

MC34063A
MC35063A
MC33063A

DC-to-DC Converter Control Circuits

The MC34063A/35063A/33063A is a series of monolithic control circuits 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 Note AN920 R2 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

DC-TO-DC CONVERTER CONTROL CIRCUITS

SILICON MONOLITHIC INTEGRATED CIRCUIT

P1 SUFFIX
PLASTIC PACKAGE
CASE 626



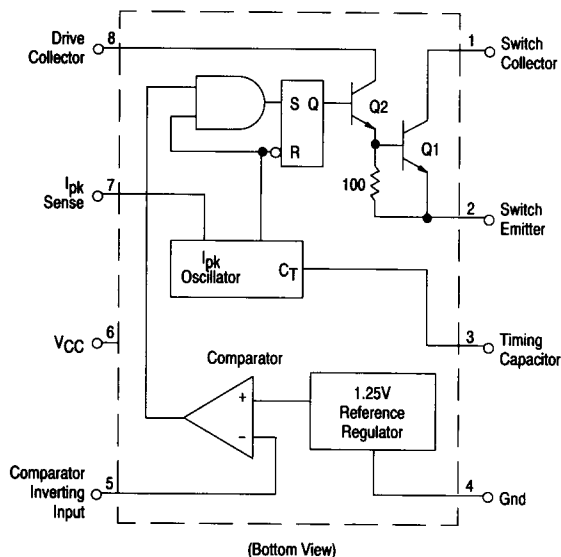
D SUFFIX
PLASTIC PACKAGE
CASE 751 (SO-8)



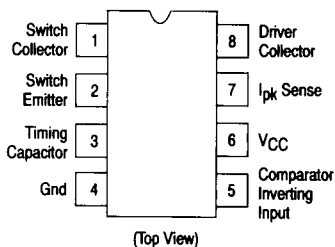
U SUFFIX
CERAMIC PACKAGE
CASE 693



Functional Block Diagram



PIN CONNECTIONS



ORDERING INFORMATION

Device	Temperature Range	Package
MC34063AD	0° to +70°C	SO-8
MC34063AP1		Plastic DIP
MC35063AU	-55° to +125°C	Ceramic DIP
MC33063AD	-40° to +85°C	SO-8
MC33063AP1		Plastic DIP

MC34063A, MC35063A, 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			
Ceramic Package, U Suffix			
$T_A = +25^\circ\text{C}$	P_D	1.25	W
Thermal Resistance	$R_{\theta JA}$	100	$^\circ\text{C/W}$
Plastic Package, P 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	mW
Thermal Resistance	$R_{\theta JA}$	160	$^\circ\text{C/W}$
Operating Junction Temperature	T_J	+150	$^\circ\text{C}$
Operating Ambient Temperature Range			
MC35063A	T_A	-55 to +125	$^\circ\text{C}$
MC33063A		-40 to +85	
MC34063A		0 to +70	
Storage Temperature Range	T_{stg}	-65 to +150	$^\circ\text{C}$

ELECTRICAL CHARACTERISTICS ($V_{CC} = 5.0\text{ V}$, $T_A = T_{low}$ to T_{high} [Note 2], unless otherwise specified.)

Characteristics	Symbol	Min	Typ	Max	Unit
OSCILLATOR					
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 V , $T_A = 25^\circ\text{C}$)	I_{chg}	24	33	42	μA
Discharge Current ($V_{CC} = 5.0\text{ V}$ to 40 V , $T_A = 25^\circ\text{C}$)	I_{dischg}	140	200	260	μA
Discharge to Charge Current Ratio (Pin 7 to V_{CC} , $T_A = 25^\circ\text{C}$)	I_{dischg}/I_{chg}	5.2	6.2	7.5	—
Current Limit Sense Voltage ($I_{chg} = I_{dischg}$, $T_A = 25^\circ\text{C}$)	$V_{ipk(\text{sense})}$	250	300	350	mV

NOTES: 1. Maximum package power dissipation limits must be observed.

2. $T_{low} = -55^\circ\text{C}$ for MC35063A
 -40°C for MC33063A
 0°C for MC34063A

$T_{high} = +125^\circ\text{C}$ for MC35063A
 $+85^\circ\text{C}$ for MC33063A
 $+70^\circ\text{C}$ for MC34063A

MC34063A, MC35063A, MC33063A

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ELECTRICAL CHARACTERISTICS — Continued ($V_{CC} = 5.0\text{ V}$; $T_A = T_{low}$ to T_{high} , unless otherwise specified.)

Characteristics	Symbol	Min	Typ	Max	Unit
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OUTPUT SWITCH (Note 3)

Saturation Voltage, Darlington Connection ($I_{SW} = 1.0\text{ A}$, Pins 1, 8 connected)	$V_{CE(sat)}$	—	1.0	1.3	V
Saturation Voltage ($I_{SW} = 1.0\text{ A}$, $R_{Pin\ 8} = 82\ \Omega$ 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	120	—	—
Collector Off-State Current ($V_{CE} = 40\text{ V}$)	$I_{C(off)}$	—	0.01	100	μA

COMPARATOR

Threshold Voltage ($T_A = 25^\circ\text{C}$) ($T_A = T_{low}$ to T_{high})	V_{th}	1.225 1.21	1.25 —	1.275 1.29	V
Threshold Voltage Line Regulation ($V_{CC} = 3.0\text{ V}$ to 40 V)	Regline	—	1.4	5.0	mV
Input Bias Current ($V_{in} = 0\text{ V}$)	I_{IB}	—	-40	-400	nA

TOTAL DEVICE

Supply Current ($V_{CC} = 5.0\text{ V}$ to 40 V , $C_T = 1.0\text{ nF}$, Pin 7 = V_{CC} , $V_{Pin\ 5} > V_{th}$, Pin 2 = Gnd, Remaining pins open)	I_{CC}	—	2.5	4.0	mA
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- NOTES:**
- Low duty cycle pulse techniques are used during test to maintain junction temperature as close to ambient temperature as possible.
 - 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 $2.0\ \mu\text{s}$ 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.

$$\text{Forced } \beta \text{ of output switch} = I_{C, \text{ output}} / (I_{C, \text{ driver}} - 7.0\text{ mA}) \geq 10$$

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

MC34063A, MC35063A, MC33063A

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

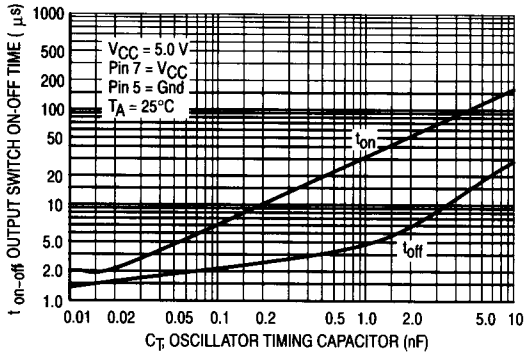


Figure 2. Timing Capacitor Waveform

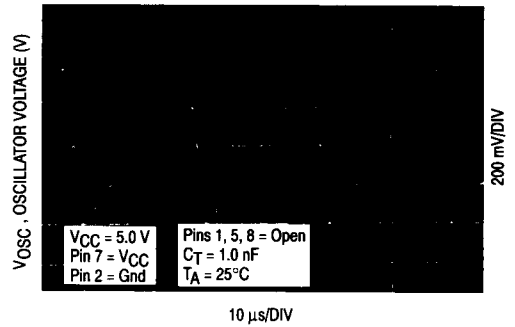


Figure 3. Emitter Follower Configuration Output Saturation Voltage versus Emitter Current

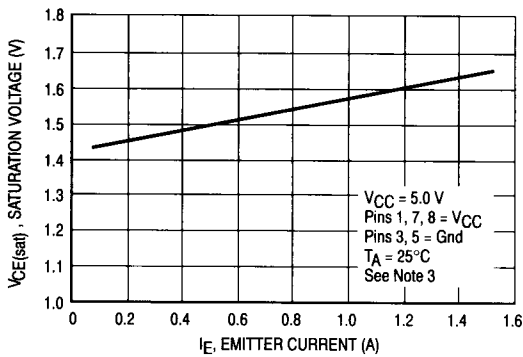


Figure 4. Common Emitter Configuration Output Switch Saturation Voltage versus Collector Current

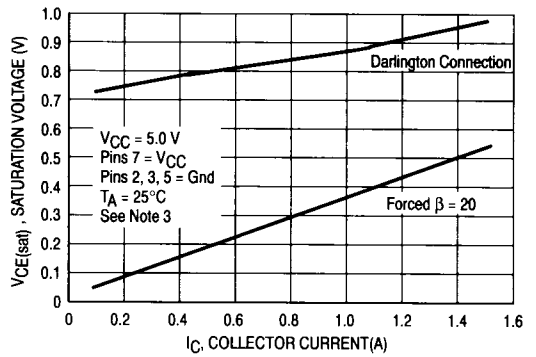


Figure 5. Current Limit Sense Voltage versus Temperature

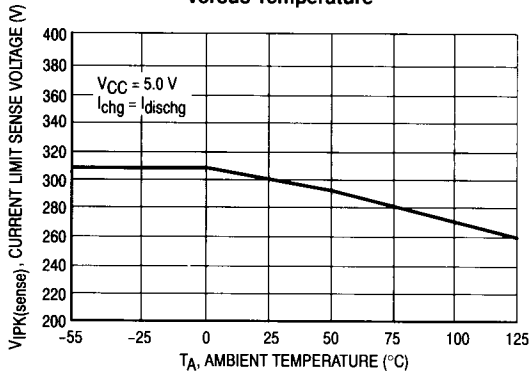
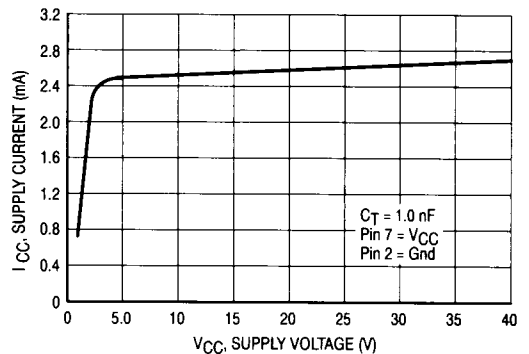
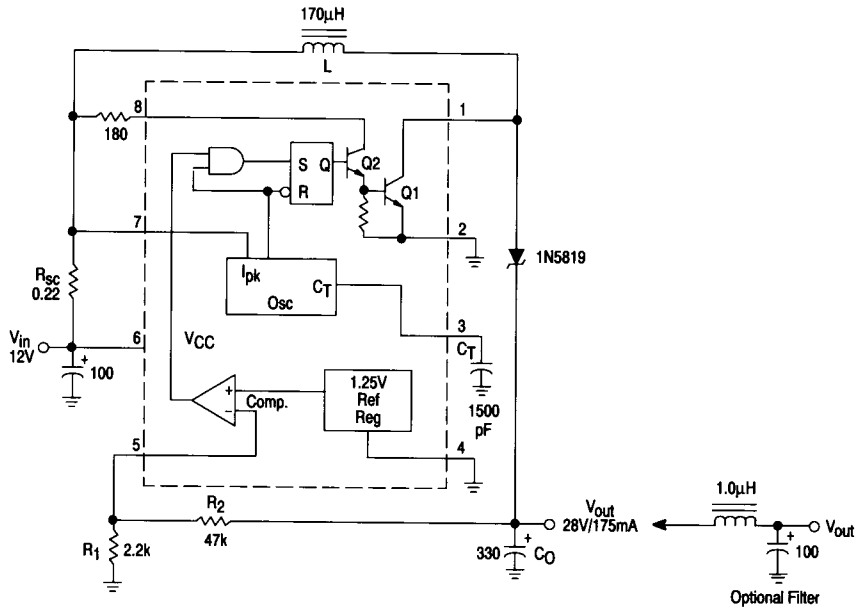


Figure 6. Standby Supply Current versus Supply Voltage



MC34063A, MC35063A, MC33063A

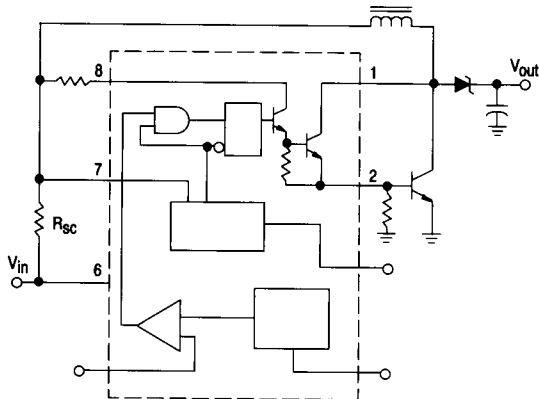
Figure 7. Step-Up Converter



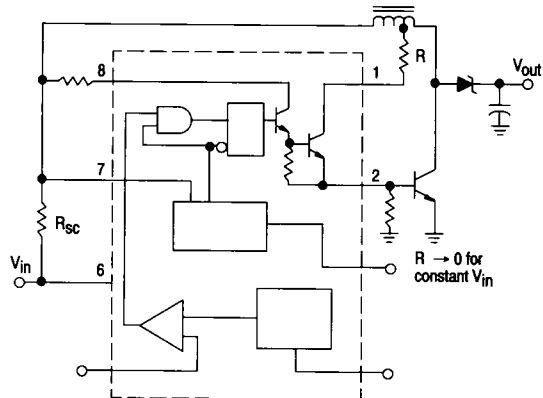
Test	Conditions	Results
Line Regulation	$V_{in} = 8.0 \text{ V to } 16 \text{ V}, I_O = 175 \text{ mA}$	$30 \text{ mV} = \pm 0.05\%$
Load Regulation	$V_{in} = 12 \text{ V}, I_O = 75 \text{ mA to } 175 \text{ mA}$	$10 \text{ mV} = \pm 0.017\%$
Output Ripple	$V_{in} = 12 \text{ V}, I_O = 175 \text{ mA}$	400 mVp-p
Efficiency	$V_{in} = 12 \text{ V}, I_O = 175 \text{ mA}$	89.2%
Output Ripple With Optional Filter	$V_{in} = 12 \text{ V}, I_O = 175 \text{ mA}$	40 mVp-p

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

External NPN Switch

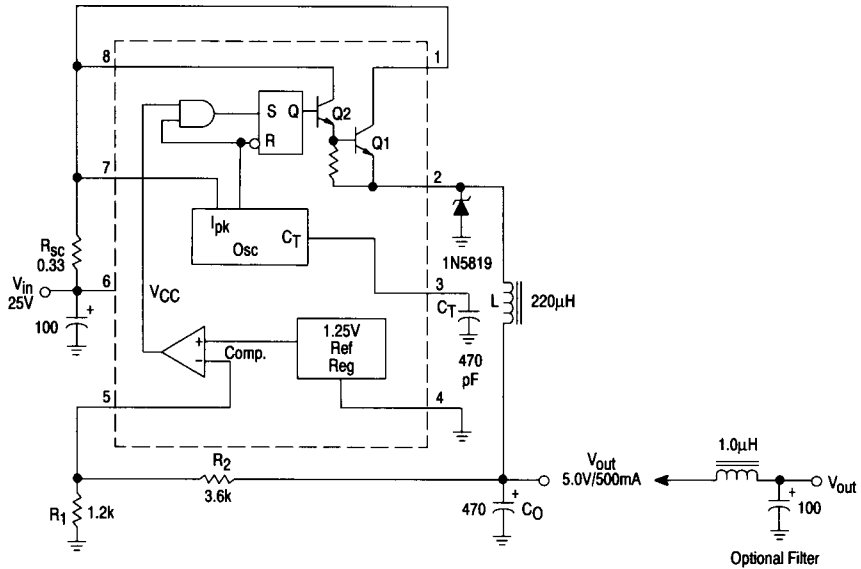


External NPN Saturated Switch
(Refer to Note 4)



MC34063A, MC35063A, MC33063A

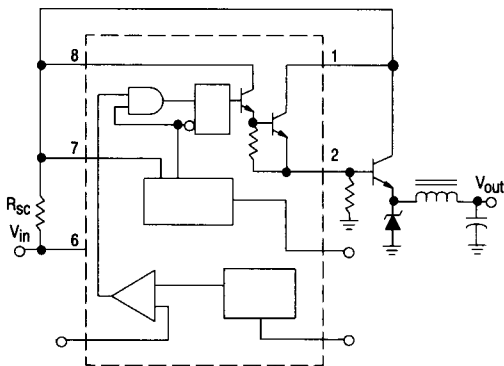
Figure 9. Step-Down Converter



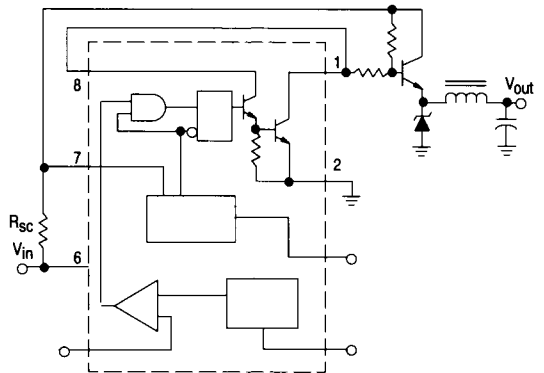
Test	Conditions	Results
Line Regulation	$V_{in} = 15 \text{ V to } 25 \text{ V}, I_O = 500 \text{ mA}$	$12 \text{ mV} = \pm 0.12\%$
Load Regulation	$V_{in} = 25 \text{ V}, I_O = 50 \text{ mA to } 500 \text{ mA}$	$3.0 \text{ mV} = \pm 0.03\%$
Output Ripple	$V_{in} = 25 \text{ V}, I_O = 500 \text{ mA}$	120 mVp-p
Short Circuit Current	$V_{in} = 25 \text{ V}, R_L = 0.1 \Omega$	1.1 A
Efficiency	$V_{in} = 25 \text{ V}, I_O = 500 \text{ mA}$	82.5%
Output Ripple With Optional Filter	$V_{in} = 25 \text{ V}, I_O = 500 \text{ mA}$	40 mVp-p

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

External NPN Switch

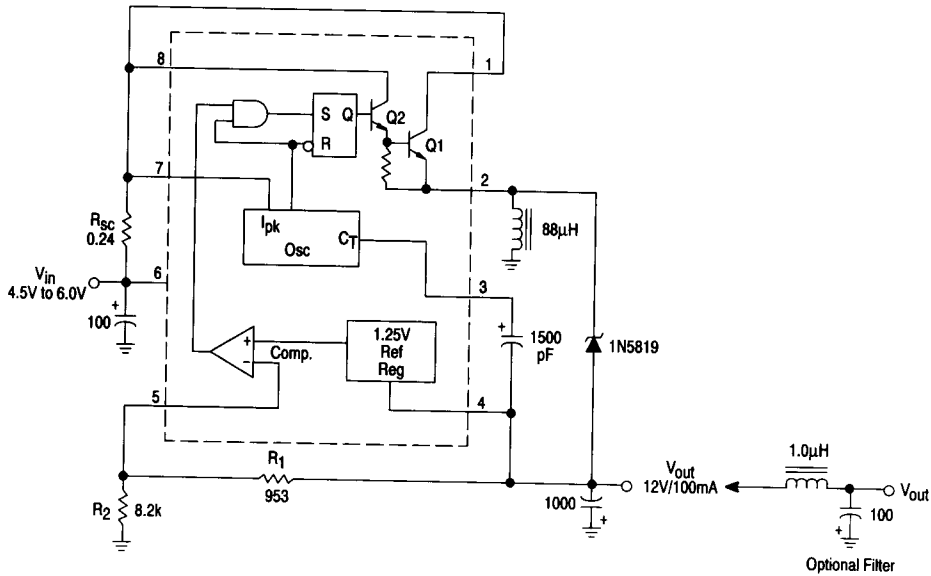


External PNP Saturated Switch



MC34063A, MC35063A, MC33063A

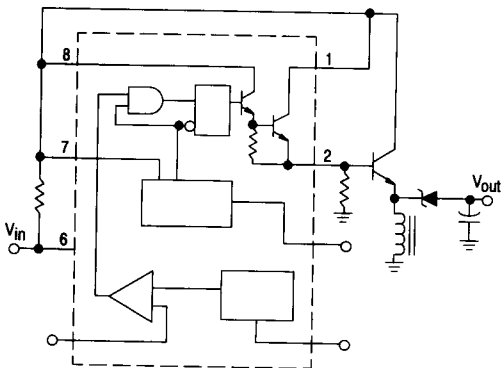
Figure 11. Voltage Inverting Converter



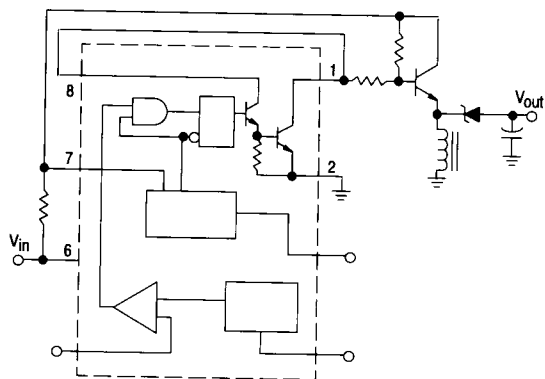
Test	Conditions	Results
Line Regulation	$V_{in} = 4.5 \text{ V to } 6.0 \text{ V}$, $I_O = 100 \text{ mA}$	3.0 mV = $\pm 0.012\%$
Load Regulation	$V_{in} = 5.0 \text{ V}$, $I_O = 10 \text{ mA to } 100 \text{ mA}$	0.022 mV = $\pm 0.09\%$
Output Ripple	$V_{in} = 5.0 \text{ V}$, $I_O = 100 \text{ mA}$	500 mVp-p
Short Circuit Current	$V_{in} = 5.0 \text{ V}$, $R_L = 0.1 \Omega$	910 mA
Efficiency	$V_{in} = 5.0 \text{ V}$, $I_O = 100 \text{ mA}$	64.5%
Output Ripple With Optional Filter	$V_{in} = 5.0 \text{ V}$, $I_O = 100 \text{ mA}$	70 mVp-p

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

External NPN Switch

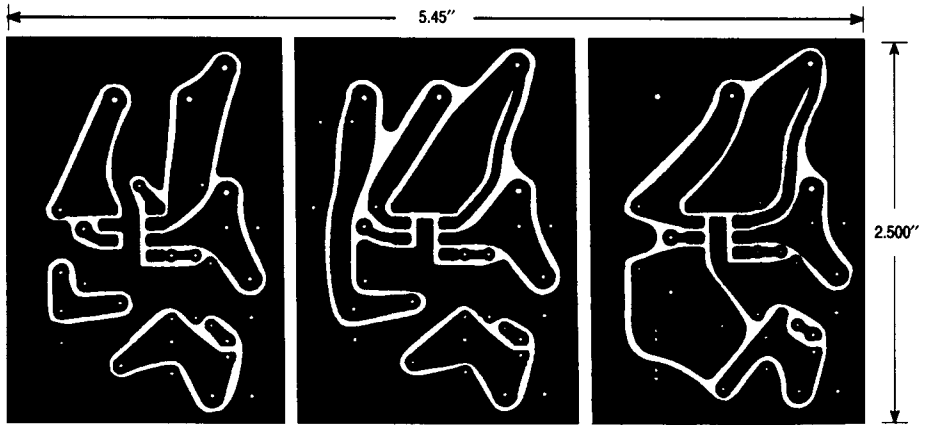


External PNP Saturated Switch

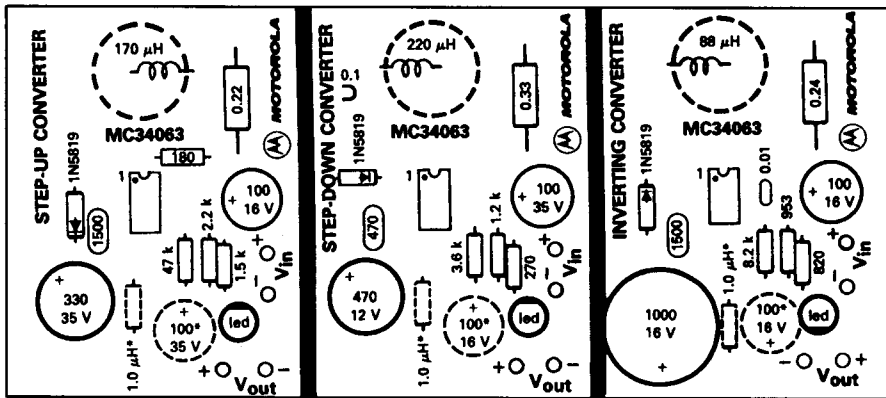


MC34063A, MC35063A, MC33063A

Figure 13. Printed Circuit Board and Component Layout
(Circuits of Figure 7, 9, 11)



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



Top View, Component Side

*Optional Filter.

INDUCTOR DATA

Converter	Inductance (μH)	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, MC35063A, MC33063A

Figure 14. Design Formula Table

Calculation	Step-Up	Step-Down	Voltage-Inverting
t_{on}/t_{off}	$\frac{V_{out}+V_F-V_{in(min)}}{V_{in(min)}-V_{sat}}$	$\frac{V_{out}+V_F}{V_{in(min)}-V_{sat}-V_{out}}$	$\frac{ V_{out} +V_F}{V_{in}+V_{sat}}$
$(t_{on} + t_{off}) \text{ max}$	$\frac{1}{f_{min}}$	$\frac{1}{f_{min}}$	$\frac{1}{f_{min}}$
C_T	$4.8 \times 10^{-5} t_{on}$	$4.8 \times 10^{-5} t_{on}$	$4.8 \times 10^{-5} t_{on}$
$I_{pk}(\text{switch})$	$2I_{out(max)} \left(\frac{t_{on}}{t_{off}} + 1 \right)$	$2I_{out(max)}$	$2I_{out(max)} \left(\frac{t_{on}}{t_{off}} + 1 \right)$
R_{SC}	$0.3/I_{pk}(\text{switch})$	$0.3/I_{pk}(\text{switch})$	$0.3/I_{pk}(\text{switch})$
$L_{(min)}$	$\left(\frac{V_{in(min)}-V_{sat}}{I_{pk}(\text{switch})} \right) t_{on(max)}$	$\left(\frac{V_{in(min)}-V_{sat}-V_{out}}{I_{pk}(\text{switch})} \right) t_{on(max)}$	$\left(\frac{V_{in(min)}-V_{sat}}{I_{pk}(\text{switch})} \right) t_{on(max)}$
C_O	$\approx \frac{I_{out}t_{on}}{V_{ripple(p-p)}}$	$\frac{I_{pk}(\text{switch})(t_{on}+t_{off})}{8V_{ripple(p-p)}}$	$\approx \frac{I_{out}t_{on}}{V_{ripple(p-p)}}$

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, $|V_{out}| = 1.25 \left(1 + \frac{R_2}{R_1} \right)$

I_{out} — Desired output current.

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

$V_{ripple(p-p)}$ — 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 AN920 Rev. 2.

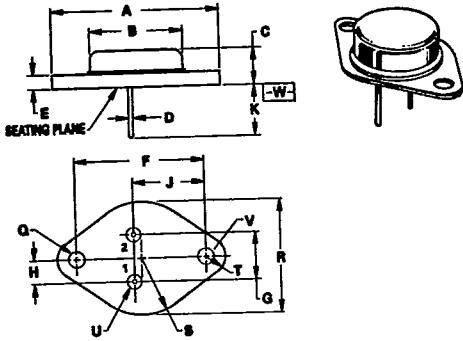
SECTION 19 PACKAGE OUTLINE DIMENSIONS

T-90-20

K SUFFIX METAL PACKAGE CASE 1-03 $R_{\theta JA} = 45^{\circ}\text{C/W (TYP)}$ (TO-3)

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
B	—	22.23	—	0.875
C	8.35	11.43	0.329	0.450
D	0.97	1.09	0.038	0.042
E	—	3.43	—	0.135
F	30.15 BSC 1.187 BSC			
G	10.92 BSC 0.430 BSC			
H	6.46 BSC 0.215 BSC			
J	16.89 BSC 0.665 BSC			
K	7.92	—	0.312	—
Q	3.94	4.09	0.151	0.161
S	—	13.34	—	0.525
T	—	4.78	—	0.188
V	3.94	4.09	0.151	0.161

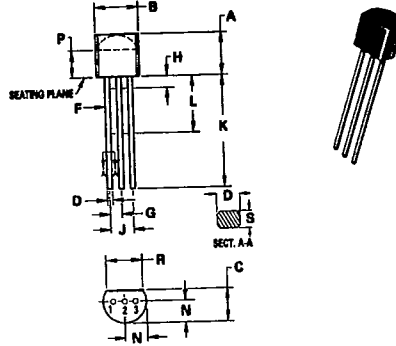
- NOTES:
1. DIAMETER V AND SURFACE W ARE DATUMS.
 2. POSITIONAL TOLERANCE FOR HOLE G:
 $\pm 0.25 (0.010) \text{ (M) } | \text{ (W) } | \text{ (V) } | \text{ (Q)}$
 3. POSITIONAL TOLERANCE FOR LEADS:
 $\pm 0.30 (0.012) \text{ (M) } | \text{ (W) } | \text{ (V) } | \text{ (Q) } | \text{ (S)}$



LP, P, Z SUFFIX PLASTIC PACKAGE CASE 29-04 $R_{\theta JA} = 200^{\circ}\text{C/W (TYP)}$ (TO-226AA/TO-92)

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	4.32	5.33	0.170	0.210
B	4.45	5.20	0.175	0.205
C	3.18	4.19	0.125	0.165
D	0.41	0.55	0.016	0.022
F	0.41	0.48	0.016	0.019
G	1.15	1.39	0.045	0.055
H	—	2.54	—	0.100
J	2.42	2.66	0.095	0.105
K	12.70	—	0.500	—
L	6.35	—	0.250	—
N	2.04	2.66	0.080	0.105
P	2.93	—	0.115	—
R	3.43	—	0.135	—
S	0.39	0.50	0.015	0.020

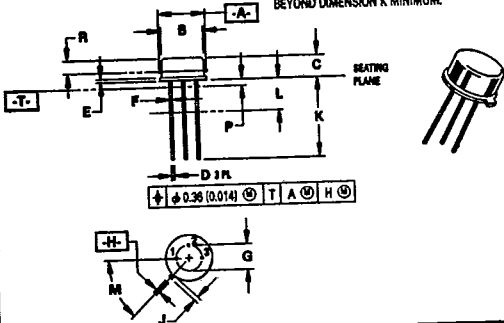
- NOTES:
1. CONTOUR OF PACKAGE BEYOND ZONE "P" IS UNCONTROLLED.
 2. DIM "F" APPLIES BETWEEN "H" AND "L". DIM "D" & "S" APPLIES BETWEEN "L" & 12.70mm (0.5") FROM SEATING PLANE. LEAD DIM IS UNCONTROLLED IN "H" & BEYOND 12.70mm (0.5") FROM SEATING PLANE.
 3. CONTROLLING DIM: INCH.



G, H SUFFIX METAL PACKAGE CASE 79-05 $R_{\theta JA} = 185^{\circ}\text{C/W (TYP)}$ (TO-39)

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	9.02	9.29	0.355	0.366
B	8.01	8.50	0.315	0.335
C	4.20	4.57	0.165	0.180
D	0.44	0.53	0.017	0.021
E	0.44	0.66	0.017	0.036
F	0.41	0.48	0.016	0.019
G	5.08 BSC 0.200 BSC			
H	0.72	0.86	0.029	0.034
J	0.74	1.01	0.029	0.040
K	12.70	19.05	0.500	0.750
L	6.35	—	0.250	—
M	45° BSC 45° BSC			
P	—	1.27	—	0.050
R	2.34	—	0.100	—

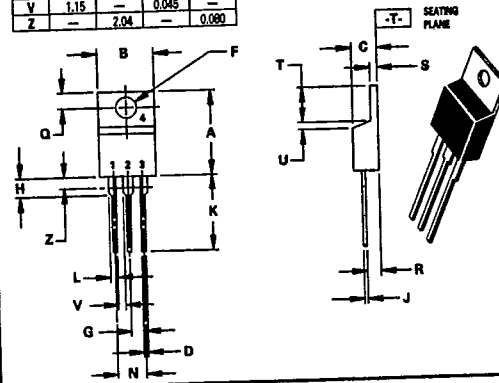
- NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
 2. CONTROLLING DIMENSION: INCH.
 3. DIMENSION J MEASURED FROM DIMENSION A MAXIMUM.
 4. DIMENSION B SHALL NOT VARY MORE THAN 0.25 (0.010) IN ZONE R. THIS ZONE CONTROLLED FOR AUTOMATIC HANDLING.
 5. DIMENSION F APPLIES BETWEEN DIMENSION P AND L. DIMENSION D APPLIES BETWEEN DIMENSION L AND K MINIMUM. LEAD DIAMETER IS UNCONTROLLED IN DIMENSION P AND BEYOND DIMENSION K MINIMUM.



KC, T SUFFIX PLASTIC PACKAGE CASE 221A-04 $R_{\theta JA} = 65^{\circ}\text{C/W (TYP)}$ (TO-220AB)

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	14.48	15.75	0.570	0.620
B	9.68	10.28	0.380	0.405
C	4.07	4.82	0.160	0.190
D	0.64	0.88	0.025	0.035
F	3.81	3.73	0.142	0.147
G	2.42	2.66	0.095	0.105
H	2.80	3.93	0.110	0.155
J	0.36	0.55	0.014	0.022
K	12.70	14.27	0.500	0.562
L	1.15	1.39	0.045	0.055
N	4.83	5.33	0.190	0.210
Q	2.54	3.04	0.100	0.120
R	2.04	2.79	0.080	0.110
S	1.15	1.39	0.045	0.055
T	5.97	6.47	0.235	0.255
U	0.03	1.27	0.000	0.050
V	1.15	—	0.045	—
Z	—	2.04	—	0.080

- NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
 2. CONTROLLING DIMENSION: INCH.
 3. DIM Z DEFINES A ZONE WHERE ALL BODY AND LEAD IRREGULARITIES ARE ALLOWED.

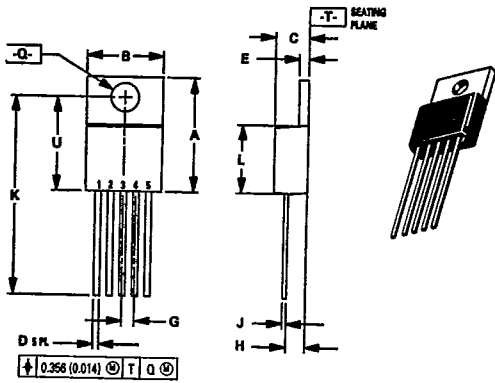


PACKAGE OUTLINE DIMENSIONS (continued)

**T SUFFIX
PLASTIC PACKAGE
CASE 314D-02**

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	14.529	15.570	0.572	0.613
B	9.908	10.541	0.390	0.415
C	4.318	4.572	0.170	0.180
D	0.635	0.965	0.025	0.038
E	1.169	1.397	0.046	0.055
G	1.702 BSC		0.067 BSC	
H	2.109	2.717	0.083	0.107
J	0.381	0.635	0.015	0.025
K	25.907	26.670	1.016	1.050
L	8.052	9.398	0.317	0.370
Q	3.556	3.937	0.140	0.155
U	11.883	12.827	0.468	0.505

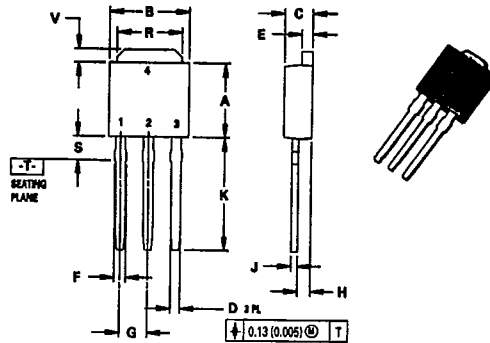
NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.



**DT-1 SUFFIX
PLASTIC PACKAGE
CASE 369-03**

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	5.97	6.72	0.235	0.245
B	6.35	6.73	0.250	0.265
C	2.19	2.38	0.086	0.094
D	0.69	0.88	0.027	0.035
E	0.84	0.94	0.033	0.037
F	0.77	1.14	0.030	0.045
G	2.29 BSC		0.090 BSC	
H	0.97	1.06	0.038	0.042
J	0.46	0.58	0.018	0.023
K	8.89	9.65	0.350	0.380
R	5.21	5.46	0.205	0.215
S	1.91	2.28	0.075	0.090
V	0.89	1.27	0.035	0.050

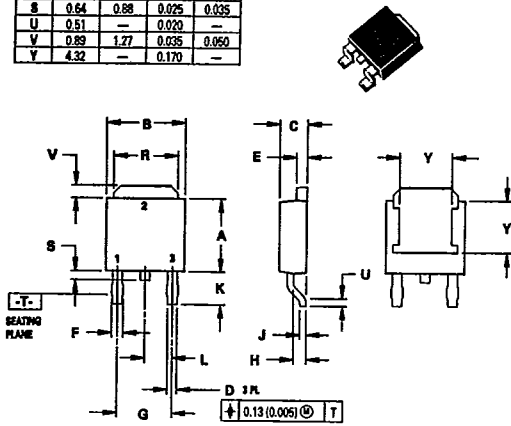
NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.



**DT SUFFIX
PLASTIC PACKAGE
CASE 369A-03
DPAK**

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	5.97	6.22	0.235	0.245
B	6.35	6.73	0.250	0.265
C	2.19	2.38	0.086	0.094
D	0.69	0.88	0.027	0.035
E	0.84	0.94	0.033	0.037
F	0.77	1.14	0.030	0.045
G	4.58 BSC		0.180 BSC	
H	0.97	1.06	0.038	0.042
J	0.46	0.58	0.018	0.023
K	2.60	2.89	0.102	0.114
L	2.29 BSC		0.090 BSC	
R	5.21	5.46	0.205	0.215
S	0.64	0.88	0.025	0.035
U	0.51	—	0.020	—
V	0.89	1.27	0.035	0.050
Y	4.32	—	0.170	—

NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.

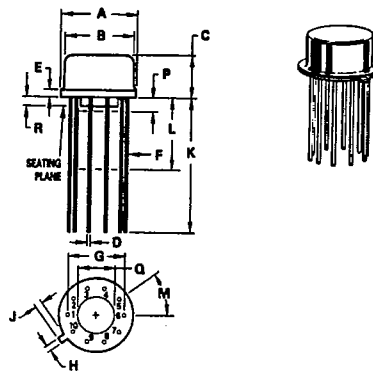


**H, G SUFFIX
METAL PACKAGE
CASE 603-04
R_{θJA} = 160°C/W
(TO-100)**

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	8.51	9.29	0.335	0.370
B	7.75	8.51	0.305	0.335
C	4.19	4.70	0.165	0.185
D	0.407	0.533	0.016	0.021
E	—	1.02	—	0.040
F	0.406	0.483	0.016	0.019
G	5.84 BSC		0.230 BSC	
H	0.712	0.864	0.028	0.034
J	0.737	1.14	0.029	0.045
K	12.70	—	0.500	—
L	6.35	12.70	0.250	0.500
M	36° BSC		36° BSC	
P	—	1.27	—	0.050
Q	3.56	4.06	0.140	0.160
R	0.254	1.02	0.010	0.040

NOTE:
LEADS WITHIN 0.18 mm (0.007) RADIUS OF TRUE POSITION AT SEATING PLANE AT MAXIMUM MATERIAL CONDITION.

All JEDEC Dimensions and Notes Apply.

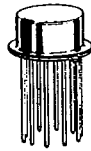
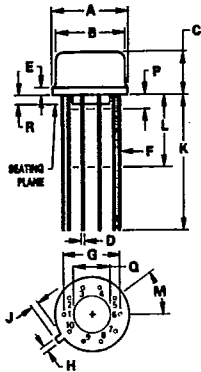


PACKAGE OUTLINE DIMENSIONS (continued)

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	8.51	9.39	0.335	0.370
B	7.75	8.51	0.305	0.335
C	4.19	6.73	0.165	0.265
D	0.407	0.533	0.016	0.021
E	—	1.02	—	0.040
F	0.406	0.483	0.016	0.019
G	5.84 BSC		0.230 BSC	
H	0.712	0.864	0.028	0.034
J	0.737	1.14	0.029	0.045
K	12.70	—	0.500	—
L	6.35	12.70	0.250	0.500
M	36° BSC		36° BSC	
P	—	1.27	—	0.050
Q	3.56	4.06	0.140	0.160
R	0.254	1.02	0.010	0.040

**G SUFFIX
METAL PACKAGE
CASE 603C-01**
R_{θJA} = 150°C/W (TYP)
(TO-100)

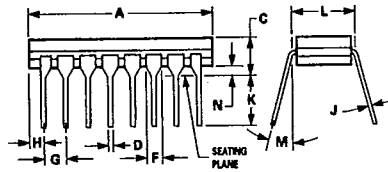
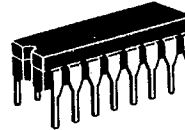
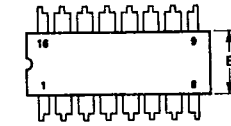
- NOTES:
1. LEADS WITHIN 0.18 mm (0.007) RADIUS OF TRUE POSITION TO DIM. "A" & "H" AT SEATING PLANE AT MAXIMUM MATERIAL CONDITION.
2. LEAD DIA UNCONTROLLED BEYOND DIM "K" MIN.



DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	19.05	19.94	0.750	0.785
B	6.10	7.49	0.240	0.295
C	—	5.08	—	0.200
D	0.38	0.53	0.015	0.021
F	1.40	1.78	0.055	0.070
G	2.54 BSC		0.100 BSC	
H	0.51	1.14	0.020	0.045
J	0.20	0.30	0.008	0.012
K	3.18	4.32	0.125	0.170
L	7.62 BSC		0.300 BSC	
M	—	15°	—	15°
N	0.51	1.02	0.020	0.040

**DP2, D, J, L, N SUFFIX
CERAMIC PACKAGE
CASE 620-10**
R_{θJA} = 100°C/W (TYP)

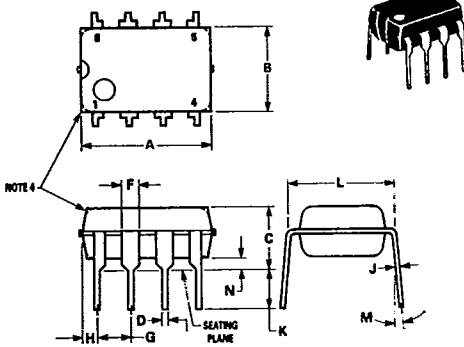
- NOTES:
1. LEADS WITHIN 0.13 mm (0.005) RADIUS OF TRUE POSITION AT SEATING PLANE AT MAXIMUM MATERIAL CONDITION.
2. PACKAGE INDEX: NOTCH IN LEAD NOTCH IN CERAMIC OR INK DOT.
3. DIM "L" TO CENTER OF LEADS WHEN FORMED PARALLEL.
4. DIM "A" AND "B" DO NOT INCLUDE GLASS RUN-OUT.
5. DIM "F" MAY NARROW TO 0.76 mm (0.030) WHERE THE LEAD ENTERS THE CERAMIC BODY.



**N, P1 SUFFIX
PLASTIC PACKAGE
CASE 626-05**
R_{θJA} = 100°C/W (TYP)

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	1.52	0.040	0.060
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

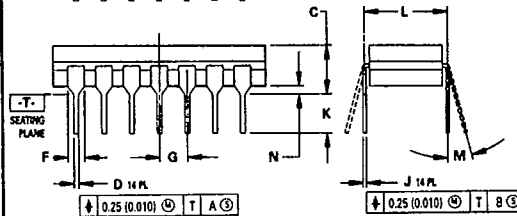
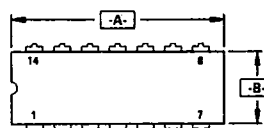
- NOTES:
1. LEAD POSITIONAL TOLERANCE:
⊕ | ⊕ 0.13 (0.005) ⊕ | T | A ⊕ | B ⊕ |
2. DIMENSION L TO CENTER OF LEADS WHEN FORMED PARALLEL.
3. PACKAGE CONTOUR OPTIONAL (ROUND OR SQUARE CORNERS).
4. DIMENSIONS A AND B ARE DATUMS.
5. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.



**L SUFFIX
CERAMIC PACKAGE
CASE 632-08**
R_{θJA} = 100°C/W (TYP)
(TO-116)

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	19.05	19.94	0.750	0.785
B	6.23	7.11	0.245	0.280
C	3.94	5.08	0.155	0.200
D	0.39	0.50	0.015	0.020
F	1.40	1.65	0.055	0.065
G	2.54 BSC		0.100 BSC	
J	0.21	0.38	0.008	0.015
K	3.18	4.31	0.125	0.170
L	7.62 BSC		0.300 BSC	
M	0°	15°	0°	15°
N	0.51	1.01	0.020	0.040

- NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSION L TO CENTER OF LEAD WHEN FORMED PARALLEL.
4. DIM F MAY NARROW TO 0.76 (0.030) WHERE THE LEAD ENTERS THE CERAMIC BODY.

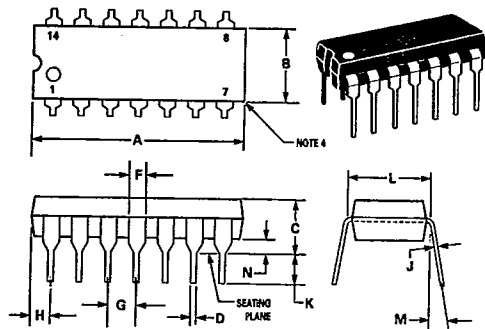


PACKAGE OUTLINE DIMENSIONS (continued)

**N, P, N-14, P2 SUFFIX
PLASTIC PACKAGE
CASE 646-06**
 $R_{\theta JA} = 100^{\circ}\text{C/W (TYP)}$

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	18.16	19.56	0.715	0.770
B	6.10	6.62	0.240	0.260
C	3.69	4.69	0.145	0.185
D	0.39	0.53	0.015	0.021
F	1.02	1.79	0.040	0.070
G	2.54 BSC		0.100 BSC	
H	1.22	2.41	0.052	0.095
J	0.20	0.38	0.008	0.015
K	2.92	3.43	0.115	0.135
L	7.62 BSC		0.300 BSC	
M	0°	10°	0°	10°
N	0.39	1.01	0.015	0.039

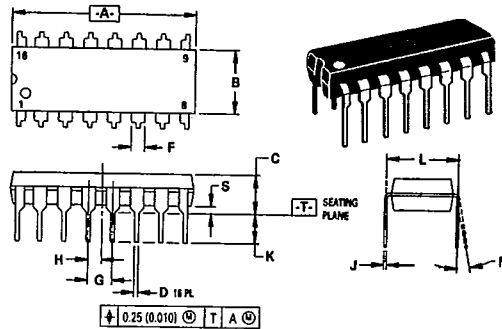
- NOTES:
- LEADS WITHIN 0.13 mm (0.005) RADIUS OF TRUE POSITION AT SEATING PLANE AT MAXIMUM MATERIAL CONDITION.
 - DIMENSION "L" TO CENTER OF LEADS WHEN FORMED PARALLEL.
 - DIMENSION "B" DOES NOT INCLUDE MOLD FLASH.
 - ROUNDED CORNERS OPTIONAL.



**N, P SUFFIX
PLASTIC PACKAGE
CASE 648-08**
 $R_{\theta JA} = 100^{\circ}\text{C/W (TYP)}$

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	18.80	19.55	0.740	0.770
B	6.35	6.85	0.250	0.270
C	3.69	4.44	0.145	0.175
D	0.39	0.53	0.015	0.021
F	1.02	1.77	0.040	0.070
G	2.54 BSC		0.100 BSC	
H	1.27 BSC		0.050 BSC	
J	0.21	0.38	0.008	0.015
K	2.90	3.30	0.110	0.130
L	7.50	7.74	0.295	0.305
M	0°	10°	0°	10°
S	0.51	1.01	0.020	0.040

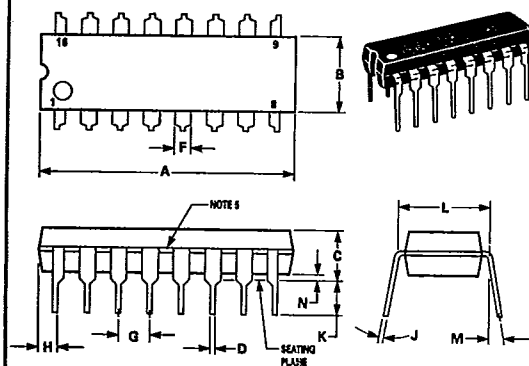
- NOTES:
- DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
 - CONTROLLING DIMENSION: INCH.
 - DIMENSION "L" TO CENTER OF LEADS WHEN FORMED PARALLEL.
 - DIMENSION "B" DOES NOT INCLUDE MOLD FLASH.
 - ROUNDED CORNERS OPTIONAL.



**P SUFFIX
PLASTIC PACKAGE
CASE 648C-02**

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	18.80	21.34	0.740	0.840
B	6.10	6.50	0.240	0.260
C	3.69	4.69	0.145	0.185
D	0.39	0.53	0.015	0.021
F	1.02	1.79	0.040	0.070
G	2.54 BSC		0.100 BSC	
H	0.39	2.41	0.015	0.095
J	0.20	0.38	0.008	0.015
K	2.92	3.43	0.115	0.135
L	7.62 BSC		0.300 BSC	
M	0°	10°	0°	10°
N	0.39	1.01	0.015	0.040

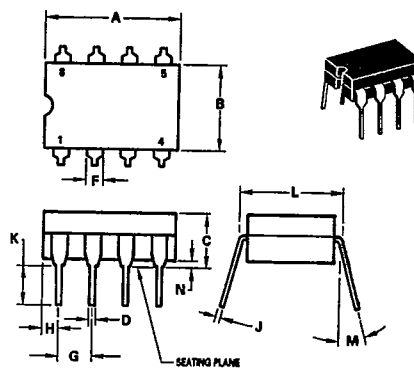
- NOTES:
- LEADS WITHIN 0.13 mm (0.005) RADIUS OF TRUE POSITION AT SEATING PLANE AT MAXIMUM MATERIAL CONDITION.
 - DIMENSION "L" TO CENTER OF LEADS WHEN FORMED PARALLEL.
 - DIMENSION "B" DOES NOT INCLUDE MOLD FLASH.
 - ROUNDED CORNERS OPTIONAL.
 - EXTERNAL LEAD CONNECTION, BETWEEN 4 AND 5, 12 AND 13 AS SHOWN.



**J-8, J, JG, U, Z SUFFIX
CERAMIC PACKAGE
CASE 693-02**
 $R_{\theta JA} = 100^{\circ}\text{C/W (TYP)}$

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	9.91	10.92	0.390	0.430
B	6.22	6.99	0.245	0.275
C	4.32	5.08	0.170	0.200
D	0.41	0.51	0.016	0.020
F	1.40	1.65	0.055	0.065
G	2.54 BSC		0.100 BSC	
H	1.14	1.65	0.045	0.065
J	0.20	0.30	0.008	0.012
K	3.18	4.06	0.125	0.160
L	7.37	7.87	0.290	0.310
M	—	15°	—	15°
N	0.51	1.02	0.020	0.040

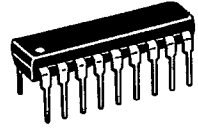
- NOTES:
- LEADS WITHIN 0.13 mm (0.005) RAD OF TRUE POSITION AT SEATING PLANE AT MAXIMUM MATERIAL CONDITION.
 - DIMENSION "L" TO CENTER OF LEADS WHEN FORMED PARALLEL.



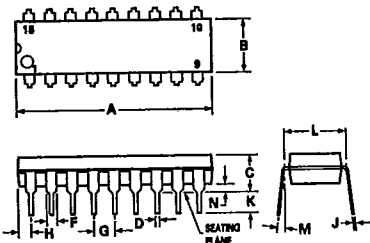
PACKAGE OUTLINE DIMENSIONS (continued)

**A, B, N, P SUFFIX
PLASTIC PACKAGE
CASE 707-02**
 $R_{\theta JA} = 100^{\circ}\text{C/W (TYP)}$

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	22.22	23.24	0.875	0.915
B	6.10	6.60	0.240	0.260
C	3.58	4.57	0.140	0.180
D	0.38	0.56	0.014	0.022
F	1.27	1.78	0.050	0.070
G	2.54 BSC		0.100 BSC	
H	1.02	1.52	0.040	0.060
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	0°	15°	0°	15°
N	0.51	1.02	0.020	0.040



- NOTES:
1. POSITIONAL TOLERANCE OF LEADS (D), SHALL BE WITHIN 0.25mm(0.010) AT MAXIMUM MATERIAL CONDITION, IN RELATION TO SEATING PLANE AND EACH OTHER.
 2. DIMENSION L TO CENTER OF LEADS WHEN FORMED PARALLEL.
 3. DIMENSION B DOES NOT INCLUDE MOLD FLASH.

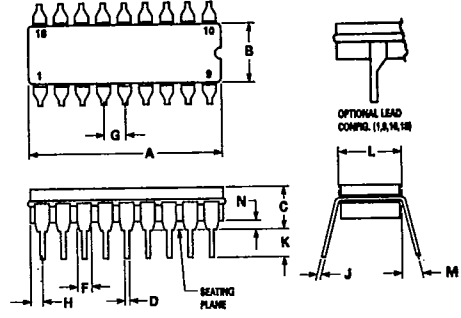


**J, L SUFFIX
CERAMIC PACKAGE
CASE 726-04**
 $R_{\theta JA} = 100^{\circ}\text{C/W (TYP)}$

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	22.35	23.11	0.880	0.910
B	6.10	7.49	0.240	0.295
C	—	5.08	—	0.200
D	0.38	0.53	0.015	0.021
F	1.40	1.78	0.055	0.070
G	2.54 BSC		0.100 BSC	
H	0.51	1.14	0.020	0.045
J	0.20	0.30	0.008	0.012
K	3.18	4.32	0.125	0.170
L	7.62 BSC		0.300 BSC	
M	0°	15°	0°	15°
N	0.51	1.02	0.020	0.040



- NOTES:
1. LEADS, TRUE POSITIONED WITHIN 0.25 mm (0.010) DIA. AT SEATING PLANE, AT MAXIMUM MATERIAL CONDITION.
 2. DIM "L" TO CENTER OF LEADS WHEN FORMED PARALLEL.
 3. DIM "A" & "B" INCLUDES MENISCUS.
 4. "F" DIMENSION IS FOR FULL LEADS. "HALF" LEADS ARE OPTIONAL AT LEAD POSITIONS 1, 9, 10, AND 18.

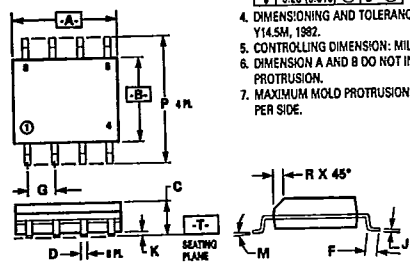


**D SUFFIX
CASE 751-03
PLASTIC PACKAGE
SO-8, SOP-8**
 $R_{\theta JA} = 190^{\circ}\text{C/W (SO-8)}$
 $R_{\theta JA} = 160^{\circ}\text{C/W (SOP-8)}$

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	4.80	5.00	0.189	0.198
B	3.80	4.00	0.150	0.157
C	1.35	1.75	0.054	0.068
D	0.35	0.49	0.014	0.019
F	0.40	1.25	0.016	0.049
G	1.27 BSC		0.050 BSC	
J	0.19	0.25	0.008	0.009
K	0.10	0.25	0.004	0.009
M	0°	7°	0°	7°
P	5.80	6.20	0.229	0.244
R	0.25	0.50	0.010	0.019

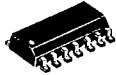


- NOTES:
1. DIMENSIONS A AND B ARE DATUMS AND T IS A DATUM SURFACE.
 2. POSITIONAL TOLERANCE FOR D DIMENSION (8 PLACES):
 $\pm 0.25 (0.010) \text{ (T) B (A)}$
 3. POSITIONAL TOLERANCE FOR P DIMENSION (4 PLACES):
 $\pm 0.25 (0.010) \text{ (B)}$
 4. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
 5. CONTROLLING DIMENSION: MILLIMETER.
 6. DIMENSION A AND B DO NOT INCLUDE MOLD PROTRUSION.
 7. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.

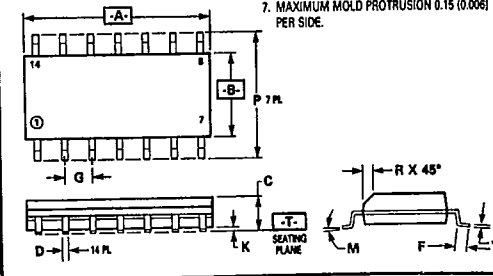


**D SUFFIX
PLASTIC PACKAGE
CASE 751A-02
SO-14**
 $R_{\theta JA} = 145^{\circ}\text{C/W (TYP)}$

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	8.55	8.75	0.337	0.344
B	3.80	4.00	0.150	0.157
C	1.35	1.75	0.054	0.068
D	0.35	0.49	0.014	0.019
F	0.40	1.25	0.016	0.049
G	1.27 BSC		0.050 BSC	
J	0.18	0.25	0.008	0.009
K	0.10	0.25	0.004	0.009
M	0°	7°	0°	7°
P	5.80	6.20	0.229	0.244
R	0.25	0.50	0.010	0.019



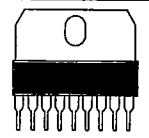
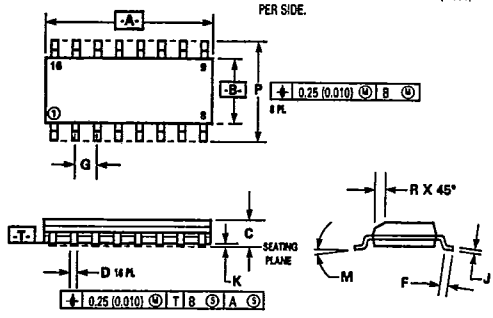
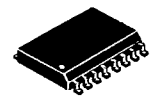
- NOTES:
1. DIMENSIONS A AND B ARE DATUMS AND T IS A DATUM SURFACE.
 2. POSITIONAL TOLERANCE FOR D DIMENSION (14 PLACES):
 $\pm 0.25 (0.010) \text{ (T) B (A)}$
 3. POSITIONAL TOLERANCE FOR P DIMENSION (7 PLACES):
 $\pm 0.25 (0.010) \text{ (B)}$
 4. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
 5. CONTROLLING DIMENSION: MILLIMETER.
 6. DIMENSION A AND B DO NOT INCLUDE MOLD PROTRUSION.
 7. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.



**DW SUFFIX
PLASTIC PACKAGE
CASE 751G-01
SO-16L**

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	10.15	10.45	0.400	0.411
B	7.40	7.60	0.292	0.299
C	2.35	2.65	0.093	0.104
D	0.35	0.49	0.014	0.019
F	0.50	0.90	0.020	0.035
G	1.27 BSC		0.050 BSC	
J	0.25	0.32	0.010	0.012
K	0.10	0.25	0.004	0.009
M	0°	7°	0°	7°
P	10.05	10.55	0.395	0.415
	0.25	0.75	0.010	0.029

- NOTES:
1. DIMENSIONS A AND B ARE DATUMS AND T IS A DATUM SURFACE.
 2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
 3. CONTROLLING DIMENSION: MILLIMETER.
 4. DIMENSION A AND B DO NOT INCLUDE MOLD PROTRUSION.
 5. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.



**CASE 762-01
PLASTIC MEDIUM
POWER PACKAGE
SIP-9**

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	22.40	23.00	0.873	0.907
B	6.40	6.80	0.252	0.269
C	3.45	3.65	0.135	0.143
D	0.40	0.55	0.015	0.021
E	3.35	3.60	0.269	0.377
F	1.40	1.60	0.055	0.062
G	2.54 BSC		0.100 BSC	
H	1.81	1.71	0.069	0.067
J	0.380	0.400	0.014	0.015
K	3.30	4.20	0.130	0.165
M	30° BSC		30° BSC	
N	2.50	2.70	0.099	0.106
Q	3.15	3.45	0.124	0.135
R	13.80	13.90	0.539	0.547
S	1.65	1.95	0.064	0.076
U	22.00	22.20	0.866	0.874
V	0.55	0.75	0.021	0.029
W	2.89 BSC		0.113 BSC	
X	0.85	0.75	0.033	0.029
Y	2.70	2.90	0.106	0.110

- NOTES:
1. DIMENSIONS A, AND C ARE DATUMS. AND -T- IS A DATUM PLANE.
 2. POSITIONAL TOLERANCE FOR LEAD DIMENSION D: $\pm 0.25 (0.010) \text{ (T) | A (A)}$
 3. POSITIONAL TOLERANCE FOR LEAD DIMENSION J: $\pm 0.25 (0.010) \text{ (T) | C (C)}$
 4. POSITIONAL TOLERANCE FOR LEAD DIMENSION Q: $\pm 0.25 (0.010) \text{ (T) | A (A)}$
 5. DIMENSIONING AND TOLERANCING PER ANSI Y14.5, 1982.
 6. CONTROLLING DIMENSION: MILLIMETER.

