MOTOROLA

TCA5600
TCF5600

Universal Microprocessor Power Supply/Controllers

UNIVERSAL MICROPROCESSOR POWER SUPPLY/CONTROLLERS

SEMICONDUCTOR TECHNICAL DATA

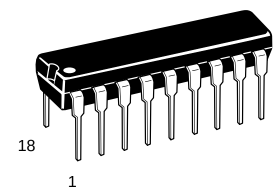
The TCA5600, TCF5600 are versatile power supply control circuits for microprocessor based systems and are mainly intended for automotive applications and battery powered instruments. To cover a wide range of applications, the devices offer high circuit flexibility with a minimum of external components.

Functions included in this IC are a temperature compensated voltage reference, on–chip dc/dc converter, programmable and remote controlled voltage regulator, fixed 5.0 V supply voltage regulator with external PNP power device, undervoltage detection circuit, power–on RESET delay and watchdog feature for safe and hazard free microprocessor operations.

- 6.0 V to 30 V Operation Range
- 2.5 V Reference Voltage Accessible for Other Tasks
- Fixed 5.0 V ± 4% Microprocessor Supply Regulator Including Current Limitation, Overvoltage Protection and Undervoltage Monitor.
- Programmable 6.0 V to 30 V Voltage Regulator Exhibiting High Peak Current (150mA), Current Limiting and Thermal Protection.
- Two Remote Inputs to Select the Regulator's Operation Mode:
  OFF = 5.0 V, 5.0 V Standby
  Programmable Output Voltage
- Self–Contained dc/dc Converter Fully Controlled by the Programmable Regulator to Guarantee Safe Operation Under All Working Conditions
- Programmable Power–On RESET Delay
- Watchdog Select Input
- Negative Edge Triggered Watchdog Input
- Low Current Consumption in the V_{CC1} Standby Mode
- All Digital Control Ports are TTL and MOS–Compatible

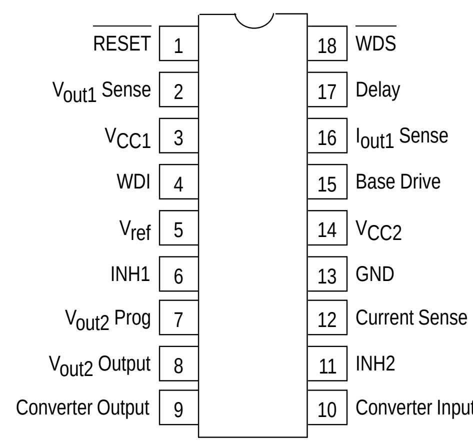
Applications Include:

- Microprocessor Systems with E^2PROMs
- High Voltage Crystal and Plasma Displays
- Decentralized Power Supplies in Computer Telecom Systems



PLASTIC PACKAGE
CASE 707

PIN CONNECTIONS



(Top View)

RECOMMENDED OPERATING CONDITIONS

Characteristics	Symbol	Min	Max	Unit
Power Supply Voltage	V_{CC1} V_{CC2}	5.0 5.5	30 30	V
Collector Current	I_C	—	800	mA
Output Voltage	V_{out2}	6.0	30	V
Reference Source Current	I_{ref}	0	2.0	mA

ORDERING INFORMATION

Device	Operating Temperature Range	Package
TCA5600	T_J = 0° to +125°C	Plastic DIP
TCF5600	T_J = – 40° to +150°C	Plastic DIP

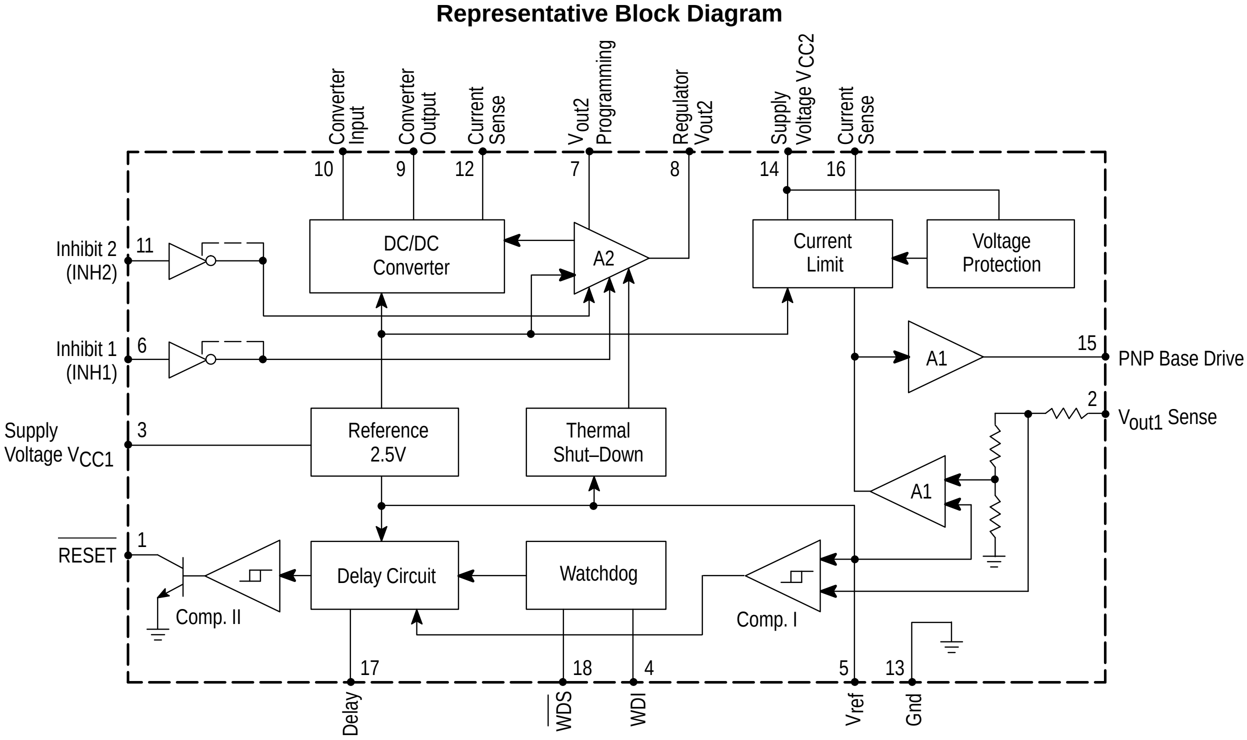
 Rev 0

MAXIMUM RATINGS (T_A = +25°C [Note 1], unless otherwise noted.)

Rating	Symbol	Value	Unit
Power Supply Voltage (Pin 3,14)	V_{CC1}, V_{CC2}	35	Vdc
Base Drive Current (Pin 15)	I_B	20	mA
Collector Current (Pin 10)	I_C	1.0	A
Forward Rectifier Current (Pin 10 to Pin 9)	I_F	1.0	A
Logic Inputs INH1, INH2, $\overline{\text{WDS}}$ (Pin 6, 11, 18)	V_{INP}	–0.3 V to V_{CC1}	Vdc
Logic Input Current WDI (Pin 4)	I_{WDI}	±0.5	mA
Output Sink Current $\overline{\text{RESET}}$ (Pin 1)	$I_{\overline{RES}}$	10	mA
Analog Inputs (Pin 2) (Pin 7)		–0.3 to 10 –0.3 to 5.0	V
Reference Source Current (Pin 5)	I_{ref}	5.0	mA
Power Dissipation (Note 2) T_A = +75°C TCA5600 T_A = +85°C TCF5600	P_D	 500 650	mW
Thermal Resistance, Junction–to–Air	$R_{\theta JA}$	100	°C/W
Operating Ambient Temperature Range TCA5600 TCF5600	T_A	 0 to +75 –40 to +85	°C
Operating Junction Temperature Range TCA5600 TCF5600	T_J	 +125 +150	°C
Storage Temperature Range	T_{stg}	–65 to +150	°C

NOTES: 1. Values beyond which damage may occur.
2. Derate at 10 mW/°C for junction temperature above +75°C (TCA5600).
Derate at 10 mW/°C for junction temperature above +85°C (TCF5600).

Representative Block Diagram



ELECTRICAL CHARACTERISTICS (V_{CC1} = V_{CC2} = 12 V; T_J = 25°C; I_{ref} = 0; I_{out1} = 0 [Note 3]; R_{SC} = 0.5 Ω; INH = High INH2 = High; WDS = High; I_{out2} = 0 [Note 4]; unless otherwise noted.)

Characteristics	Figure	Symbol	Min	Typ	Max	Unit
REFERENCE SECTION						
Nominal Reference Voltage	1	$V_{ref\ nom}$	2.42	2.5	2.58	V
Reference Voltage I_{ref} = 0.5 mA, $T_{low} \le T_J \le T_{high}$ (Note 5), 6.0 V ≤ V_{CC1} ≤ 18 V		V_{ref}	2.4	—	2.6	V
Line Regulation (6.0 V ≤ V_{CC2} ≤ 18 V)		Reg_{line}	—	2.0	15	mV
Average Temperature Coefficient $T_{low} \le T_J \le T_{high}$ (Note 5)	2	$\frac{\Delta V_{ref}}{\Delta T_J}$	—	—	±0.5	mV/°C
Ripple Rejection Ratio f = 1.0 kHz, V_{sin} = 1.0 V_{pp}	3	RR	60	70	—	dB
Output Impedance 0 ≤ I_{ref} ≤ 2.0 mA		Z_O	—	1.0	—	Ω
Standby Current Consumption V_{CC2} = Open	4	I_{CC1}	—	3.0	—	mA
5.0 V MICROPROCESSOR VOLTAGE REGULATOR SECTION						
Nominal Output Voltage		$V_{out1(nom)}$	4.8	5.0	5.2	V
Output Voltage 5.0 mA ≤ I_{out1} ≤ 300 mA, $T_{low} \le T_J \le T_{high}$ (Note 5) 6.0 V ≤ V_{CC2} ≤ 18 V	 5 6	V_{out1}	4.75	—	5.25	V
Line Regulation (6.0 V ≤ V_{CC2} ≤ 18 V)		Reg_{line}	—	10	50	mV
Load Regulation (5.0 mA ≤ I_{out1} ≤ 300 mA)		Reg_{load}	—	20	100	mV
Base Current Drive (V_{CC2} = 6.0 V, V_{15} = 4.0 V)		I_B	10	15	—	mA
Ripple Rejection Ratio f = 1.0 kHz, V_{sin} = 1.0 V_{pp}	3	RR	50	65	—	dB
Undervoltage Detection Level (R_{SC} = 5.0 Ω)	7	V_{low}	4.5	0.93 × V_{out1}	—	V
Current Limitation Threshold (R_{SC} = 5.0 Ω)		V_{RSC}	210	250	290	mV
Average Temperature Coefficient $T_{low} \le T_J \le T_{high}$ (Note 5)		$\frac{\Delta V_{out1}}{\Delta T_J}$	—	—	±1.0	mV/°C
DC/DC CONVERTER SECTION						
Collector Current Detection Level High RC = 10 k Low	9	$V_{12}(H)$ $V_{12}(L)$	350 —	400 50	450 —	mV
Collector Saturation Voltage I_C = 600 mA (Note 6)	10	$V_{CE(sat)}$	—	—	1.6	V
Rectifier Forward Voltage Drop I_F = 600 mA (Note 6)	11	V_F	—	—	1.4	V

NOTES: 3. The external PNP power transistor satisfies the following minimum specifications:
h_{FE} ≥ 60 at I_C = 500 mA and V_{CE} = 5.0 V;
$V_{CE(sat)}$ ≤ 300 mV at I_B = 10 mA and I_C = 300 mA
4. Regulator V_{out2} programmed for nominal 24 V output by means of R4, R5 (see Figure 1).
5. T_{low} = 0°C for TCA5600 T_{low} = –40°C for TCF5600
T_{high} = +125°C for TCA5600 T_{high} = +150°C for TCF5600
6. Pulse tested t_p ≤ 300 µs.

ELECTRICAL CHARACTERISTICS (V_{CC1} = V_{CC2} = 12 V; T_J = 25°C; I_{ref} = 0; I_{out1} = 0 [Note 3]; R_{SC} = 0.5 Ω; INH = High INH2 = High; WDS = High; I_{out2} = 0 [Note 4]; unless otherwise noted.)

Characteristics	Symbol	Min	Typ	Max	Unit
PROGRAMMABLE VOLTAGE REGULATOR SECTION (Note 6)					
Nominal Output Voltage	$V_{out2(nom)}$	23	24	25	V
Output Voltage (Figure 8) 1.0 mA ≤ I_{out2} ≤ 100 mA, T_{low} ≤ T_J ≤ T_{high} (Notes 5, 7)	V_{out2}	22.8	—	25.2	V
Load Regulation 1.0 mA ≤ I_{out2} ≤ 100 mA (Note 7)	Reg_{load}	—	40	200	mV
DC Output Current	I_{out2}	100	—	—	mA
Peak Output Current (Internally Limited)	$I_{out2\ p}$	150	200	—	mA
Ripple Rejection Ratio f = 20 kHz, V = 0.4 V_{pp}	RR	45	55	—	dB
Output Voltage (Fixed 5.0 V) 1.0 mA ≤ I_{out2} ≤ 20 mA, T_{low} ≤ T_J ≤ T_{high} INH1 = HIGH (Note 5)	$V_{out2(5.0\ V)}$	4.75	—	5.25	V
Off State Output Impedance (INH2 = Low)	R_{out1}	—	10	—	kΩ
Average Temperature Coefficient T_{low} ≤ T_J ≤ T_{high} (Note 5)	$\frac{\Delta V_{out2}}{\Delta T_J V_{out2}}$	—	—	±0.25	mV/°C V
WATCHDOG AND $\overline{\text{RESET}}$ CIRCUIT SECTION					
Threshold Voltage High (Static) Low	$V_{C5(H)}$ $V_{C5(L)}$	— —	2.5 1.0	— —	V
Current Source T_{low} ≤ T_J ≤ T_{high} (Note 5) Power–Up RESET Watchdog Time Out Watchdog RESET	I_{C5}	 –1.8 — —	 –2.5 5×I_{C5} –50×I_{C5}	 –3.2 — —	µA
Watchdog Input Voltage Swing	V_{WDI}	—	—	±5.5	V
Watchdog Input Impedance	r_i	12	15	—	kΩ
Watchdog Reset Pulse Width (C8 = 1.0 nF) (Note 9)	t_p	—	—	10	µs
DIGITAL PORTS: $\overline{\text{WDS}}$, INH 1, INH 2, $\overline{\text{RESET}}$ (Note 8)					
Input Voltage Range	V_{INP}	—	—	–0.3 to V_{CC1}	V
Input High Current 2.0 V ≤ V_{IH} ≤ 5.5 V 5.5 V ≤ V_{IH} ≤ V_{CC1}	I_{IH}	 — —	 — —	 100 150	µA
Input Low Current –0.3 V ≤ V_{IL} ≤ 0.8 V for INH1, INH2, –0.3 V ≤ V_{IL} ≤ 0.4 V for $\overline{\text{WDS}}$	I_{IL}	—	—	–100	µA
Leakage Current Immunity (INH2, High “Z” State) (Figure 12)	I_Z	±20	—	—	µA
Output Low Voltage $\overline{\text{RESET}}$ (I_{OL} = 6.0 mA)	V_{OL}	—	—	0.4	V
Output High Voltage $\overline{\text{RESET}}$ (V_{OH} = 5.5 V)	V_{OH}	—	—	20	µA

NOTES: 3. The external PNP power transistor satisfies the following minimum specifications:
h_{FE} ≥ 60 at I_C = 500 mA and V_{CE} = 5.0 V;
$V_{CE(sat)}$ ≤ 300 mV at I_B = 10 mA and I_C = 300 mA
4. Regulator V_{out2} programmed for nominal 24 V output by means of R4, R5 (see Figure 1).
5. T_{low} = 0°C for TCA5600 T_{low} = –40°C for TCF5600
T_{high} = +125°C for TCA5600 T_{high} = +150°C for TCF5600
6. V_9 = 28 V, INH1 = LOW for this Electrical Characteristic section unless otherwise noted.
7. Pulse tested t_p ≤ 300 µs.
8. Temperature range T_{low} ≤ T_J ≤ T_{high} applies to this Electrical Characteristics section.
9. For test purposes, a negative pulse is applied to Pin 4 (–2.5 V ≥ V_4 ≥ –5.5 V).

Figure 1. Reference Voltage versus Supply Voltage

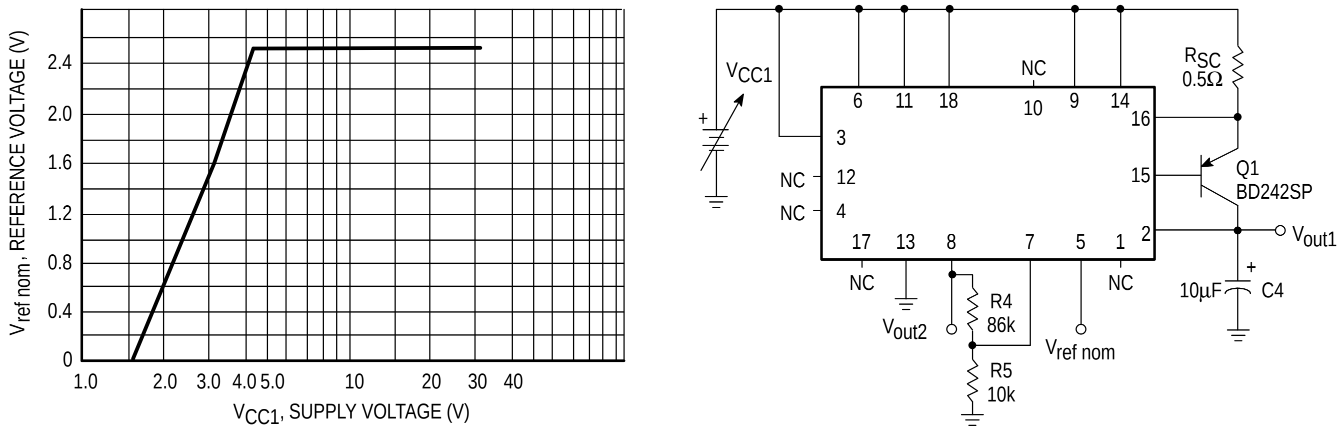


Figure 2. Reference Stability versus Temperature

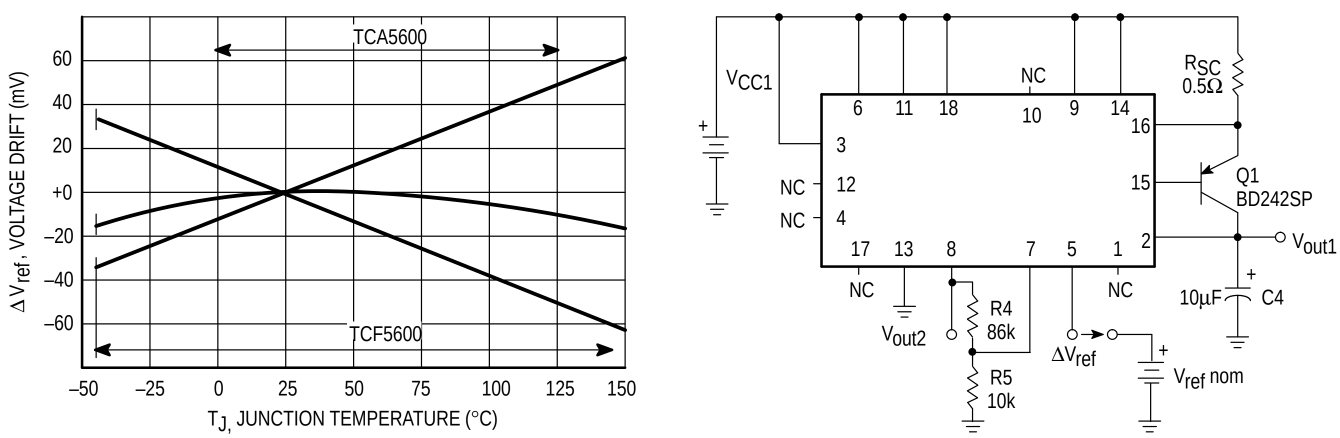


Figure 3. Ripple Rejection versus Frequency

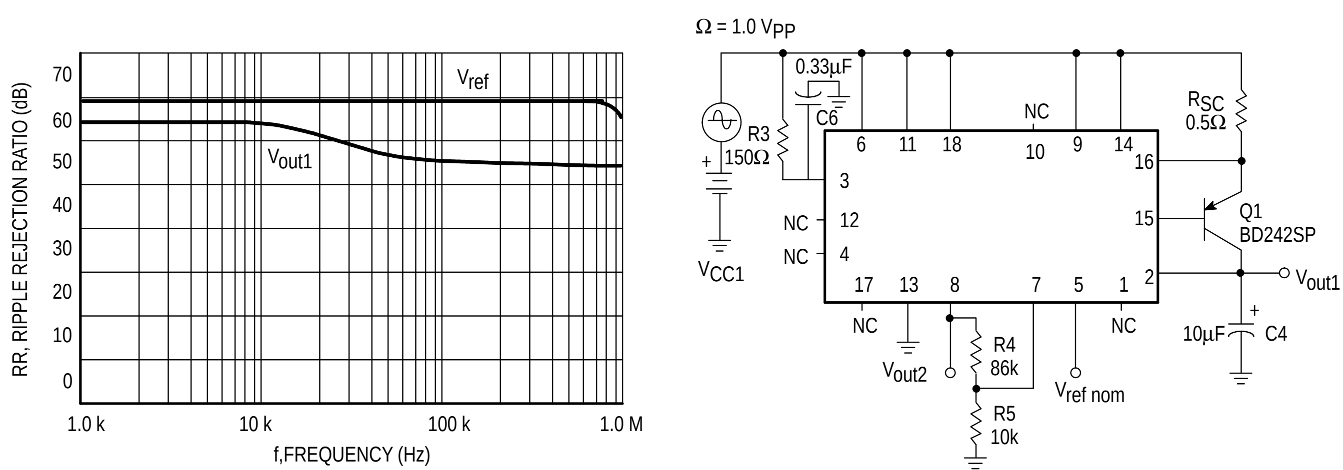


Figure 4. Standby Current versus Supply Voltage

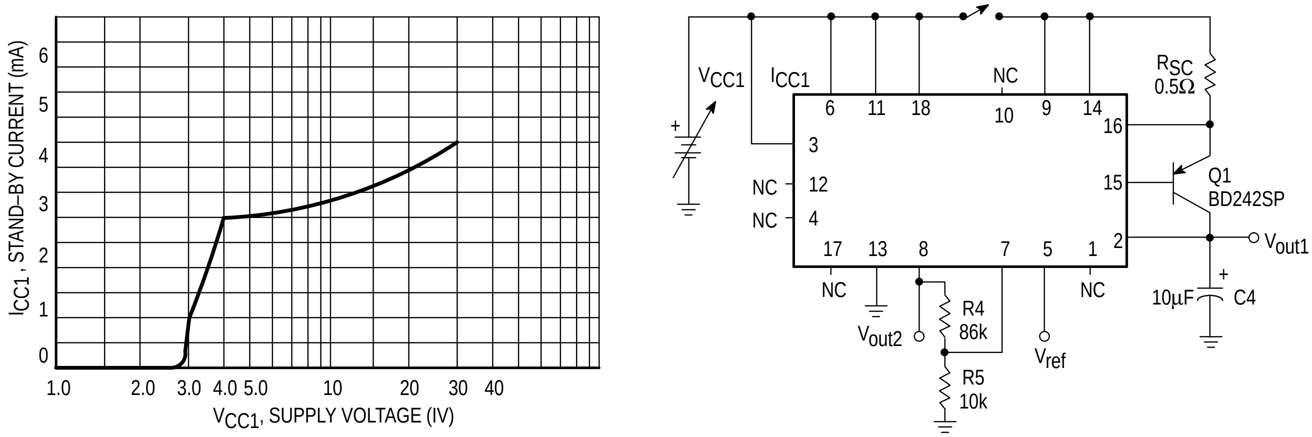


Figure 5. Power–Up Behavior of the 5.0 V Regulator

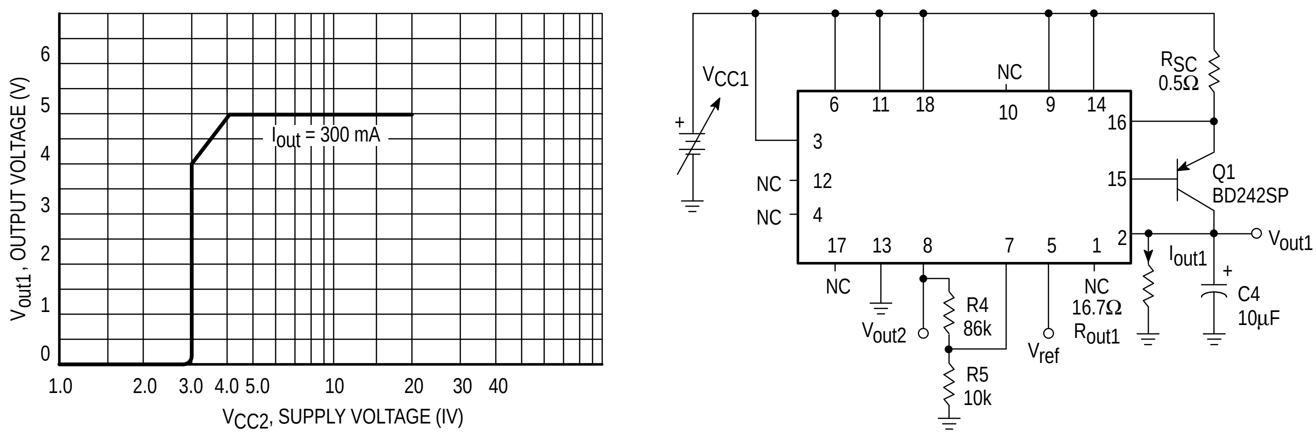


Figure 6. Foldback Characteristics of the 5.0 V Regulator

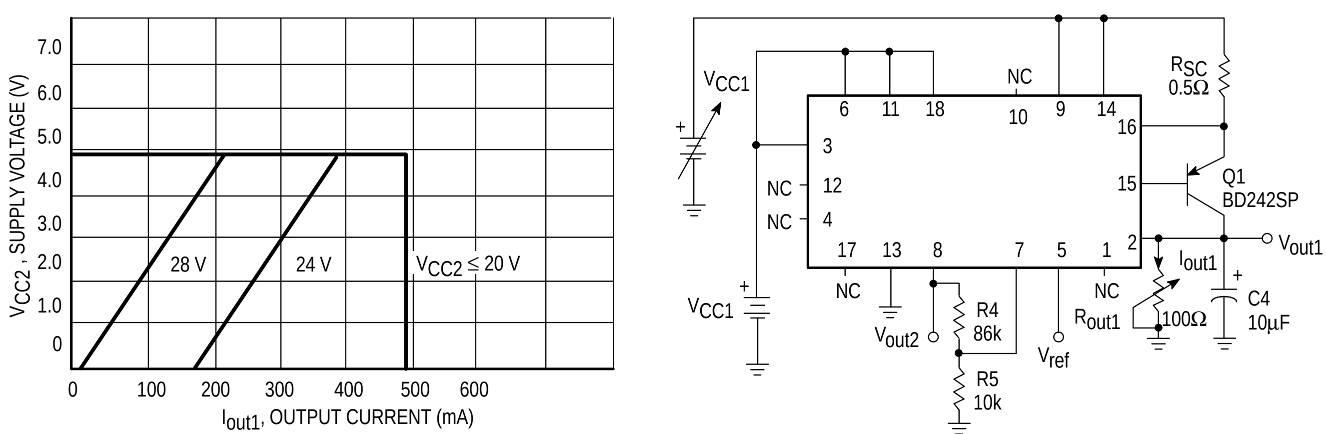


Figure 7. Undervoltage Lockout Characteristics

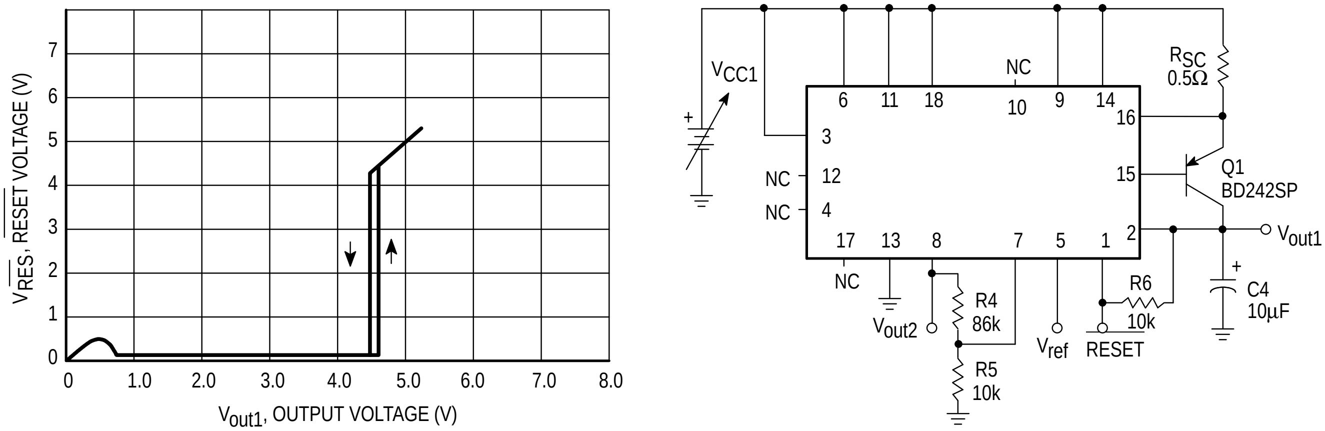


Figure 8. Output Current Capability of the Programming Regulator

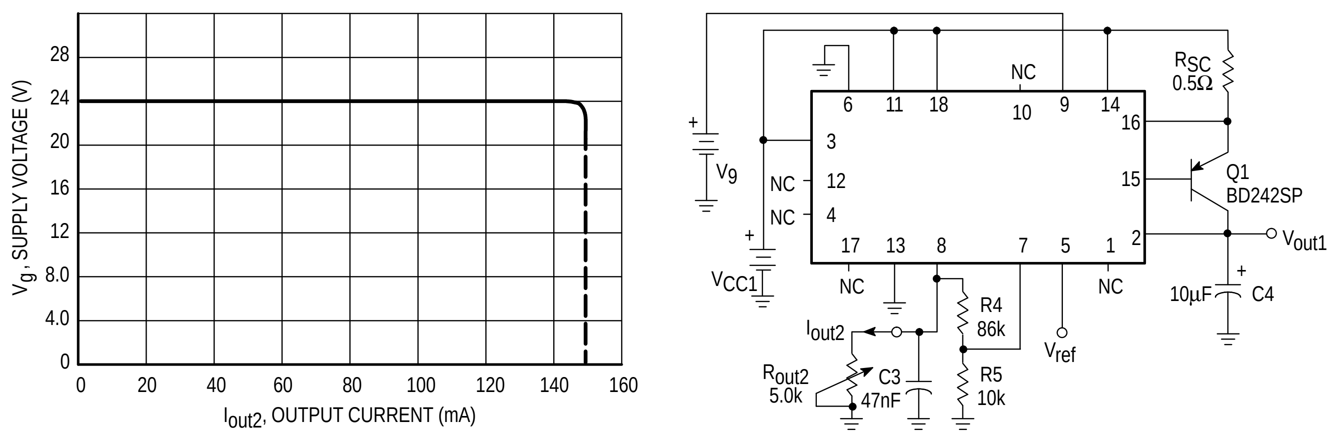


Figure 9. Collector Current Detection Level

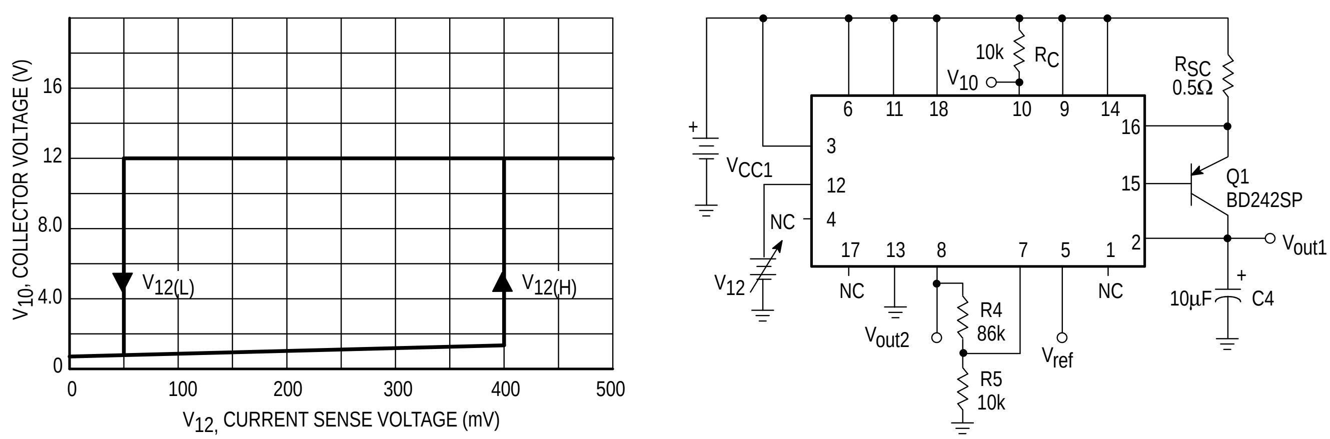
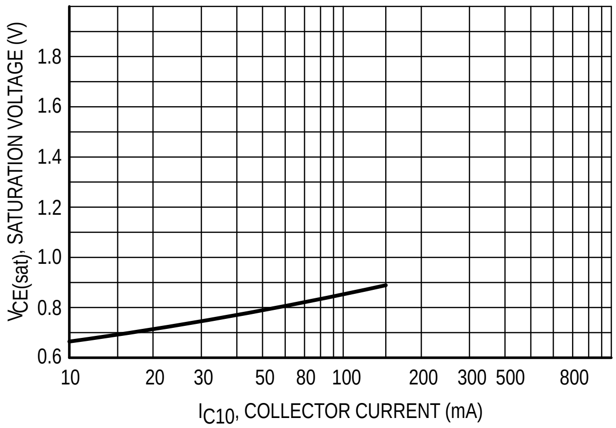


Figure 10. Power Switch Characteristics



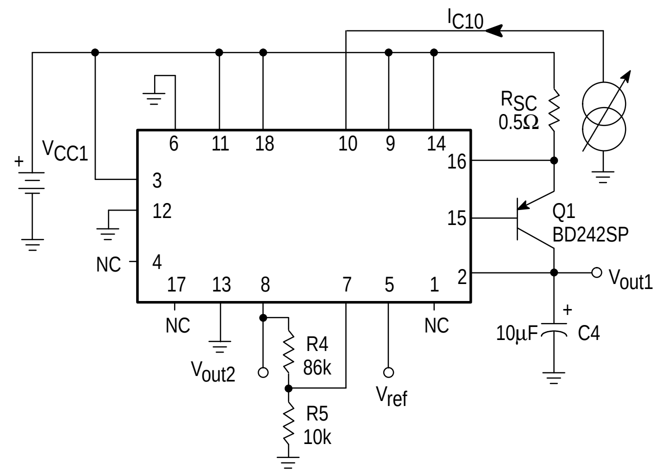
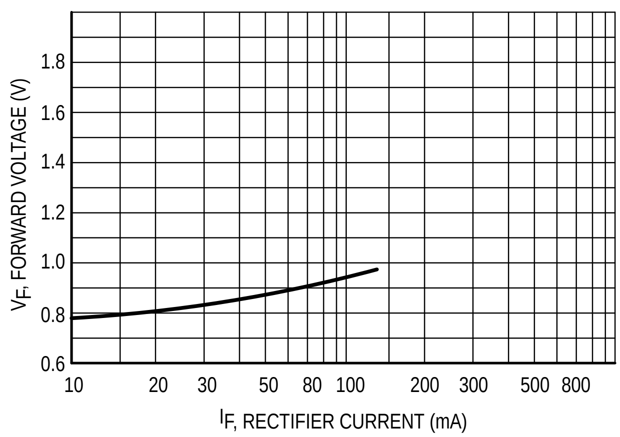


Figure 11. Rectifier Characteristics



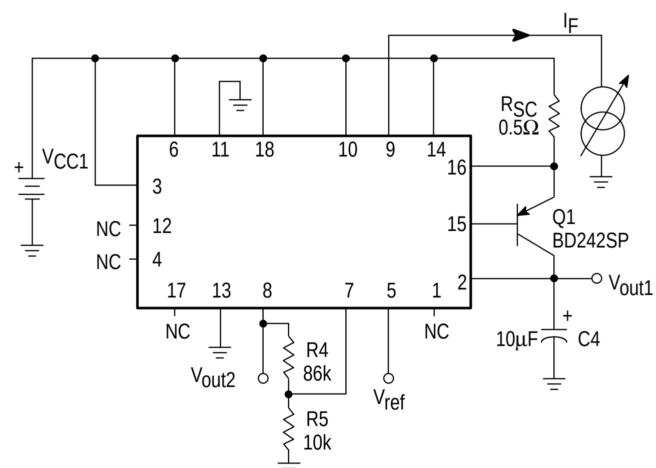
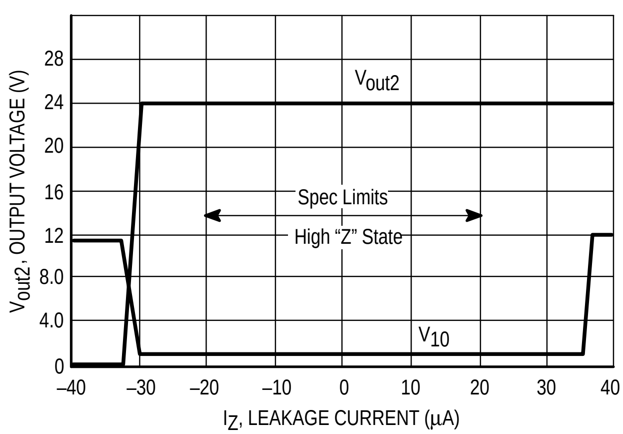
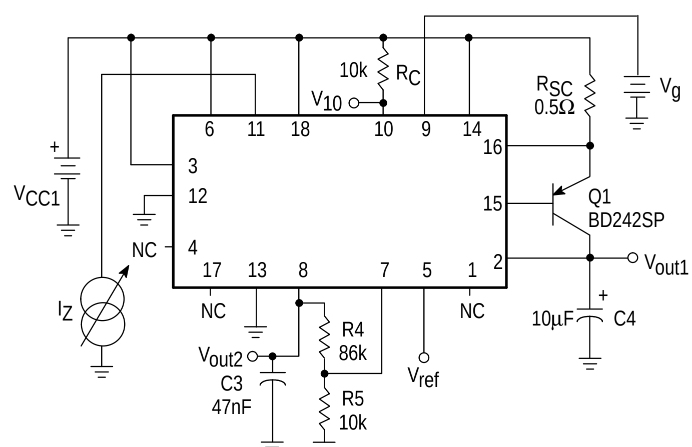


Figure 12. INH 2 Leakage Current Immunity





APPLICATIONS INFORMATION

(See Figure 18)

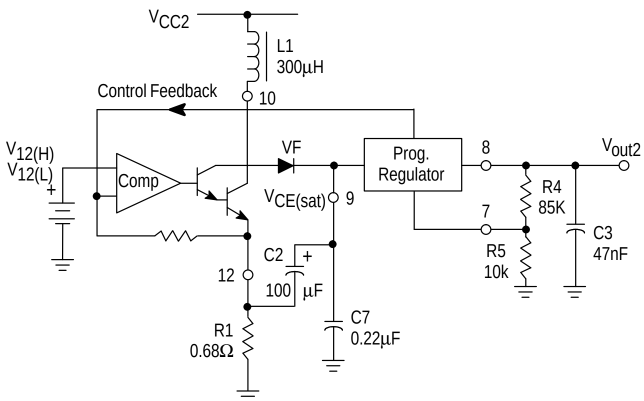
Voltage Reference (V_{ref})

The voltage reference V_{ref} is based upon a highly stable bandgap voltage reference and is accessible on Pin 5 for additional tasks. This circuit part has its own supply connection on Pin 3 and is, therefore, able to operate in standby mode. The RC network R3, C6 improves the ripple rejection on both regulators.

DC/DC Converter

The dc/dc converter performs according to the flyback principle and does not need a time base circuit. The maximum coil current is well defined by means of the current sensing resistor R1 under all working conditions (startup phase, circuit overload, wide supply voltage range and extreme load current change). Figure 13 shows the Simplified Converter Schematic.

Figure 13. Simplified Converter Schematic



A simplified method on “how to calculate the coil inductance” is given below. The operation point at minimum supply voltage (V_{CC2}) and max. output current (I_{out2}) for a fixed output voltage (V_{out2}) determines the coil data. Figure 14 shows the typical voltage and current waveforms on the coil L1 (coil losses neglected).

Equations (1) and (2) yield the respective coil voltage V_L- and V_L+ (see Figure 14):

$$V_L+ = V_{out2} + \Delta V_{(Pin\ 9\ -\ Pin\ 8)} + V_F - V_{CC2} \quad (1)$$

$$V_L- = V_{CC2} - V_{CE(sat)} - V_{12(H)} \quad (2)$$

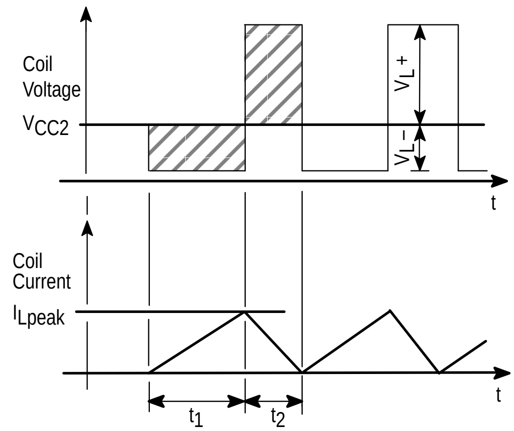
[$\Delta V_{(Pin\ 9 - Pin\ 8)}$: input/output voltage drop of the regulator, 2.5 V typical]

[V_F, $V_{CE(sat)}$, $V_{12(H)}$: see Electrical Characteristics Table]

The time ratio α for the charging time to dumping time is defined by Equation (3):

$$\alpha = \frac{t_1}{t_2} = \frac{V_L+}{V_L-} \quad (3)$$

Figure 14. Voltage and Current Waveform on the Coil (not to scale)



The coil charging time t_1 is found using Equation (4):

$$t_1 = \frac{1}{(1 + \frac{1}{\alpha}) \cdot f} \quad (4)$$

[f : minimum oscillation frequency which should be chosen above the audio frequency band (e.g. 20 kHz)]

Knowing the dc output current I_{out2} of the programmable regulator, the peak coil current $I_{L(peak)}$ can now be calculated:

$$I_{L(peak)} = 2 \cdot (I_{out2}) (1 + \alpha) \quad (5)$$

The coil inductance L1 of the nonsaturated coil is given by Equation (6):

$$L1 = \frac{t_1}{I_{L(peak)}} (V_L-) \quad (6)$$

The formula (6a) yields the current sensing resistor R1 for a defined peak coil current $I_{L(peak)}$:

$$R1 = \frac{V_{12(H)}}{I_{L(peak)}} \quad (6a)$$

In order to limit the by–pass current through capacitor C7 during the energy dumping phase the value C2>>C7 should be implemented.

For all other operation conditions, the feedback signal from the programmable voltage regulator controls the activity of the converter.

Programmable Voltage Regulator

This series voltage regulator is programmable by the voltage divider R4, R5 for a nominal output voltage of $6.0\ V \le V_{out2} \le 30\ V$.

$$R4 = \frac{(V_{out2} - V_{ref\ nom}) \bullet R5}{V_{ref\ nom}} \qquad (7)$$

$[R5 = 10\ k,\ V_{ref\ nom} = 2.5\ V]$

Current limitation and thermal shutdown capability are standard features of this regulator. The voltage drop $\Delta V_{(Pin\ 9 - Pin\ 8)}$ across the series pass transistor generates the feedback signal to control the dc/dc converter (see Figure 13).

Control Inputs INH1, INH2

The dc/dc converter and/or the regulator V_{out2} are remote controllable through the TTL, MOS compatible inhibit inputs INH1 and INH2 where the latter is a three–level detector (Logic "0", High Impedance "Z", Logic "1"). Both inputs are set–up to provide the following truth table:

Figure 15. INH1, INH2 TruthTable

Mode	INH1	INH2	V_{out2}	DC/DC
1	0	0	OFF	INT
2	0	High "Z"	V_{out2}	ON
3	0	1	V_{out2}	INT
4	1	0	OFF	INT
5	1	High "Z"	5.0 V	ON
6	1	1	5.0 V	INT

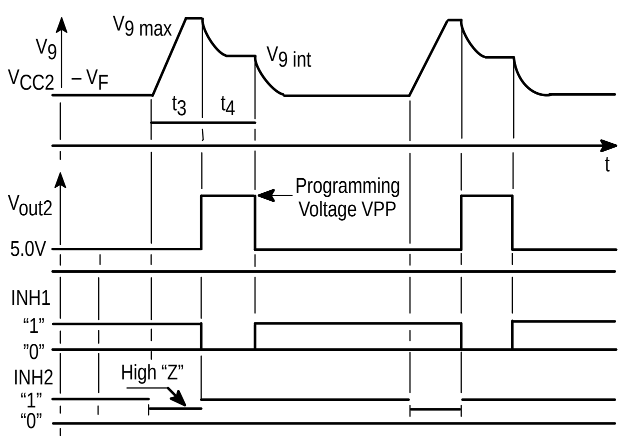
INT: Intermittent operation of the converter means that the converter operates only if $V_{CC2} < V_{out2}$.

ON: The converter loads the storage capacitor C2 to its full charge (V_9 = 33 V), allowing fast response time of the regulator V_{out2} when addressed by the control software.

OFF: High impedance (internal resistor 10 k to ground)

Figure 16 represents a typical timing diagram for an E^2PROM programming sequence in a microprocessor based system. The High "Z" state enables the dc/dc converter to ramp during t_3 to the voltage V_9 at Pin 9 to a high level before the write cycle takes place in the memory.

Figure 16. Typical E^2PROM Programming Sequence
(not to scale)



Microprocessor Supply Regulator

Together with an external PNP power transistor (Q1), a 5.0 V supply exhibiting low voltage drop is obtained to power microprocessor systems and auxiliary circuits. Using a power Darlington with adequate heat sink in the output stage boosts the output current I_{out1} above 1.0 A.

The current limitation circuit measures the emitter current of Q1 by means of the sensing resistor, R_{SC}:

$$R_{SC} = \frac{V_{RSC}}{I_E} \qquad (8)$$

[I_E: emitter current of Q1]

[V_{RSC}: threshold voltage (see Electrical Characteristics Table)]

The voltage protection circuit performs a foldback characteristic above a nominal operating voltage, $V_{CC2} \ge 18\ V$.

Delay and Watchdog Circuit

The undervoltage monitor supervises the power supply V_{out1} and releases the delay circuit RESET as soon as the regulator output reaches the microprocessor operating a range [e.g., $V_{low} \ge 0.93 \bullet V_{out1(nom)}$]. The RESET output has an open–collector and may be connected in a "wired–OR" configuration.

The watchdog circuit consists of a retriggerable monostable with a negative edge sensitive control input WDI. The watchdog feature may be disabled by means of the watchdog select input WDS driven to a "1". Figure 17 displays the Typical RESET Timing Diagram.

The commuted current source I_{C5} on Pin 17, threshold voltage $V_{C5(L)}$, $V_{C5(H)}$ and an external capacitor C5 define the RESET delay and the watchdog timing. The relationship of the timing signals are indicated by the Equations (9) to (11).

$$\overline{\text{RESET}}\text{ delay:}\quad t_d = \frac{C5 \bullet V_{C5(H)}}{|I_{C5}|} \qquad (9)$$

$$\text{Watchdog timeout:}\quad t_{wd} = \frac{C5 \bullet (V_{C5(H)} - V_{C5(L)})}{5 \bullet I_{C5}} \qquad (10)$$

$$\text{Watchdog }\overline{\text{RESET}}\text{:}\quad t_r = \frac{C5 \bullet (V_{C5(H)} - V_{C5(L)})}{50 \bullet |I_{C5}|} \qquad (11)$$

[I_{C5}, $V_{C5(H)}$, $V_{C5(L)}$: see Electrical Characteristics Table]

Figure 17. Typical $\overline{RESET}$ Timing Diagram (not to scale)

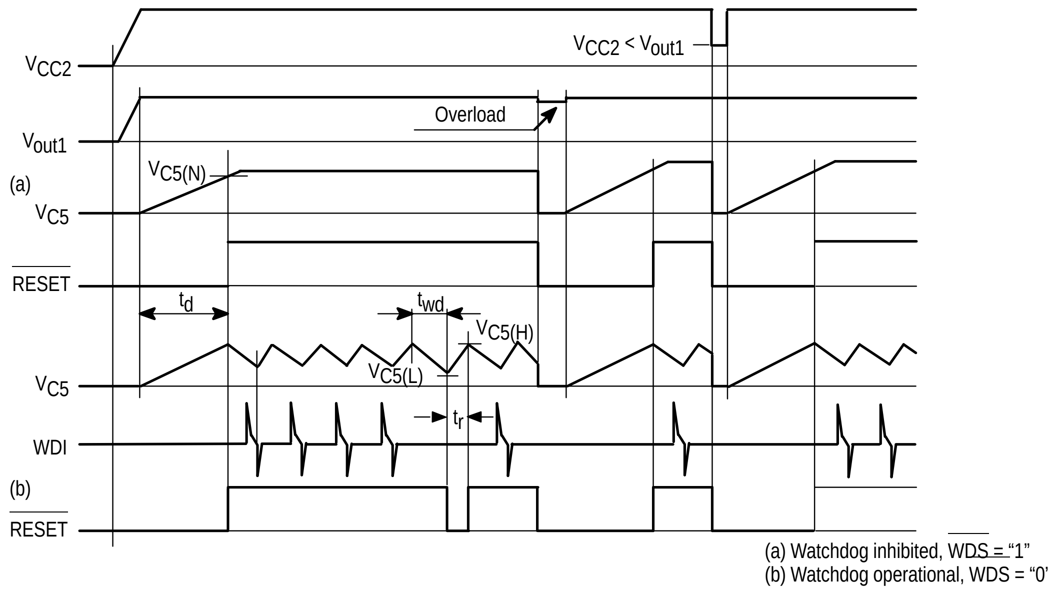
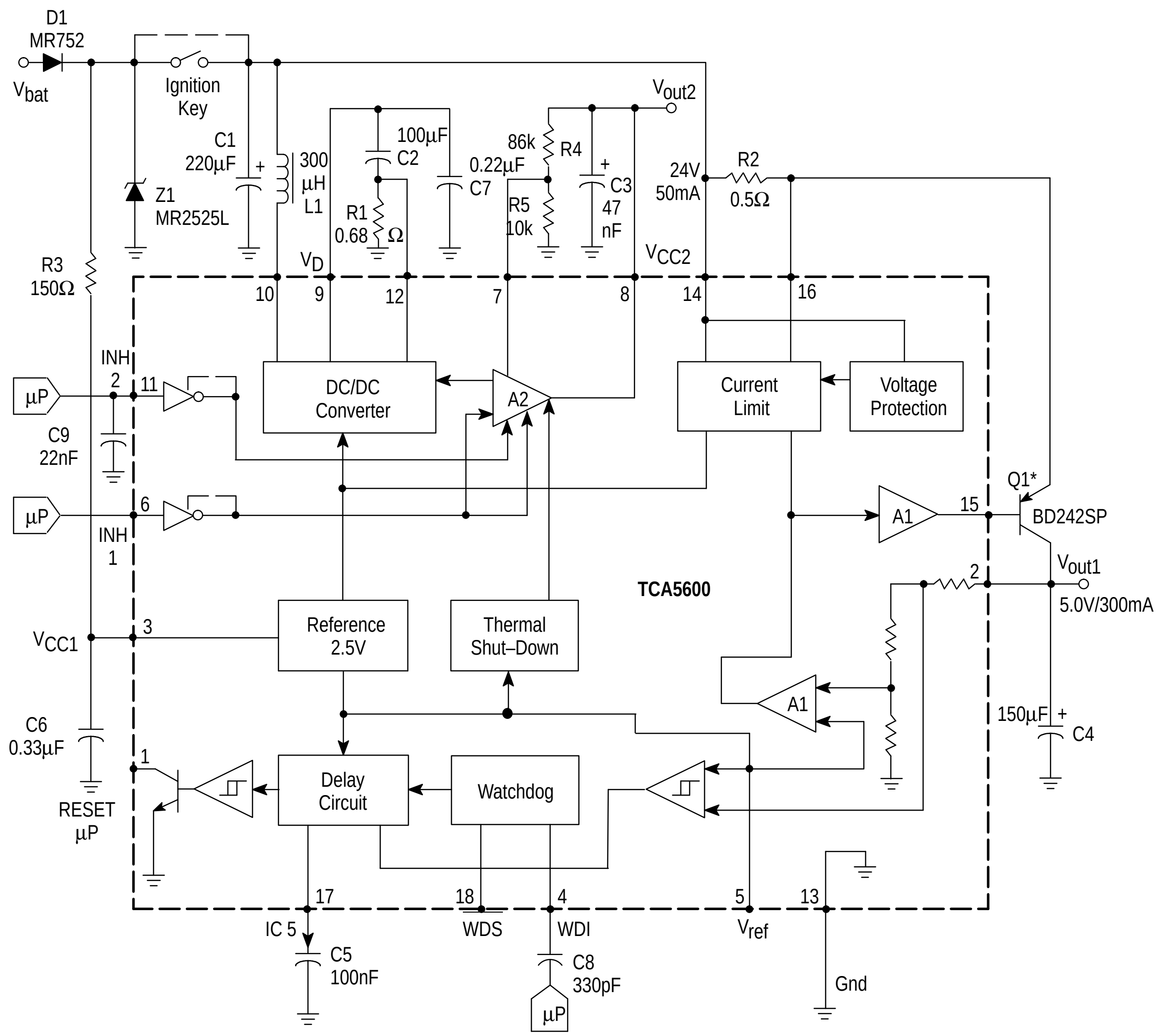
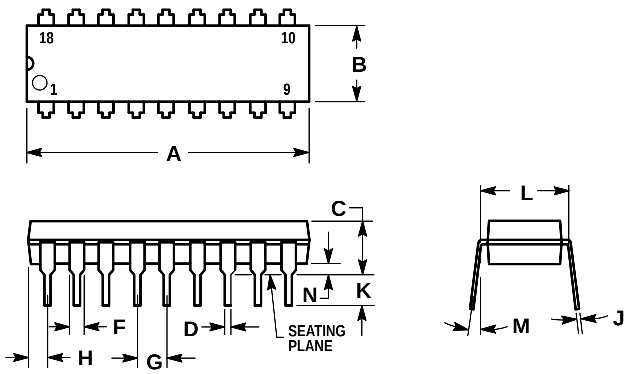


Figure 18. Typical Automative Application



OUTLINE DIMENSIONS

PLASTIC PACKAGE
CASE 707–02
ISSUE C



NOTES:
1. POSITIONAL TOLERANCE OF LEADS (D), SHALL BE WITHIN 0.25 (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.

	MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN	MAX
A	22.22	23.24	0.875	0.915
B	6.10	6.60	0.240	0.260
C	3.56	4.57	0.140	0.180
D	0.36	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

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