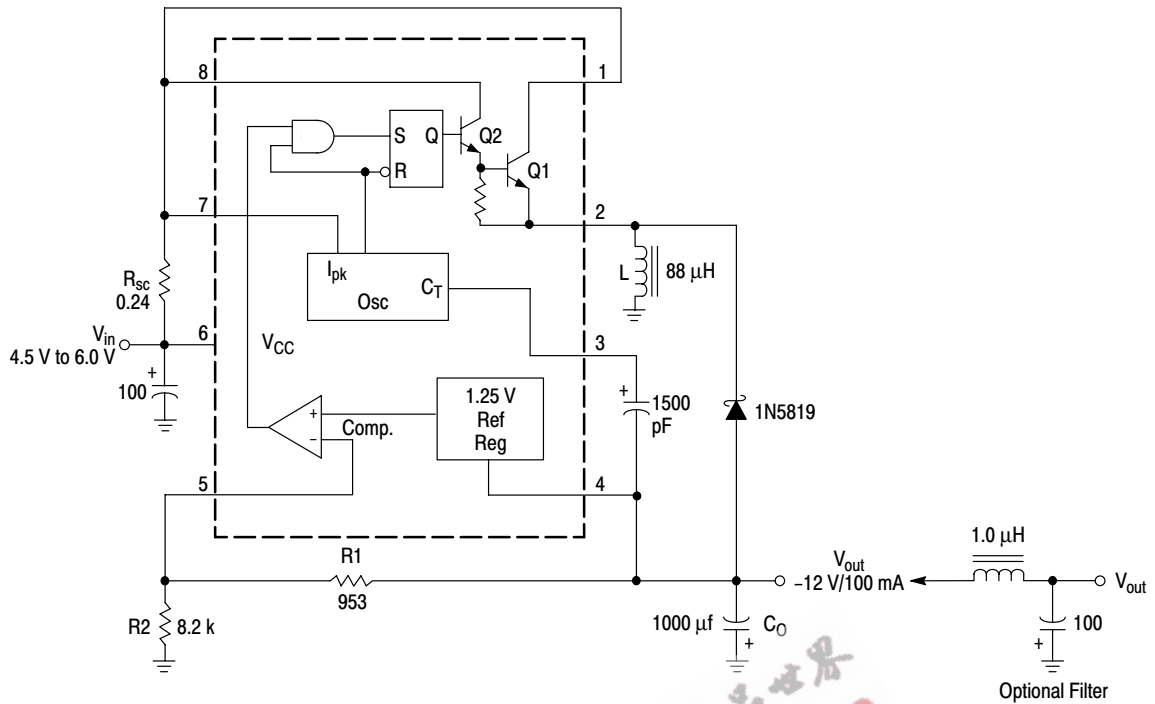


Figure 10. External Current Boost Connections for  $I_C$  Peak Greater than 1.5 A

10a. External NPN Switch

10b. External PNP Saturated Switch

## MC34063A, MC33063A



| Test                               | Conditions   | Results                        |
|------------------------------------|--|--------------------------------|
| Line Regulation                    | $V_{in} = 4.5 \text{ V to } 6.0 \text{ V}, I_O = 100 \text{ mA}$ | $3.0 \text{ mV} = \pm 0.012\%$ |
| Load Regulation                    | $V_{in} = 5.0 \text{ V}, I_O = 10 \text{ mA to } 100 \text{ mA}$ | $0.022 \text{ V} = \pm 0.09\%$ |
| Output Ripple                      | $V_{in} = 5.0 \text{ V}, I_O = 100 \text{ mA}$                   | $500 \text{ mVpp}$             |
| Short Circuit Current              | $V_{in} = 5.0 \text{ V}, R_L = 0.1 \Omega$                       | $910 \text{ mA}$               |
| Efficiency                         | $V_{in} = 5.0 \text{ V}, I_O = 100 \text{ mA}$                   | $62.2\%$                       |
| Output Ripple With Optional Filter | $V_{in} = 5.0 \text{ V}, I_O = 100 \text{ mA}$                   | $70 \text{ mVpp}$              |

Figure 11. Voltage Inverting Converter

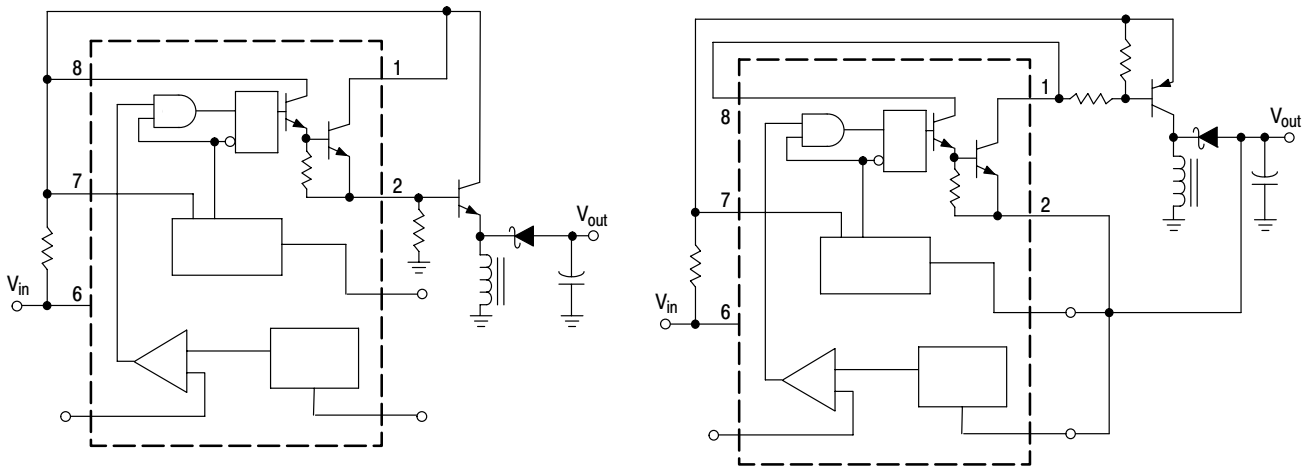


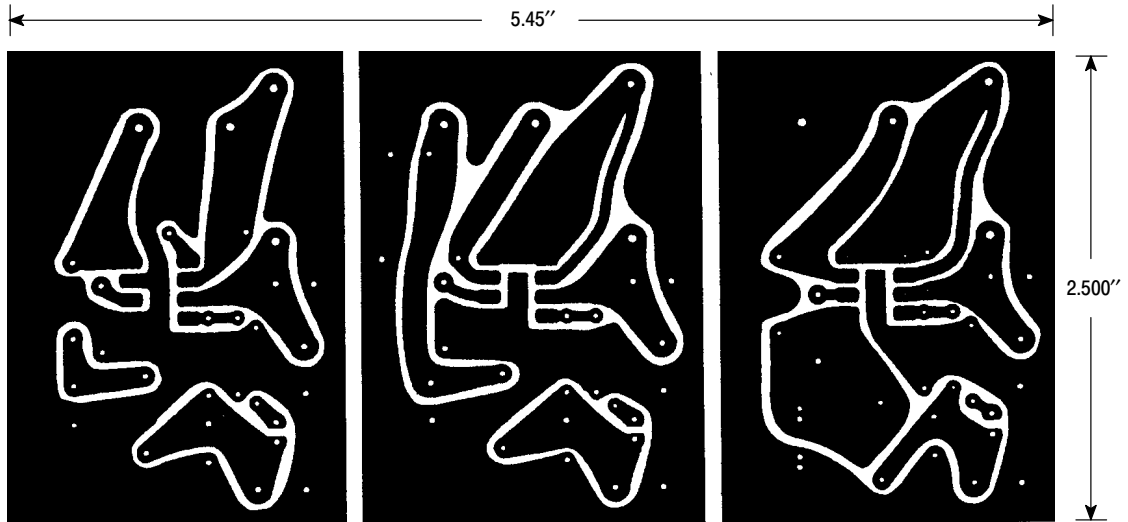
Figure 12. External Current Boost Connections for  $I_C$  Peak Greater than 1.5 A

12a. External NPN Switch

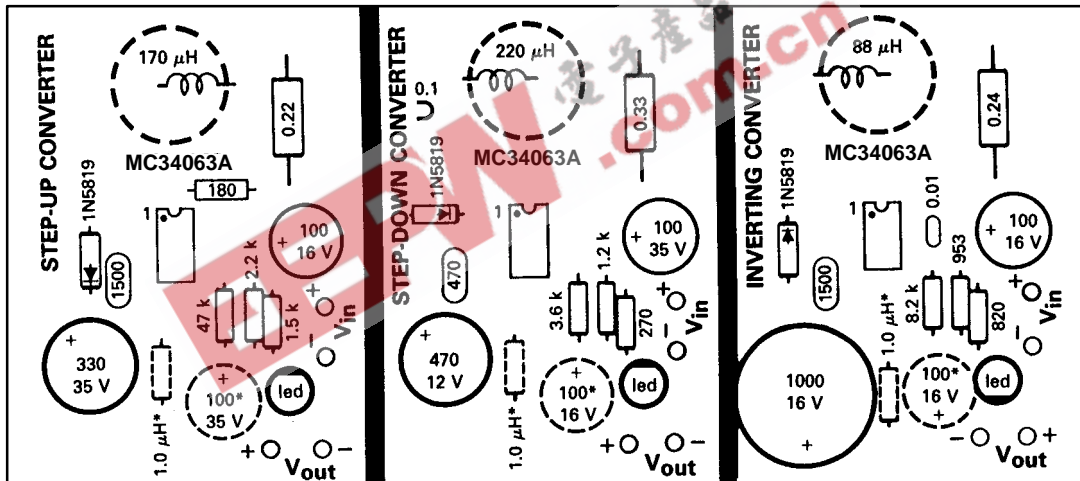
12b. External PNP Saturated Switch



# MC34063A, MC33063A



(Top view, copper foil as seen through the board from the component side)



(Top View, Component Side)

\*Optional Filter.

**Figure 13. Printed Circuit Board and Component Layout**

(Circuits of Figures 7, 9, 11)

### INDUCTOR DATA

| Converter         | Inductance ( $\mu\text{H}$ ) | Turns/Wire          |
|-------------------|------------------------------|---------------------|
| Step-Up           | 170                          | 38 Turns of #22 AWG |
| Step-Down         | 220                          | 48 Turns of #22 AWG |
| Voltage-Inverting | 88                           | 28 Turns of #22 AWG |

All inductors are wound on Magnetics Inc. 55117 toroidal core.

## MC34063A, MC33063A

| Calculation          | Step-Up   | Step-Down   | Voltage-Inverting   |
|----------------------|---|---|---|
| $t_{on}/t_{off}$     | $\frac{V_{out} + V_F - V_{in(min)}}{V_{in(min)} - V_{sat}}$                 | $\frac{V_{out} + V_F}{V_{in(min)} - V_{sat} - V_{out}}$                               | $\frac{ V_{out}  + V_F}{V_{in} - V_{sat}}$                                  |
| $(t_{on} + t_{off})$ | $\frac{1}{f}$   | $\frac{1}{f}$   | $\frac{1}{f}$   |
| $t_{off}$            | $\frac{t_{on} + t_{off}}{\frac{t_{on}}{t_{off}} + 1}$                       | $\frac{t_{on} + t_{off}}{\frac{t_{on}}{t_{off}} + 1}$                                 | $\frac{t_{on} + t_{off}}{\frac{t_{on}}{t_{off}} + 1}$                       |
| $t_{on}$             | $(t_{on} + t_{off}) - t_{off}$  | $(t_{on} + t_{off}) - t_{off}$  | $(t_{on} + t_{off}) - t_{off}$  |
| $C_T$                | $4.0 \times 10^{-5} t_{on}$   | $4.0 \times 10^{-5} t_{on}$   | $4.0 \times 10^{-5} t_{on}$   |
| $I_{pk( switch )}$   | $2I_{out(max)} \left( \frac{t_{on}}{t_{off}} + 1 \right)$                   | $2I_{out(max)}$   | $2I_{out(max)} \left( \frac{t_{on}}{t_{off}} + 1 \right)$                   |
| $R_{sc}$             | $0.3/I_{pk( switch )}$  | $0.3/I_{pk( switch )}$  | $0.3/I_{pk( switch )}$  |
| $L_{(min)}$          | $\left( \frac{V_{in(min)} - V_{sat}}{I_{pk( switch )}} \right) t_{on(max)}$ | $\left( \frac{V_{in(min)} - V_{sat} - V_{out}}{I_{pk( switch )}} \right) t_{on(max)}$ | $\left( \frac{V_{in(min)} - V_{sat}}{I_{pk( switch )}} \right) t_{on(max)}$ |
| $C_O$                | $9 \frac{I_{out} t_{on}}{V_{ripple(pp)}}$                                   | $\frac{I_{pk( switch )} (t_{on} + t_{off})}{8V_{ripple(pp)}}$                         | $9 \frac{I_{out} t_{on}}{V_{ripple(pp)}}$                                   |

$V_{sat}$  = Saturation voltage of the output switch.  
 $V_F$  = Forward voltage drop of the output rectifier.

**The following power supply characteristics must be chosen:**

$V_{in}$  – Nominal input voltage.

$V_{out}$  – Desired output voltage,  $|V_{out}| = 1.25 \left( 1 + \frac{R2}{R1} \right)$

$I_{out}$  – Desired output current.

$f_{min}$  – Minimum desired output switching frequency at the selected values of  $V_{in}$  and  $I_O$ .

$V_{ripple(pp)}$  – Desired peak-to-peak output ripple voltage. In practice, the calculated capacitor value will need to be increased due to its equivalent series resistance and board layout. The ripple voltage should be kept to a low value since it will directly affect the line and load regulation.

**NOTE:** For further information refer to Application Note AN920A/D and AN954/D.

**Figure 14. Design Formula Table**

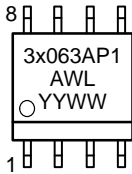
# MC34063A, MC33063A

## ORDERING INFORMATION

| Device       | Package  | Shipping                 |
|--------------|----------|--------------------------|
| MC33063AD    | SO-8     | 98 Units / Rail          |
| MC33063ADR2  | SO-8     | 2500 Units / Tape & Reel |
| MC33063AP1   | DIP-8    | 50 Units / Rail          |
| MC33063AVD   | SO-8     | 98 Units / Rail          |
| MC33063AVDR2 | SO-8     | 2500 Units / Tape & Reel |
| MC33063AVP   | DIP-8    | 50 Units / Rail          |
| MC34063AD    | SO-8     | 98 Units / Rail          |
| MC34063ADR2  | SO-8     | 2500 Units / Tape & Reel |
| MC34063AP1   | DIP-8    | 50 Units / Rail          |
| MC34063BD    | SO-8     | 98 Units / Rail          |
| MC34063BDR2  | SO-8     | 2500 Units / Tape & Reel |
| MC34063AM    | SOEIAJ-8 | 94 Units / Rail          |
| MC34063AMEL  | SOEIAJ-8 | 1000 Units / Tape & Reel |
| MC34063AML1  | SOEIAJ-8 | 1000 Units / Tape & Reel |
| MC34063AML2  | SOEIAJ-8 | 2000 Units / Tape & Reel |
| MC34063AMR1  | SOEIAJ-8 | 1000 Units / Tape & Reel |
| MC34063AMR2  | SOEIAJ-8 | 2000 Units / Tape & Reel |

## MARKING DIAGRAMS

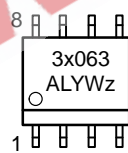
PDIP-8  
P, P1 SUFFIX  
CASE 626



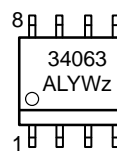
PDIP-8  
P, P1 SUFFIX  
CASE 626



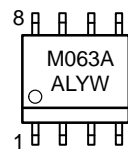
SO-8  
D SUFFIX  
CASE 751



SO-8  
D SUFFIX  
CASE 751



SOEIAJ-8  
M SUFFIX  
CASE 968

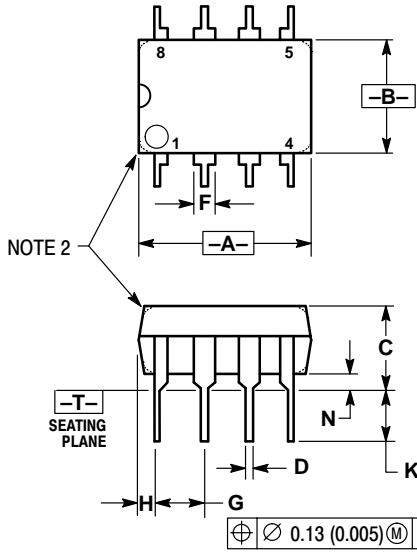


- x = 3 or 4
- z = A denotes AD suffix  
J denotes BD suffix
- A = Assembly Location
- WL, L = Wafer Lot
- YY, Y = Year
- WW, W = Work Week

# MC34063A, MC33063A

## PACKAGE DIMENSIONS

**PDIP-8**  
**P, P1 SUFFIX**  
 PLASTIC PACKAGE  
 CASE 626-05  
 ISSUE K

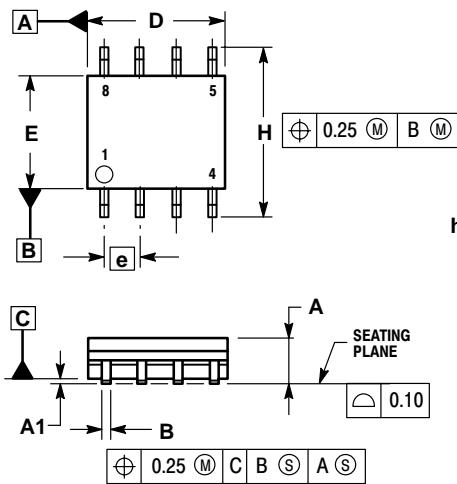


- NOTES:
1. DIMENSION L TO CENTER OF LEAD WHEN FORMED PARALLEL.
  2. PACKAGE CONTOUR OPTIONAL (ROUND OR SQUARE CORNERS).
  3. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.

| DIM | MILLIMETERS |       | INCHES    |       |
|-----|-------------|-------|-----------|-------|
|     | MIN         | MAX   | MIN       | MAX   |
| A   | 9.40        | 10.16 | 0.370     | 0.400 |
| B   | 6.10        | 6.60  | 0.240     | 0.260 |
| C   | 3.94        | 4.45  | 0.155     | 0.175 |
| D   | 0.38        | 0.51  | 0.015     | 0.020 |
| F   | 1.02        | 1.78  | 0.040     | 0.070 |
| G   | 2.54 BSC    |       | 0.100 BSC |       |
| H   | 0.76        | 1.27  | 0.030     | 0.050 |
| J   | 0.20        | 0.30  | 0.008     | 0.012 |
| K   | 2.92        | 3.43  | 0.115     | 0.135 |
| L   | 7.62 BSC    |       | 0.300 BSC |       |
| M   | 10°         |       | 10°       |       |
| N   | 0.76        | 1.01  | 0.030     | 0.040 |

|   |                  |   |     |     |
|---|------------------|---|-----|-----|
| ⊕ | ∅ 0.13 (0.005) M | T | A M | B M |
|---|------------------|---|-----|-----|

**SO-8**  
**D SUFFIX**  
 PLASTIC PACKAGE  
 CASE 751-06  
 ISSUE T



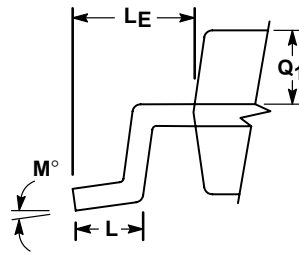
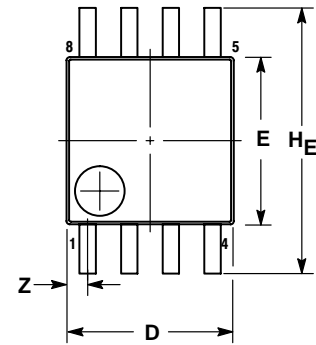
- NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
  2. DIMENSIONS ARE IN MILLIMETER.
  3. DIMENSION D AND E DO NOT INCLUDE MOLD PROTRUSION.
  4. MAXIMUM MOLD PROTRUSION 0.15 PER SIDE.
  5. DIMENSION B DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 TOTAL IN EXCESS OF THE B DIMENSION AT MAXIMUM MATERIAL CONDITION.

| DIM | MILLIMETERS |      |
|-----|-------------|------|
|     | MIN         | MAX  |
| A   | 1.35        | 1.75 |
| A1  | 0.10        | 0.25 |
| B   | 0.35        | 0.49 |
| C   | 0.19        | 0.25 |
| D   | 4.80        | 5.00 |
| E   | 3.80        | 4.00 |
| e   | 1.27 BSC    |      |
| H   | 5.80        | 6.20 |
| h   | 0.25        | 0.50 |
| L   | 0.40        | 1.25 |
| θ   | 0°          | 7°   |

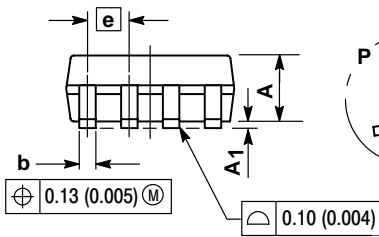
|   |        |   |     |     |
|---|--------|---|-----|-----|
| ⊕ | 0.25 M | C | B S | A S |
|---|--------|---|-----|-----|

# MC34063A, MC33063A

SOEIAJ-8  
M SUFFIX  
PLASTIC PACKAGE  
CASE 968-01  
ISSUE O



DETAIL P



NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER
3. DIMENSION D AND E DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS AND ARE MEASURED AT THE PARTING LINE. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.15 (0.006) PER SIDE.
4. TERMINAL NUMBERS ARE SHOWN FOR REFERENCE ONLY.
5. THE LEAD WIDTH DIMENSION (b) DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.08 (0.003) TOTAL IN EXCESS OF THE LEAD WIDTH DIMENSION AT MAXIMUM MATERIAL CONDITION. DAMBAR CANNOT BE LOCATED ON THE LOWER RADIUS OR THE FOOT MINIMUM SPACE BETWEEN PROTRUSIONS AND ADJACENT LEAD TO BE 0.46 (0.018).

| DIM            | MILLIMETERS |      | INCHES    |       |
|----------------|-------------|------|-----------|-------|
|                | MIN         | MAX  | MIN       | MAX   |
| A              | ---         | 2.05 | ---       | 0.081 |
| A <sub>1</sub> | 0.05        | 0.20 | 0.002     | 0.008 |
| b              | 0.35        | 0.50 | 0.014     | 0.020 |
| c              | 0.18        | 0.27 | 0.007     | 0.011 |
| D              | 5.10        | 5.50 | 0.201     | 0.217 |
| E              | 5.10        | 5.45 | 0.201     | 0.215 |
| e              | 1.27 BSC    |      | 0.050 BSC |       |
| HE             | 7.40        | 8.20 | 0.291     | 0.323 |
| L              | 0.50        | 0.85 | 0.020     | 0.033 |
| LE             | 1.10        | 1.50 | 0.043     | 0.059 |
| M              | 0°          | 10°  | 0°        | 10°   |
| Q <sub>1</sub> | 0.70        | 0.90 | 0.028     | 0.035 |
| Z              | ---         | 0.94 | ---       | 0.037 |

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**Notes**


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