

# MC34060A, MC33060A

## Fixed Frequency, PWM, Voltage Mode Single Ended Controllers

The MC34060A is a low cost fixed frequency, pulse width modulation control circuit designed primarily for single-ended SWITCHMODE™ power supply control.

The MC34060A is specified over the commercial operating temperature range of 0° to +70°C, and the MC33060A is specified over an automotive temperature range of -40° to +85°C.

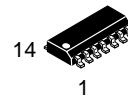
- Complete Pulse Width Modulation Control Circuitry
- On-Chip Oscillator with Master or Slave Operation
- On-Chip Error Amplifiers
- On-Chip 5.0 V Reference, 1.5% Accuracy
- Adjustable Dead-Time Control
- Uncommitted Output Transistor Rated to 200 mA Source or Sink
- Undervoltage Lockout



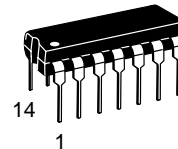
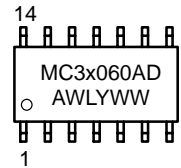
ON Semiconductor™

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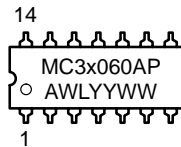
### MARKING DIAGRAMS



SO-14  
D SUFFIX  
CASE 751A

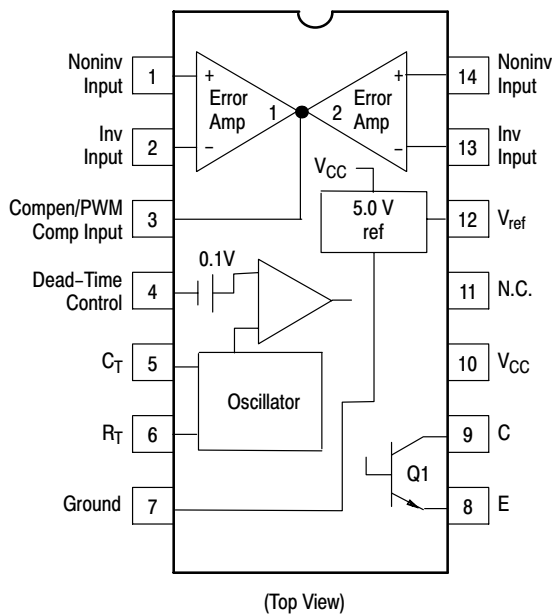


PDIP-14  
P SUFFIX  
CASE 646



x = 3 or 4  
A = Assembly Location  
WL = Wafer Lot  
YY, Y = Year  
WW = Work Week

### PIN CONNECTIONS



### ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 14 of this data sheet.

# MC34060A, MC33060A

**MAXIMUM RATINGS** (Full operating ambient temperature range applies, unless otherwise noted.)

Rating	Symbol	Value	Unit
Power Supply Voltage	$V_{CC}$	42	V
Collector Output Voltage	$V_C$	42	V
Collector Output Current (Note 1)	$I_C$	500	mA
Amplifier Input Voltage Range	$V_{in}$	-0.3 to +42	V
Power Dissipation @ $T_A \leq 45^\circ\text{C}$	$P_D$	1000	mW
Operating Junction Temperature	$T_J$	125	$^\circ\text{C}$
Storage Temperature Range	$T_{stg}$	-55 to +125	$^\circ\text{C}$
Operating Ambient Temperature Range For MC34060A For MC33060A	$T_A$	0 to +70 -40 to +85	$^\circ\text{C}$

## THERMAL CHARACTERISTICS

Characteristics	Symbol	P Suffix Package	D Suffix Package	Unit
Thermal Resistance, Junction-to-Ambient	$R_{\theta JA}$	80	120	$^\circ\text{C}/\text{W}$
Derating Ambient Temperature	$T_A$	45	45	$^\circ\text{C}$

## RECOMMENDED OPERATING CONDITIONS

Condition/Value	Symbol	Min	Typ	Max	Unit
Power Supply Voltage	$V_{CC}$	7.0	15	40	V
Collector Output Voltage	$V_C$	-	30	40	V
Collector Output Current	$I_C$	-	-	200	mA
Amplifier Input Voltage	$V_{in}$	-0.3	-	$V_{CC} - 2$	V
Current Into Feedback Terminal	$I_{fb}$	-	-	0.3	mA
Reference Output Current	$I_{ref}$	-	-	10	mA
Timing Resistor	$R_T$	1.8	47	500	$k\Omega$
Timing Capacitor	$C_T$	0.00047	0.001	10	$\mu\text{F}$
Oscillator Frequency	$f_{osc}$	1.0	25	200	kHz
PWM Input Voltage (Pins 3 and 4)	-	-0.3	-	5.3	V

1. Maximum thermal limits must be observed.

# MC34060A, MC33060A

**ELECTRICAL CHARACTERISTICS** ( $V_{CC} = 15\text{ V}$ ,  $C_T = 0.01\ \mu\text{F}$ ,  $R_T = 12\ \text{k}\Omega$ , unless otherwise noted. For typical values  $T_A = 25^\circ\text{C}$ , for min/max values  $T_A$  is the operating ambient temperature range that applies, unless otherwise noted.)

Characteristics	Symbol	Min	Typ	Max	Unit
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## REFERENCE SECTION

Reference Voltage ( $I_O = 1.0\ \text{mA}$ , $T_A = 25^\circ\text{C}$ ) $T_A = T_{\text{low}}$ to $T_{\text{high}}$ – MC34060A – MC33060A	$V_{\text{ref}}$	4.925 4.9 4.85	5.0 – –	5.075 5.1 5.1	V
Line Regulation ( $V_{CC} = 7.0\ \text{V}$ to $40\ \text{V}$ , $I_O = 10\ \text{mA}$ )	$\text{Reg}_{\text{line}}$	–	2.0	25	mV
Load Regulation ( $I_O = 1.0\ \text{mA}$ to $10\ \text{mA}$ )	$\text{Reg}_{\text{load}}$	–	2.0	15	mV
Short Circuit Output Current ( $V_{\text{ref}} = 0\ \text{V}$ )	$I_{\text{SC}}$	15	35	75	mA

## OUTPUT SECTION

Collector Off–State Current ( $V_{CC} = 40\ \text{V}$ , $V_{CE} = 40\ \text{V}$ )	$I_{C(\text{off})}$	–	2.0	100	$\mu\text{A}$
Emitter Off–State Current ( $V_{CC} = 40\ \text{V}$ , $V_{CE} = 40\ \text{V}$ , $V_E = 0\ \text{V}$ )	$I_{E(\text{off})}$	–	–	–100	$\mu\text{A}$
Collector–Emitter Saturation Voltage (Note 2) Common–Emitter ( $V_E = 0\ \text{V}$ , $I_C = 200\ \text{mA}$ ) Emitter–Follower ( $V_C = 15\ \text{V}$ , $I_E = -200\ \text{mA}$ )	$V_{\text{sat}(C)}$  $V_{\text{sat}(E)}$	–  –	1.1  1.5	1.5  2.5	V
Output Voltage Rise Time ( $T_A = 25^\circ\text{C}$ ) Common–Emitter (See Figure 12) Emitter–Follower (See Figure 13)	$t_r$	– –	100 100	200 200	ns
Output Voltage Fall Time ( $T_A = 25^\circ\text{C}$ ) Common–Emitter (See Figure 12) Emitter–Follower (See Figure 13)	$t_r$	– –	40 40	100 100	ns

## ERROR AMPLIFIER SECTION

Input Offset Voltage ( $V_{O[\text{Pin } 3]} = 2.5\ \text{V}$ )	$V_{\text{IO}}$	–	2.0	10	mV
Input Offset Current ( $V_{C[\text{Pin } 3]} = 2.5\ \text{V}$ )	$I_{\text{IO}}$	–	5.0	250	nA
Input Bias Current ( $V_{O[\text{Pin } 3]} = 2.5\ \text{V}$ )	$I_{\text{IB}}$	–	–0.1	–2.0	$\mu\text{A}$
Input Common Mode Voltage Range ( $V_{CC} = 40\ \text{V}$ )	$V_{\text{ICR}}$	0 to $V_{CC} - 2.0$	–	–	V
Inverting Input Voltage Range	$V_{\text{IR(INV)}}$	–0.3 to $V_{CC} - 2.0$	–	–	V
Open–Loop Voltage Gain ( $\Delta V_O = 3.0\ \text{V}$ , $V_O = 0.5\ \text{V}$ to $3.5\ \text{V}$ , $R_L = 2.0\ \text{k}\Omega$ )	$A_{\text{VOL}}$	70	95	–	dB
Unity–Gain Crossover Frequency ( $V_O = 0.5\ \text{V}$ to $3.5\ \text{V}$ , $R_L = 2.0\ \text{k}\Omega$ )	$f_c$	–	600	–	kHz
Phase Margin at Unity–Gain ( $V_O = 0.5\ \text{V}$ to $3.5\ \text{V}$ , $R_L = 2.0\ \text{k}\Omega$ )	$\phi_m$	–	65	–	deg.
Common Mode Rejection Ratio ( $V_{CC} = 40\ \text{V}$ , $V_{\text{in}} = 0\ \text{V}$ to $38\ \text{V}$ )	CMRR	65	90	–	dB
Power Supply Rejection Ratio ( $\Delta V_{CC} = 33\ \text{V}$ , $V_O = 2.5\ \text{V}$ , $R_L = 2.0\ \text{k}\Omega$ )	PSRR	–	100	–	dB
Output Sink Current ( $V_{O[\text{Pin } 3]} = 0.7\ \text{V}$ )	$I_{O-}$	0.3	0.7	–	mA
Output Source Current ( $V_{O[\text{Pin } 3]} = 3.5\ \text{V}$ )	$I_{O+}$	–2.0	–4.0	–	mA

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

$T_{\text{low}} = -40^\circ\text{C}$  for MC33060A  
=  $0^\circ\text{C}$  for MC34060A

$T_{\text{high}} = +85^\circ\text{C}$  for MC33060A  
=  $+70^\circ\text{C}$  for MC34060A

# MC34060A, MC33060A

**ELECTRICAL CHARACTERISTICS (continued)** ( $V_{CC} = 15\text{ V}$ ,  $C_T = 0.01\ \mu\text{F}$ ,  $R_T = 12\ \text{k}\Omega$ , unless otherwise noted.)

For typical values  $T_A = 25^\circ\text{C}$ , for min/max values  $T_A$  is the operating ambient temperature range that applies, unless otherwise noted.)

Characteristics	Symbol	Min	Typ	Max	Unit
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## PWM COMPARATOR SECTION (Test circuit Figure 11)

Input Threshold Voltage (Zero Duty Cycle)	$V_{TH}$	–	3.5	4.5	V
Input Sink Current ( $V_{[Pin\ 3]} = 0.7\ \text{V}$ )	$I_I$	0.3	0.7	–	mA

## DEAD-TIME CONTROL SECTION (Test circuit Figure 11)

Input Bias Current (Pin 4) ( $V_{in} = 0\ \text{V}$ to $5.25\ \text{V}$ )	$I_{B(DT)}$	–	–1.0	–10	$\mu\text{A}$
Maximum Output Duty Cycle ( $V_{in} = 0\ \text{V}$ , $C_T = 0.01\ \mu\text{F}$ , $R_T = 12\ \text{k}\Omega$ ) ( $V_{in} = 0\ \text{V}$ , $C_T = 0.001\ \mu\text{F}$ , $R_T = 47\ \text{k}\Omega$ )	$DC_{max}$	90 –	96 92	100 –	%
Input Threshold Voltage (Pin 4) (Zero Duty Cycle) (Maximum Duty Cycle)	$V_{TH}$	– 0	2.8 –	3.3 –	V

## OSCILLATOR SECTION

Frequency ( $C_T = 0.01\ \mu\text{F}$ , $R_T = 12\ \text{k}\Omega$ , $T_A = 25^\circ\text{C}$ ) $T_A = T_{low}$ to $T_{high}$ – MC34060A – MC33060A ( $C_T = 0.001\ \mu\text{F}$ , $R_T = 47\ \text{k}\Omega$ )	$f_{osc}$	9.7 9.5 9.0 –	10.5 – – 25	11.3 11.5 11.5 –	kHz
Standard Deviation of Frequency* ( $C_T = 0.001\ \mu\text{F}$ , $R_T = 47\ \text{k}\Omega$ )	$\sigma_{f_{osc}}$	–	1.5	–	%
Frequency Change with Voltage ( $V_{CC} = 7.0\ \text{V}$ to $40\ \text{V}$ )	$\Delta f_{osc}(\Delta V)$	–	0.5	2.0	%
Frequency Change with Temperature ( $\Delta T_A = T_{low}$ to $T_{high}$ ) ( $C_T = 0.01\ \mu\text{F}$ , $R_T = 12\ \text{k}\Omega$ )	$\Delta f_{osc}(\Delta T)$	– –	4.0 –	– –	%

## UNDERVOLTAGE LOCKOUT SECTION

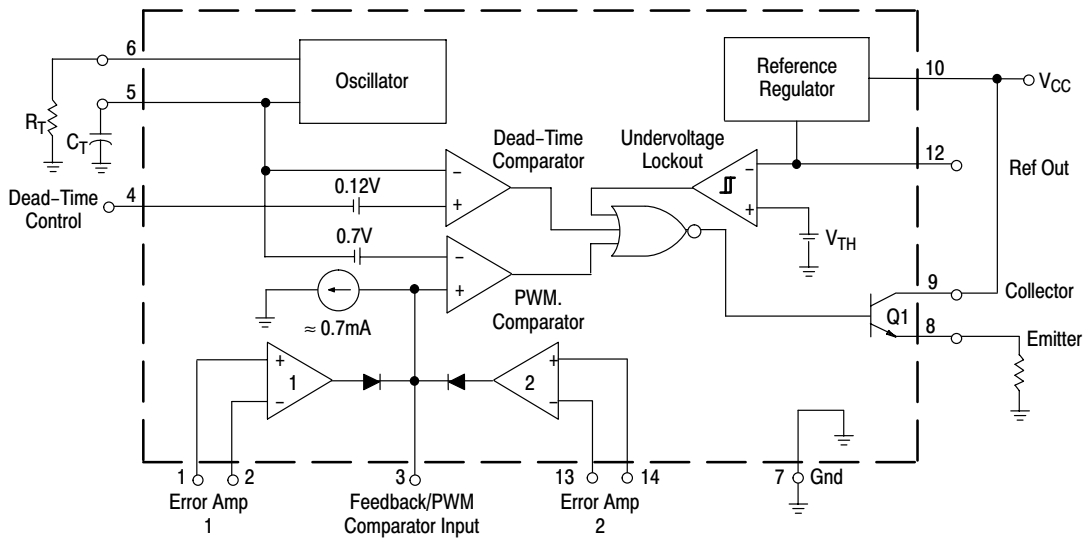
Turn-On Threshold ( $V_{CC}$ increasing, $I_{ref} = 1.0\ \text{mA}$ )	$V_{th}$	4.0	4.7	5.5	V
Hysteresis	$V_H$	50	150	300	mV

## TOTAL DEVICE

Standby Supply Current (Pin 6 at $V_{ref}$ , all other inputs and outputs open) ( $V_{CC} = 15\ \text{V}$ ) ( $V_{CC} = 40\ \text{V}$ )	$I_{CC}$	– –	5.5 7.0	10 15	mA
Average Supply Current ( $V_{[Pin\ 4]} = 2.0\ \text{V}$ , $C_T = 0.001\ \mu\text{F}$ , $R_T = 47\ \text{k}\Omega$ ). See Figure 11.	$I_S$	–	7.0	–	mA

\*Standard deviation is a measure of the statistical distribution about the mean as derived from the formula;  $\sigma = \sqrt{\frac{\sum_{n=1}^N (x_n - \bar{x})^2}{n - 1}}$

# MC34060A, MC33060A



This device contains 46 active transistors.

**Figure 1. Block Diagram**

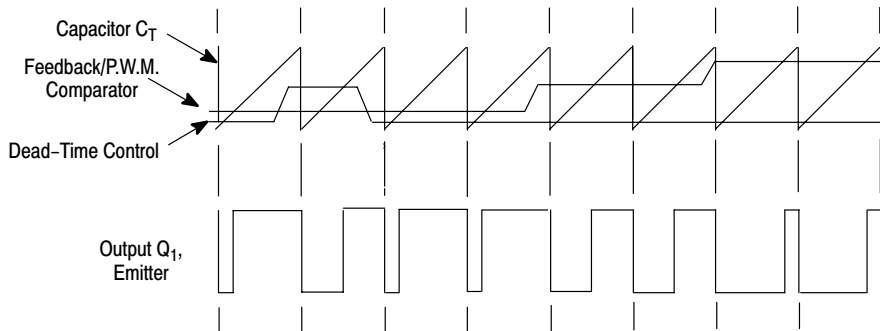
## Description

The MC34060A is a fixed-frequency pulse width modulation control circuit, incorporating the primary building blocks required for the control of a switching power supply (see Figure 1). An internal-linear sawtooth oscillator is frequency-programmable by two external components,  $R_T$  and  $C_T$ . The approximate oscillator frequency is determined by:

$$f_{osc} \cong \frac{1.2}{R_T \cdot C_T}$$

For more information refer to Figure 3.

Output pulse width modulation is accomplished by comparison of the positive sawtooth waveform across capacitor  $C_T$  to either of two control signals. The output is enabled only during that portion of time when the sawtooth voltage is greater than the control signals. Therefore, an increase in control-signal amplitude causes a corresponding linear decrease of output pulse width. (Refer to the Timing Diagram shown in Figure 2.)



**Figure 2. Timing Diagram**

## MC34060A, MC33060A

### APPLICATIONS INFORMATION

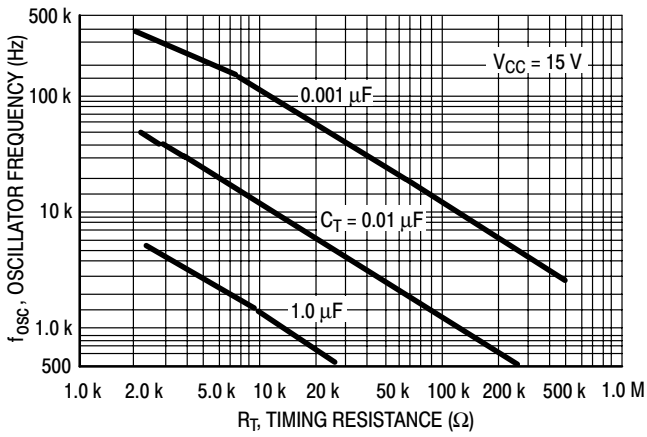
The control signals are external inputs that can be fed into the dead-time control, the error amplifier inputs, or the feed-back input. The dead-time control comparator has an effective 120 mV input offset which limits the minimum output dead time to approximately the first 4% of the sawtooth-cycle time. This would result in a maximum duty cycle of 96%. Additional dead time may be imposed on the output by setting the dead time-control input to a fixed voltage, ranging between 0 V to 3.3 V.

The pulse width modulator comparator provides a means for the error amplifiers to adjust the output pulse width from the maximum percent on-time, established by the dead time control input, down to zero, as the voltage at the feedback

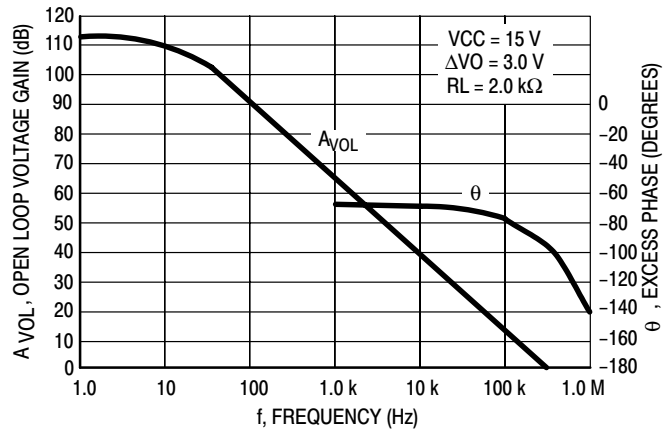
pin varies from 0.5 V to 3.5 V. Both error amplifiers have a common mode input range from  $-0.3\text{ V}$  to  $(V_{CC} - 2.0\text{ V})$ , and may be used to sense power supply output voltage and current. The error-amplifier outputs are active high and are ORed together at the noninverting input of the pulse-width modulator comparator. With this configuration, the amplifier that demands minimum output on time, dominates control of the loop.

The MC34060A has an internal 5.0 V reference capable of sourcing up to 10 mA of load currents for external bias circuits. The reference has an internal accuracy of  $\pm 5\%$  with a typical thermal drift of less than 50 mV over an operating temperature range of  $0^\circ$  to  $+70^\circ\text{C}$ .

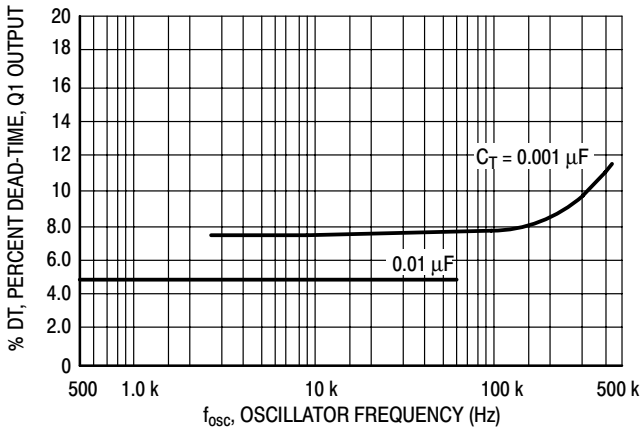
# MC34060A, MC33060A



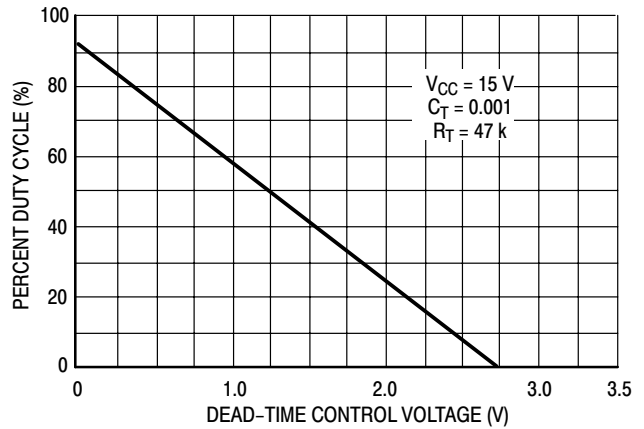
**Figure 3. Oscillator Frequency versus Timing Resistance**



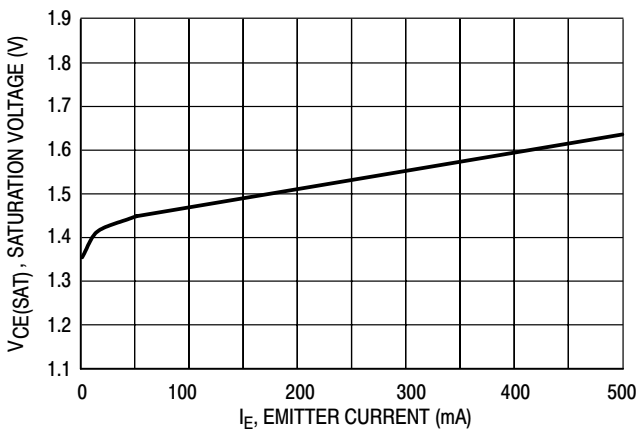
**Figure 4. Open Loop Voltage Gain and Phase versus Frequency**



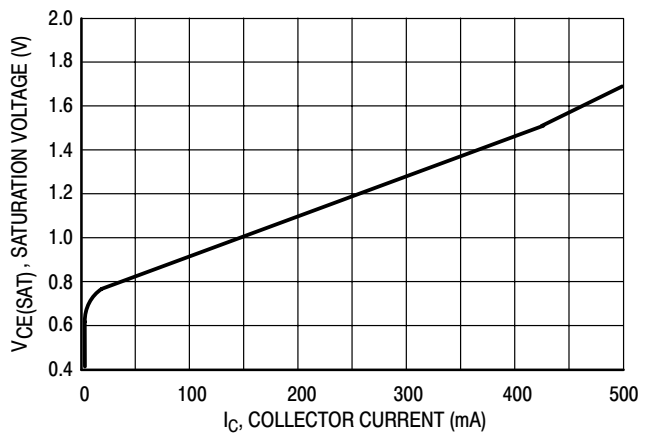
**Figure 5. Percent Deadtime versus Oscillator Frequency**



**Figure 6. Percent Duty Cycle versus Dead-Time Control Voltage**

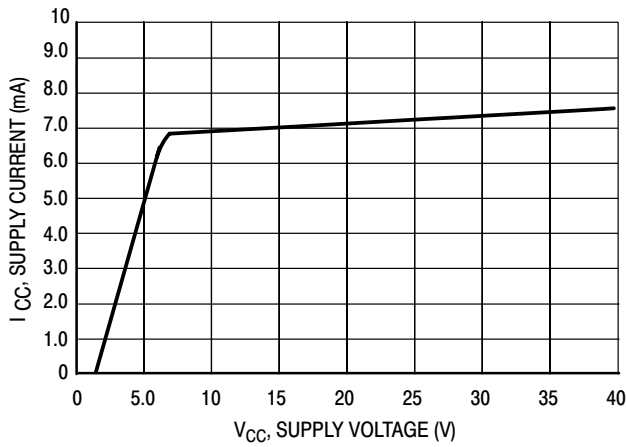


**Figure 7. Emitter-Follower Configuration Output Saturation Voltage versus Emitter Current**

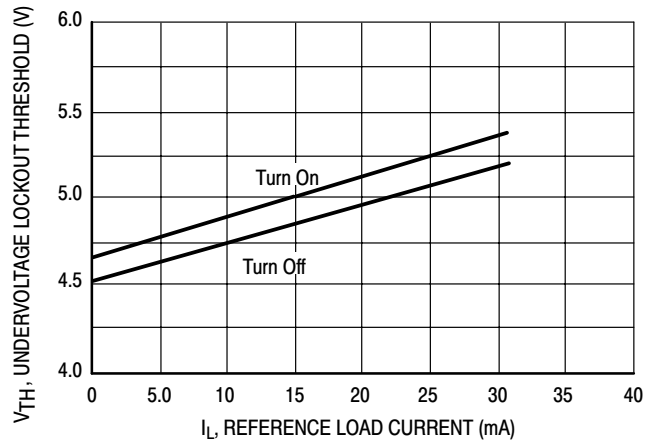


**Figure 8. Common-Emitter Configuration Output Saturation Voltage versus Collector Current**

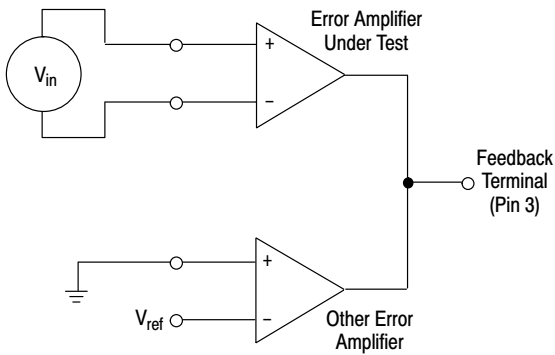
# MC34060A, MC33060A



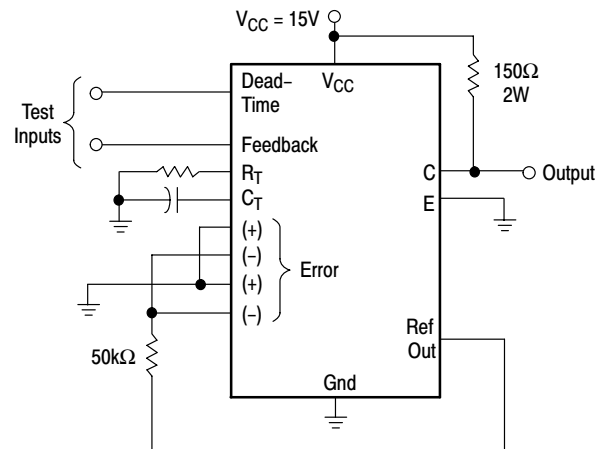
**Figure 9. Standby Supply Current versus Supply Voltage**



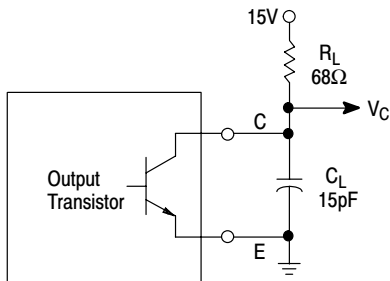
**Figure 10. Undervoltage Lockout Thresholds versus Reference Load Current**



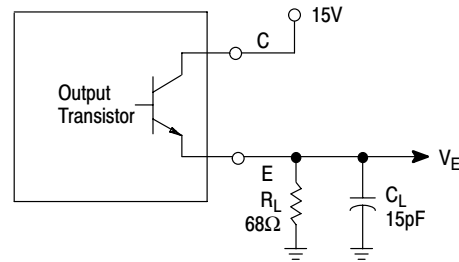
**Figure 11. Error Amplifier Characteristics**



**Figure 12. Deadtime and Feedback Control**



**Figure 13. Common-Emitter Configuration and Waveform**



**Figure 14. Emitter-Follower Configuration and Waveform**



# MC34060A, MC33060A

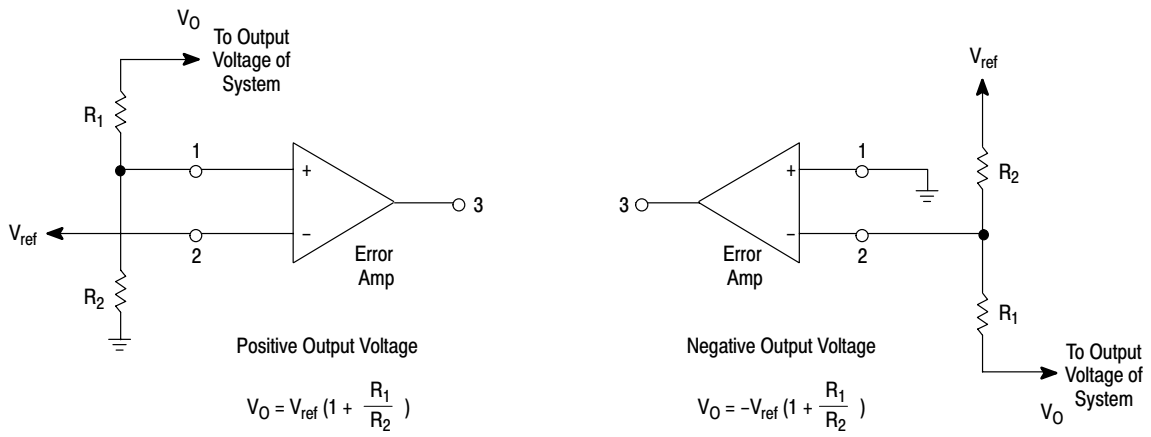


Figure 15. Error Amplifier Sensing Techniques

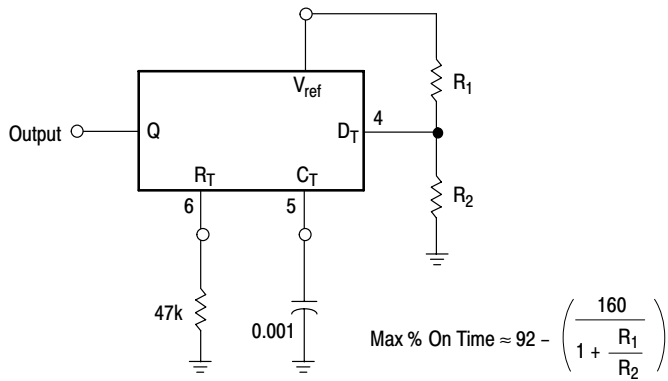


Figure 16. Deadtime Control Circuit

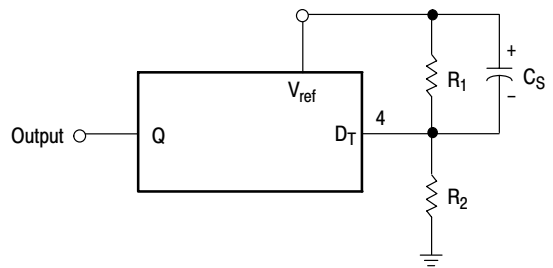


Figure 17. Soft-Start Circuit

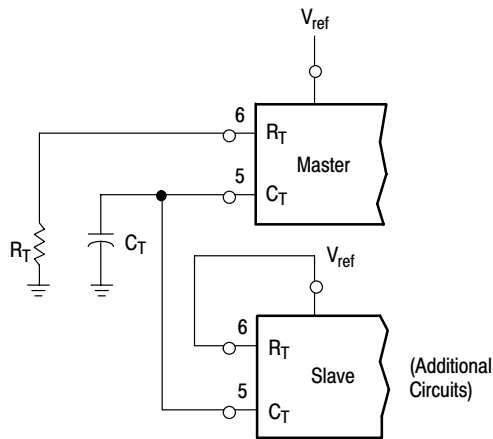
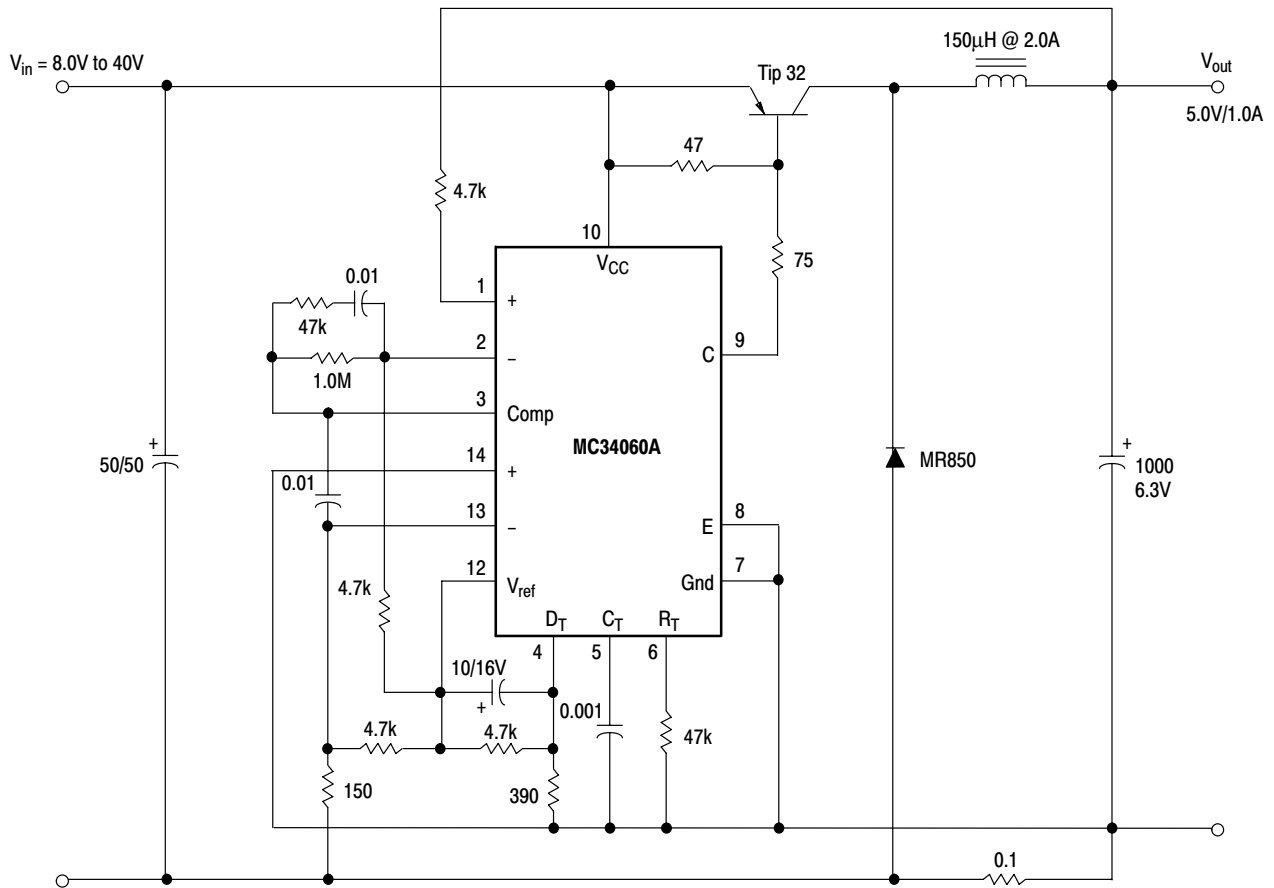


Figure 18. Slaving Two or More Control Circuits

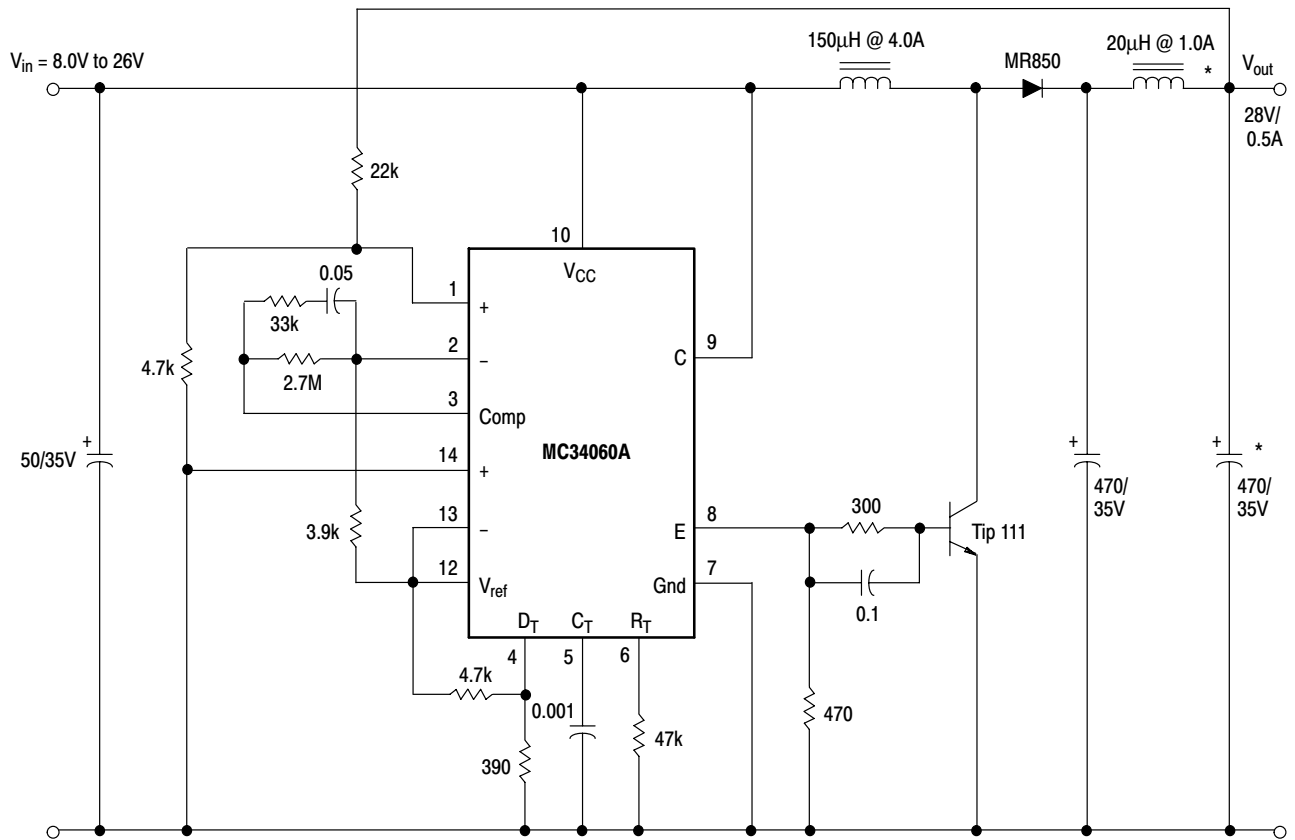
## MC34060A, MC33060A



Test	Conditions	Results
Line Regulation	$V_{in} = 8.0 \text{ V to } 40 \text{ V}, I_O = 1.0 \text{ A}$	25 mV    0.5%
Load Regulation	$V_{in} = 12 \text{ V}, I_O = 1.0 \text{ mA to } 1.0 \text{ A}$	3.0 mV    0.06%
Output Ripple	$V_{in} = 12 \text{ V}, I_O = 1.0 \text{ A}$	75 mV p-p P.A.R.D.
Short Circuit Current	$V_{in} = 12 \text{ V}, R_L = 0.1 \Omega$	1.6 A
Efficiency	$V_{in} = 12 \text{ V}, I_O = 1.0 \text{ A}$	73%

**Figure 19. Step-Down Converter with Soft-Start and Output Current Limiting**

# MC34060A, MC33060A

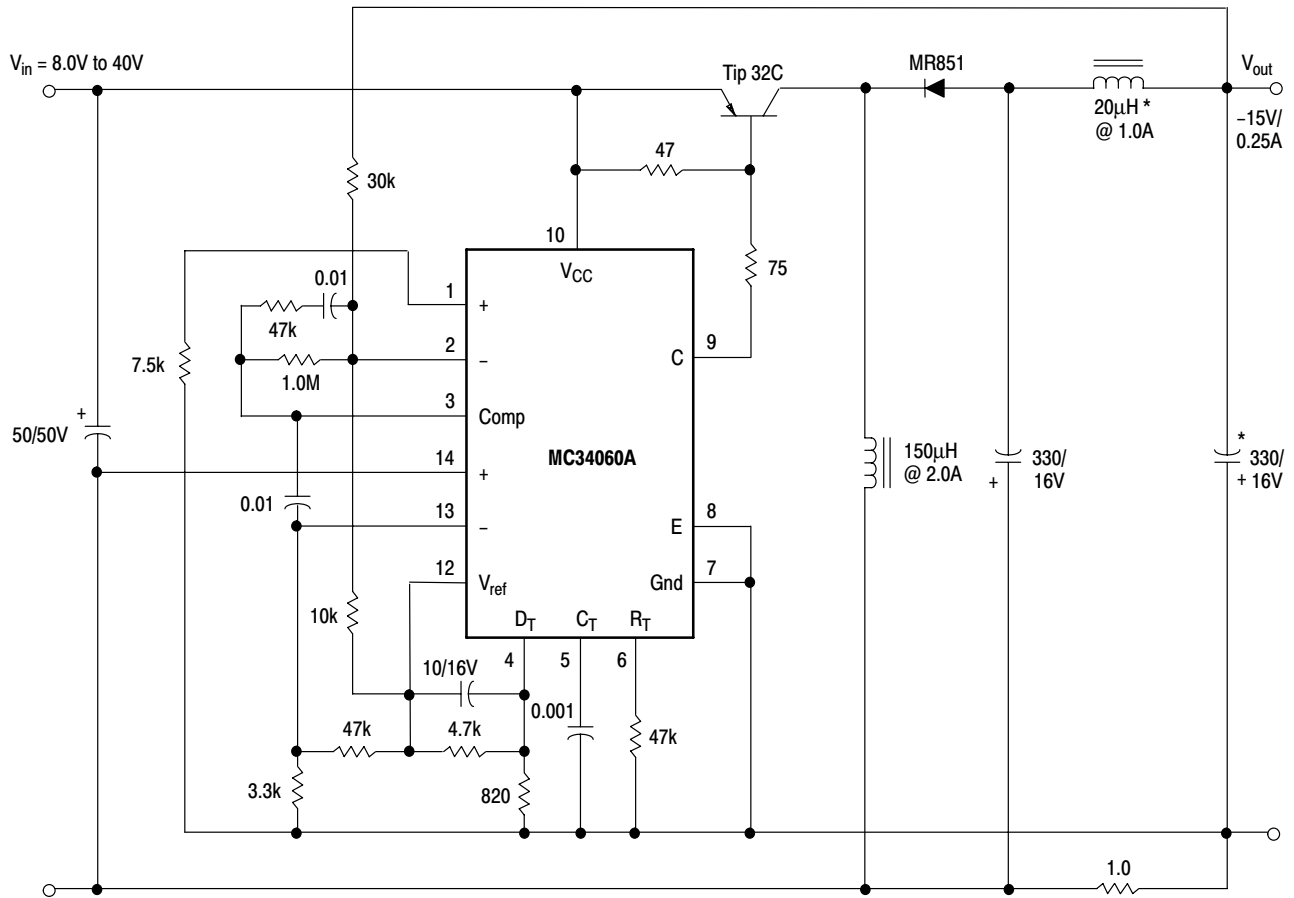


Test	Conditions	Results
Line Regulation	$V_{in} = 8.0 \text{ V to } 26 \text{ V}, I_O = 0.5 \text{ A}$	40 mV 0.14%
Load Regulation	$V_{in} = 12 \text{ V}, I_O = 1.0 \text{ mA to } 0.5 \text{ A}$	5.0 mV 0.18%
Output Ripple	$V_{in} = 12 \text{ V}, I_O = 0.5 \text{ A}$	24 mV p-p P.A.R.D.
Efficiency	$V_{in} = 12 \text{ V}, I_O = 0.5 \text{ A}$	75%

\*Optional circuit to minimize output ripple

Figure 20. Step-Up Converter

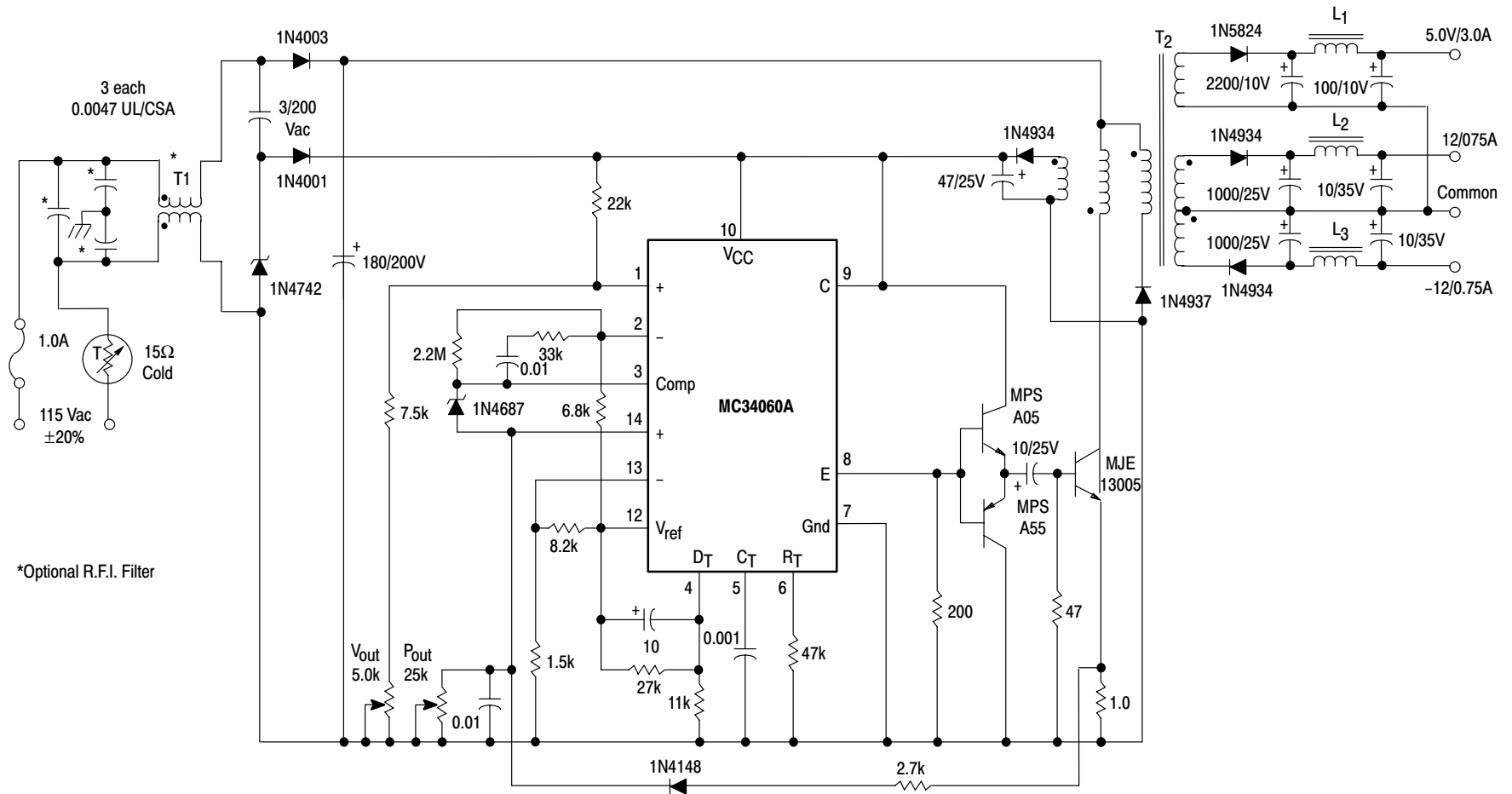
# MC34060A, MC33060A



Test	Conditions	Results
Line Regulation	$V_{in} = 8.0 \text{ V to } 40 \text{ V}, I_O = 250 \text{ mA}$	52 mV 0.35%
Load Regulation	$V_{in} = 12 \text{ V}, I_O = 1.0 \text{ to } 250 \text{ mA}$	47 mV 0.32%
Output Ripple	$V_{in} = 12 \text{ V}, I_O = 250 \text{ mA}$	10 mV p-p P.A.R.D.
Short Circuit Current	$V_{in} = 12 \text{ V}, R_L = 0.1 \Omega$	330 mA
Efficiency	$V_{in} = 12 \text{ V}, I_O = 250 \text{ mA}$	86%

\*Optional circuit to minimize output ripple

**Figure 21. Step-Up/Down Voltage Inverting Converter with Soft-Start and Current Limiting**



\*Optional R.F.I. Filter

Test	Conditions	Results
Line Regulation 5.0 V	$V_{in} = 95 \text{ Vac to } 135 \text{ Vac}, I_O = 3.0 \text{ A}$	20 mV 0.40%
Line Regulation ±12 V	$V_{in} = 95 \text{ Vac to } 135 \text{ Vac}, I_O = \pm 0.75 \text{ A}$	52 mV 0.26%
Load Regulation 5.0 V	$V_{in} = 115 \text{ Vac}, I_O = 1.0 \text{ A to } 4.0 \text{ A}$	476 mV 9.5%
Load Regulation ±12 V	$V_{in} = 115 \text{ Vac}, I_O = \pm 0.4 \text{ A to } \pm 0.9 \text{ A}$	300 mV 2.5%
Output Ripple 5.0 V	$V_{in} = 115 \text{ Vac}, I_O = 3.0 \text{ A}$	45 mV p-p P.A.R.D.
Output Ripple ±12 V	$V_{in} = 115 \text{ Vac}, I_O = \pm 0.75 \text{ A}$	75 mV p-p P.A.R.D.
Efficiency	$V_{in} = 115 \text{ Vac}, I_O 5.0 \text{ V} = 3.0 \text{ A}$ $I_O \pm 12 \text{ V} = \pm 0.75 \text{ A}$	74%

T1 – Coilcraft W2961  
T2 – Core: Coilcraft 11–464–16,  
0.025" gap in each leg.  
Bobbin: Coilcraft 37–573  
Windings:  
Primary, 2 each, 75 turns #25 Awg Bifilar wound  
Feedback: 15 turns #26 Awg  
Secondary, 5.0 V, 6 turns @33 Awg Bifilar wound  
Secondary, 2 each, 14 turns #24 Awg Bifilar wound  
L1 – Coilcraft Z7156, 15 μH @ 5.0 A  
L2, L3 – Coilcraft Z7157, 25 μH @ 1.0 A

Figure 22. 33 W Off-Line Flyback Converter with Soft-Start and Primary Power Limiting

# MC34060A, MC33060A

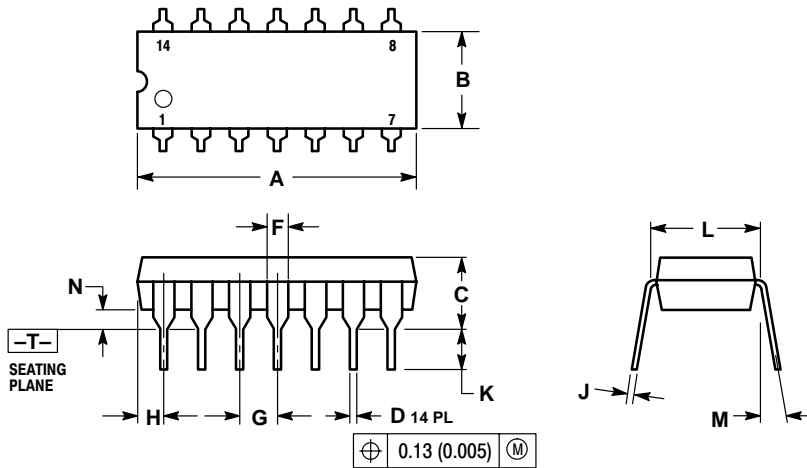
## ORDERING INFORMATION

Device	Operating Temperature Range	Package	Shipping
MC34060AD	$T_A = 0^\circ \text{ to } +70^\circ\text{C}$	SO-14	55 Units/Rail
MC34060ADR2		SO-14	2500 Tape & Reel
MC34060AP		PDIP-14	25 Units/Rail
MC33060AD	$T_A = -40^\circ \text{ to } +85^\circ\text{C}$	SO-14	55 Units/Rail
MC33060ADR2		SO-14	2500 Tape & Reel
MC33060AP		PDIP-14	25 Units/Rail

# MC34060A, MC33060A

## PACKAGE DIMENSIONS

PDIP-14  
P SUFFIX  
CASE 646-06  
ISSUE M

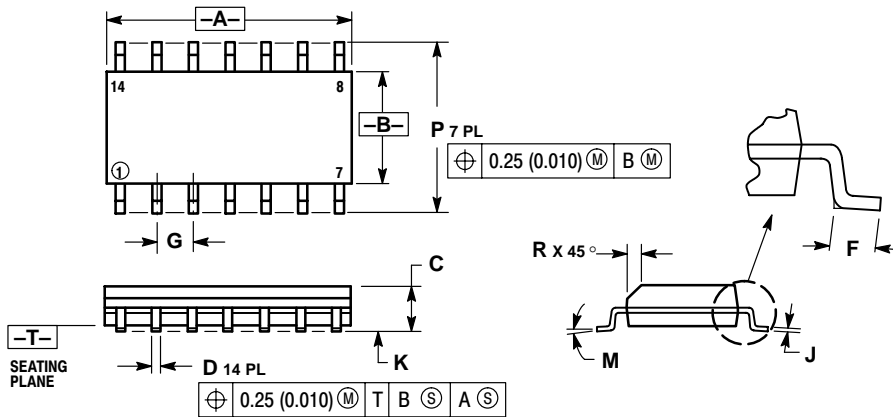


NOTES:

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

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.715	0.770	18.16	18.80
B	0.240	0.260	6.10	6.60
C	0.145	0.185	3.69	4.69
D	0.015	0.021	0.38	0.53
F	0.040	0.070	1.02	1.78
G	0.100 BSC		2.54 BSC	
H	0.052	0.095	1.32	2.41
J	0.008	0.015	0.20	0.38
K	0.115	0.135	2.92	3.43
L	0.290	0.310	7.37	7.87
M	---	10°	---	10°
N	0.015	0.039	0.38	1.01

SO-14  
D SUFFIX  
CASE 751A-03  
ISSUE F




NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSIONS A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
5. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.

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	0.19	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	0.228	0.244
R	0.25	0.50	0.010	0.019

# MC34060A, MC33060A

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