MOTOROLA

Power Management Controller

The MC33128 is a power management controller specifically designed for use in battery powered cellular telephone and pager applications. This device contains all of the active functions required to interface the user to the system electronics via a microprocessor. This integrated circuit consists of a low dropout voltage regulator with power–up reset for MPU power, two low dropout voltage regulators for independant powering of analog and digital circuitry, and a negative charge pump voltage regulator for full depletion of gallium arsenide MESFETs.
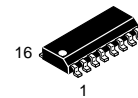
Also included are protective system shutdown features consisting of a battery latch that is activated upon battery insertion, low battery voltage shutdown, and a thermal over temperature detector. This device is available in a 16–pin narrow body surface mount plastic package.

- Three Positive Regulated Outputs Featuring Low Dropout Voltage
- Negative Regulated Output for Full Depletion of GaAs MESFETs
- MPU Power Up Reset
- Battery Latch
- Low Battery Shutdown
- Pinned–Out Reference for MPU A/D Converter
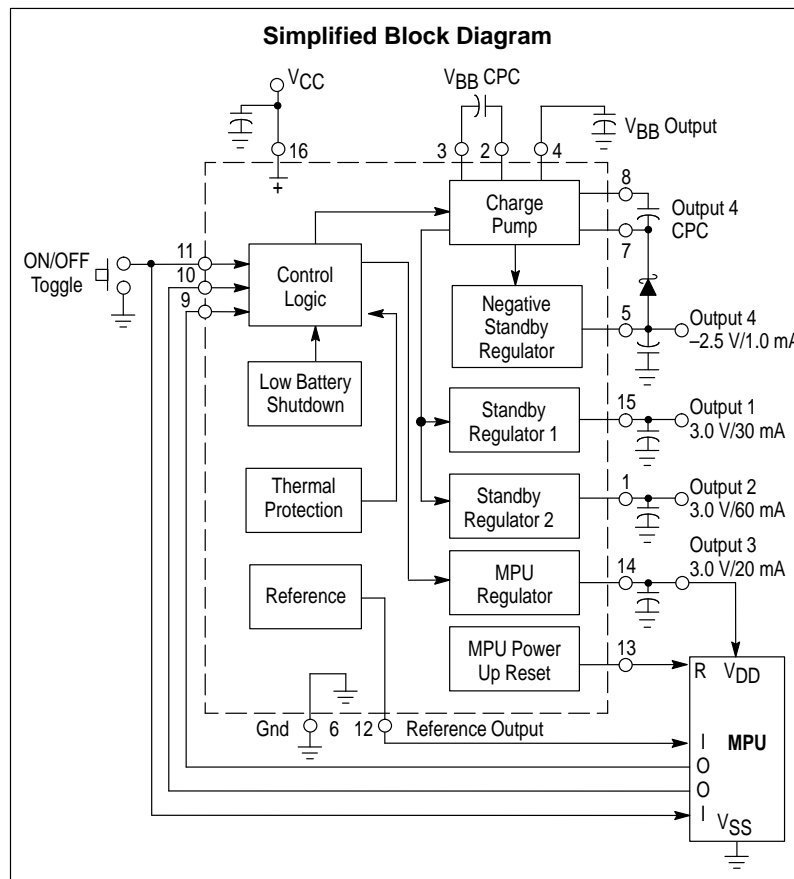- Low Start–Up and Operating Current
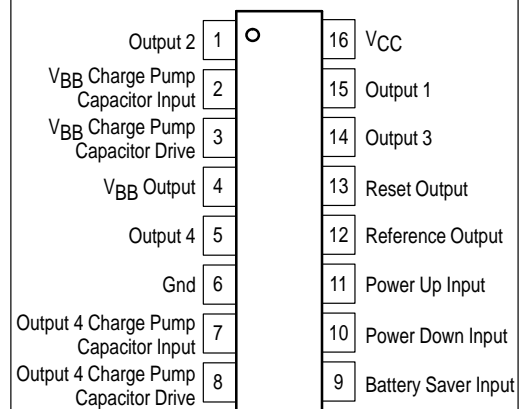- Thermal Protection

MC33128

POWER MANAGEMENT CONTROLLER

SEMICONDUCTOR TECHNICAL DATA

D SUFFIX
PLASTIC PACKAGE
CASE 751B
(SO–16)

PIN CONNECTIONS

Output 2	1	16 V$_{CC}$
V$_{BB}$ Charge Pump Capacitor Input	2	15 Output 1
V$_{BB}$ Charge Pump Capacitor Drive	3	14 Output 3
V$_{BB}$ Output	4	13 Reset Output
Output 4	5	12 Reference Output
Gnd	6	11 Power Up Input
Output 4 Charge Pump Capacitor Input	7	10 Power Down Input
Output 4 Charge Pump Capacitor Drive	8	9 Battery Saver Input

(Top View)

ORDERING INFORMATION

Device	Operating Temperature Range	Package
MC33128D	T$_A$ = – 30° to +60°C	SO–16

Simplified Block Diagram

© Motorola, Inc. 1996   Rev 0

MC33128

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Power Supply Input Voltage (Pin 16)	V_{CC}	+7.0	V
Input Voltage Range Power Up, Power Down, and Battery Saver Inputs (Pins 11, 10, 9)	V_{in}	−1.0 to V_{CC} + 1.0	V
Charge Pump Capacitor Drive Outputs, Source or Sink Current (Pins 3, 8)	$I_{O(max)}$	30	mA
Schottky Diode Forward Current (Pins 16 to 2, 2 to 4, and 7 to 6)	$I_{F(max)}$	30	mA
Output Source Current (Note 1) Regulator Output 1 (Pin 15) Regulator Output 2 (Pin 1) Regulator Output 3 (Pin 14) Regulator Output 4 (Pin 5) Reference (Pin 12)	I_{Source}	150 250 50 10 40	mA
Reset Sink Current (Pin 13)	I_{Sink}	5.0	mA
Power Dissipation and Thermal Characteristic D Suffix, Plastic Package Case 751B Maximum Power Dissipation @ T_A = 50°C Thermal Resistance, Junction–to–Air	P_D $R_{\varnothing JA}$	560 180	mW °C/W
Operating Junction Temperature	T_J	+150	°C
Operating Ambient Temperature (Note 1)	T_A	−30 to +60	°C
Storage Temperature	T_{stg}	−60 to +150	°C

ELECTRICAL CHARACTERISTICS (V_{CC} = 4.5 V, C_{in} = 33 µF with ESR ≤ 1.6 Ω, C_O = 4.7 µF with ESR ≤ 4.5 Ω, I_{O1} = 30 mA, I_{O2} = 60 mA, I_{O3} = 20 mA, I_{O4} = 1.0 mA, I_{Oref} = 10 mA [Note 2], T_A = 25°C.)

Characteristic	Symbol	Min	Typ	Max	Unit
POWER UP INPUT (Pin 11)					
Low State Input Threshold Voltage	$V_{th(toggle)}$	V_{CC} − 1.5	V_{CC} − 1.2	V_{CC} − 0.8	V
Input Current (V_{in} = V_{O3})	$I_{in(toggle)}$	−	−	120	µA
Internal Pull Up Resistance	$R_{PU(ON/OFF)}$	10	20	30	kΩ
POWER DOWN INPUT (Pin 10)					
High State Input Threshold Voltage (Places IC in Standby Mode)	$V_{th(PDI)}$	1.3	1.5	1.8	V
Input Current (V_{in} = V_{O3})	$I_{in(PDI)}$	−	−	120	µA
BATTERY SAVER INPUT (Pin 9)					
High State Input Threshold Voltage (V_{BB}, V_{O1}, V_{O2}, V_{O4} Activated)	$V_{th(BSI)}$	1.2	1.4	1.7	V
Input Current (V_{in} = V_{O3})	$I_{in(BSI)}$	−	−	120	µA
V_{BB} GENERATOR					
Oscillator Frequency	f_{OSC}	85	95	105	kHz
Oscillator Duty Cycle	DC	35	50	65	%
Charge Pump Capacitor Drive Output Voltage Swing (Pin 3) High State (I_{Source} = 3.0 mA) Low State (I_{Sink} = 3.0 mA)	V_{OH} V_{OL}	− −	V_{CC} − 0.9 0.15	− −	V
Schottky Diode (Pins 2, 4) Forward Voltage Drop (I_F = 3.0 mA) Reverse Leakage Current (V_{BB} = 7.0 V)	V_F I_L	− −	0.5 0.01	− −	V µA
Output Voltage (Pin 4) V_{CC} = 4.5 V V_{CC} = 2.9 V	$V_{O(VBB)}$	− −	7.9 4.4	− −	V

NOTES: 1. Maximum package power dissipation limits must be observed.
2. All outputs are fully loaded as stated in the Electrical Characteristics Table above, except for the one under test.

MC33128

ELECTRICAL CHARACTERISTICS (V_{CC} = 4.5 V, C_{in} = 33 µF with ESR ≤ 1.6 Ω, C_O = 4.7 µF with ESR ≤ 4.5 Ω, I_{O1} = 30 mA, I_{O2} = 60 mA, I_{O3} = 20 mA, I_{O4} = 1.0 mA, I_{Oref} = 10 mA [Note 2], T_A = 25°C.)

Characteristic	Symbol	Min	Typ	Max	Unit
REGULATOR OUTPUT 1 (Pin 15)					
Output Voltage (V_{CC} = 3.15 V to 4.5 V, I_{O1} = 30 mA)	Reg_{line1}	2.9	3.0	3.1	V
Load Regulation (I_{O1} = 0 mA to 35 mA)	Reg_{load1}	–	5.0	30	mV
Dropout Voltage (V_{CC} = 2.9 V, I_{O1} = 30 mA)	$V_{in} - V_{O1}$	–	–	0.1	V

Power Supply Rejection Ratio
  f = 120 Hz
  f = 100 kHz
	PSRR 1	
		–
		–
			
			70
			40
				
				–
				–
					dB

Turn ON Delay Time (Battery Saver Input to 90% V_{O1} Output)	t_{DLY1}	–	0.2	2.0	ms
REGULATOR OUTPUT 2 (Pin 1)					
Output Voltage (V_{CC} = 3.15 V to 4.5 V, I_{O2} = 60 mA)	Reg	2.9	3.0	3.1	V
Load Regulation (I_{O2} = 0 mA to 60 mA)	Reg_{load2}	–	5.0	40	mV
Dropout Voltage (V_{CC} = 2.9 V, I_{O2} = 60 mA)	$V_{in} - V_{O2}$	–	–	0.11	V

Power Supply Rejection Ratio
  f = 120 Hz
  f = 100 kHz
	PSRR 2	
		–
		–
			
			70
			40
				
				–
				–
					dB

Turn ON Delay Time (Battery Saver Input to 90% V_{O2} Output)	t_{DLY2}	–	0.2	2.0	ms
REGULATOR OUTPUT 3 (Pin 14)					
Output Voltage (V_{CC} = 3.15 V to 4.5 V, I_{O3} = 20 mA)	Reg_{line3}	2.9	3.0	3.1	V
Load Regulation (I_{O3} = 0 mA to 20 mA)	Reg_{load3}	–	5.0	25	mV
Dropout Voltage (V_{CC} = 2.9 V, I_{O3} = 20 mA)	$V_{in} - V_{O3}$	–	–	0.1	V

Power Supply Rejection Ratio
  f = 120 Hz
  f = 100 kHz
	PSRR 3	
		–
		–
			
			70
			40
				
				–
				–
					dB

Turn ON Delay Time (ON/OFF Toggle Input to 90% V_{O3} Output)	t_{DLY3}	–	0.5	3.0	ms
REGULATOR OUTPUT 4 (Pin 5)					
Output Voltage (V_{CC} = 3.15 V to 4.5 V, I_{O4} = 1.0 mA)	Reg_{line4}	−2.35	−2.5	−2.65	V
Load Regulation (I_{O4} = 0 mA to 1.0 mA)	Reg_{load4}	–	5.0	20	mV

Power Supply Rejection Ratio
  f = 120 Hz
  f = 100 kHz
	PSRR 4	
		–
		–
			
			70
			40
				
				–
				–
					dB

Schottky Diode Forward Voltage Drop (Pins 7, 6, I_F = 1.0 mA)	V_F	–	0.5	–	V

Charge Pump Capacitor Drive Output Voltage Swing (Pin 8)
  High State (I_{Source} = 1.0 mA)
  Low State (I_{Sink} = 1.0 mA)
	
	V_{OH}
	V_{OL}
		
		–
		–
			
			$V_{BB} - 0.25$
			0.15
				
				–
				–
					V

Turn ON Delay Time (Battery Saver Input to 90% V_{O4} Output)	t_{DLY4}	–	4.0	10	ms
REFERENCE OUTPUT (Pin 12)					
Output Voltage (I_O = 0 mA to 10 mA)	Reg_{load}	1.46	1.5	1.54	V
MPU POWER UP RESET COMPARATOR (Pin 13)					

Threshold Voltage
  Low State Output (V_{O3} Decreasing)
  Hysteresis (V_{O3} Increasing)
	
	$V_{th(low)}$
	V_H
		
		2.5
		40
			
			2.6
			60
				
				2.7
				100
					
					V
					mV

Output Sink Saturation (I_{Sink} = 100 µA, V_{O3} = 2.5 V to 1.0 V)	$V_{CE(sat)}$	–	130	300	mV
Internal Pull–up Resistance	R_{PU}	10	26	40	kΩ
High State Output Voltage (V_{O3} = 2.8 V)	V_{OH}	0.95 V_{O3}	V_{O3}	–	V

NOTE: 2. All outputs are fully loaded as stated in the Electrical Characteristics Table above, except for the one under test.

MC33128

ELECTRICAL CHARACTERISTICS (V_{CC} = 4.5 V, C_{in} = 33 µF with ESR ≤ 1.6 Ω, C_O = 4.7 µF with ESR ≤ 4.5 Ω, I_{O1} = 30 mA, I_{O2} = 60 mA, I_{O3} = 20 mA, I_{O4} = 1.0 mA, I_{Oref} = 10 mA [Note 2], T_A = 25°C.)

| Characteristic	Symbol	Min	Typ	Max	Unit
LOW BATTERY SHUTDOWN COMPARATOR (Pin 16)					
Shutdown Threshold Voltage (V_{CC} Decreasing, Pin 10 = Gnd)	$V_{th(LBSC)}$	2.25	2.4	2.55	V
TOTAL DEVICE (Pin 16)					
Power Supply Current (No Load On All Outputs) Operating	I_{CC}				
Battery Saver Input High (Pin 9 = 2.0 V)		–	2.6	4.0	mA
Battery Saver Input Low (Pin 9 ≤ 0.8 V)		–	270	330	µA
Standby (After Power Down Input Strobe)		–	8.0	12	µA

NOTE: 2. All outputs are fully loaded as stated in the Electrical Characteristics Table above, except for the one under test.

Figure 1. Dropout Voltage versus Source Current
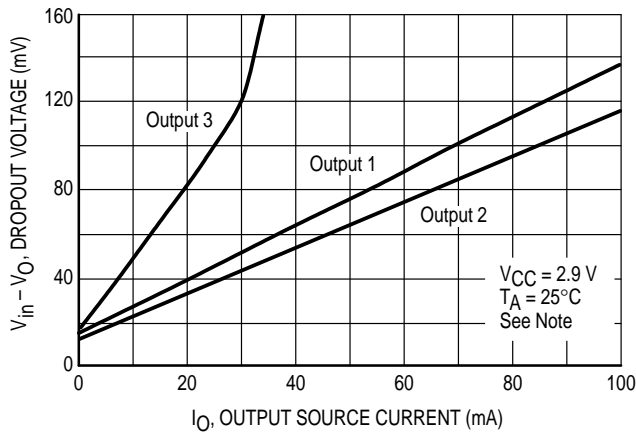
Figure 2. Output 4 Voltage versus Source Current
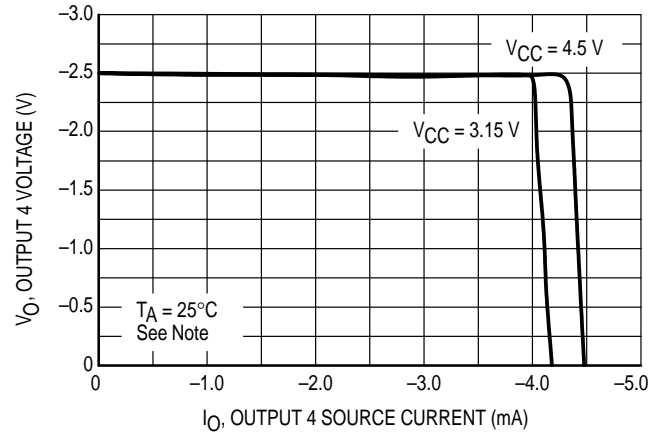
Figure 3. Reference Output Voltage Change versus Source Current
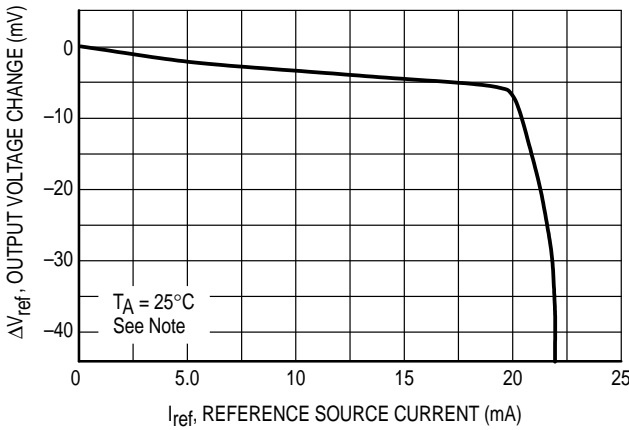
Figure 4. V_{BB} Output Voltage Change versus Source Current
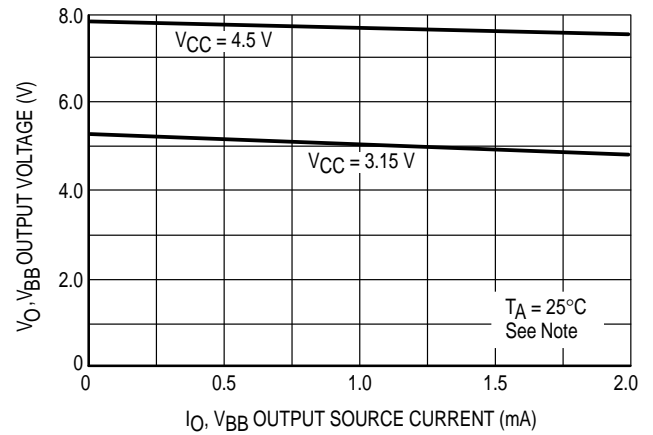
NOTE: All outputs are fully loaded as stated in the Electrical Characteristics Table above, except for the one under test.

MC33128

OPERATING DESCRIPTION

The MC33128 is a complete power management controller that is designed to interface the user to the system electronics via a microprocessor.

Outputs

Three low dropout voltage regulators are provided at outputs 1, 2 and 3. Outputs 1 and 2 were contemplated for independent powering of the systems analog and digital circuitry. This significantly reduces the possibility of digitally generated noise and spurious signals from coupling into the RF and analog circuits. The low dropout characteristic of Outputs 1 and 2 is achieved by applying a boosted battery voltage, V_{BB}, to their respective driver transistors. This allows the output pass transistors to be driven into saturation when the battery voltage approaches 3.0 V. The V_{BB} Output appears at Pin 4 and can be used to provide gate bias for enhancing external N channel MOSFET switches. Excessive loading of the V_{BB} output will result in an increase in dropout voltage.

Output 4 is derived from a voltage inverting charge pump circuit and is intended to provide the negative gate bias required for full depletion of RF gallium arsenide MESFETs. In personal communication system applications such as cellular telephone, negative gate bias is usually required by the antenna switch and power amplifier circuit blocks with a typical combined current of less than 1.0 mA. Output 4 can supply in excess of 2.0 mA, but there will be an increase in dropout voltage of Outputs 1, 2 and 3.

Outputs 1, 2, 4, V_{BB} Generator and Thermal Protection are all enabled and disabled in unison by the Battery Saver Input, Pin 9. The microprocessor can be programmed to significantly extend the system battery operating time by periodically enabling the receiver circuitry.

Output 3 provides power to the microprocessor, flash EPROM and the system display. These blocks are enabled by the Power Up Input, Pin 11, and disabled by the Power Down Input, Pin 10. By having separate power up and power down inputs, the microprocessor can store any pending information before turning the system and then itself OFF. This allows a controlled or graceful shutdown. Note that the power down request is initiated by pressing the toggle switch while the system is "ON". This action generates a microprocessor non–maskable interrupt that initiates the graceful shutdown.

Battery Voltage Detection

Reverse biasing and eventual failure of the lowest capacity cell in the battery pack can occur if the system is accidentally left on for an extended time period. To prevent this condition the following circuit blocks were incorporated.

A means for low battery detection is accomplished by using the Reference Output, Pin 12, in conjunction with the microprocessor's analog to digital converter input. A microprocessor output (LBO) can be designated to flash a display enunciator when a low battery condition exists. The Reference Output is 1.5 V $\pm 2.7\%$ and is capable of sourcing in excess of 10 mA.

The Power Up Reset Output, Pin 13, is designed to hold the microprocessor reset input low until the voltage at Output 3 rises above 2.66 V. This feature prevents the microprocessor from hanging or writing invalid information into its memory during power up. Notice that the output of the MPU Power Up Reset comparator also drives the base of transistor Q_{PD}. If Output 3 should fall below 2.6 V, due to an overload or a low battery condition, the comparator will drive Q_{PD} "ON", causing its collector to pull high on the Power Down Input, immediately forcing the system into standby mode. Externally pulling down on Pin 13, base of Q_{PD}, will also force the system into standby mode.

A redundant Low Battery Shutdown circuit is included. This circuit directly monitors the battery voltage and also forces the system into standby mode when the battery voltage falls below 2.4 V. To test the functionality of this circuit, the high state signal generated by transistor Q_{PD} must be clamped low, to prevent resetting the ON/OFF Latch. An external short or a pull–down, capable of sinking 2.0 mA at less than 0.8 V, must be connected to Pin 10.

A Battery Latch circuit is designed into the IC to prevent the system from turning on when the batteries are inserted into the finished product. This feature is useful for the end customer as well as the equipment manufacturer. Upon initial application of battery voltage, the lower comparator (0.7 V threshold) forces the Battery Latch into a reset state with its "Q" output low. This in turn triggers a reset of the ON/OFF Latch via the OR gate and also locks out the set signal present at the upper input of the AND gate. As the voltage at Pin 11 rises above (V_{CC} – 1.5 V), the set signal disappears, leaving the state of the ON/OFF Latch unchanged (reset). When the voltage at Pin 11 rises above (V_{CC} –1.0 V), the upper comparator forces the Battery Latch into a set state causing its "Q" output to go high. This allows the AND gate and the ON/OFF Latch to receive a set signal from Pin 11. The initial Battery Latch lockout time is controlled by the internal 20 kΩ resistor and the external 0.1 μF capacitor.

MC33128

Figure 5. MC33128 Block Diagram

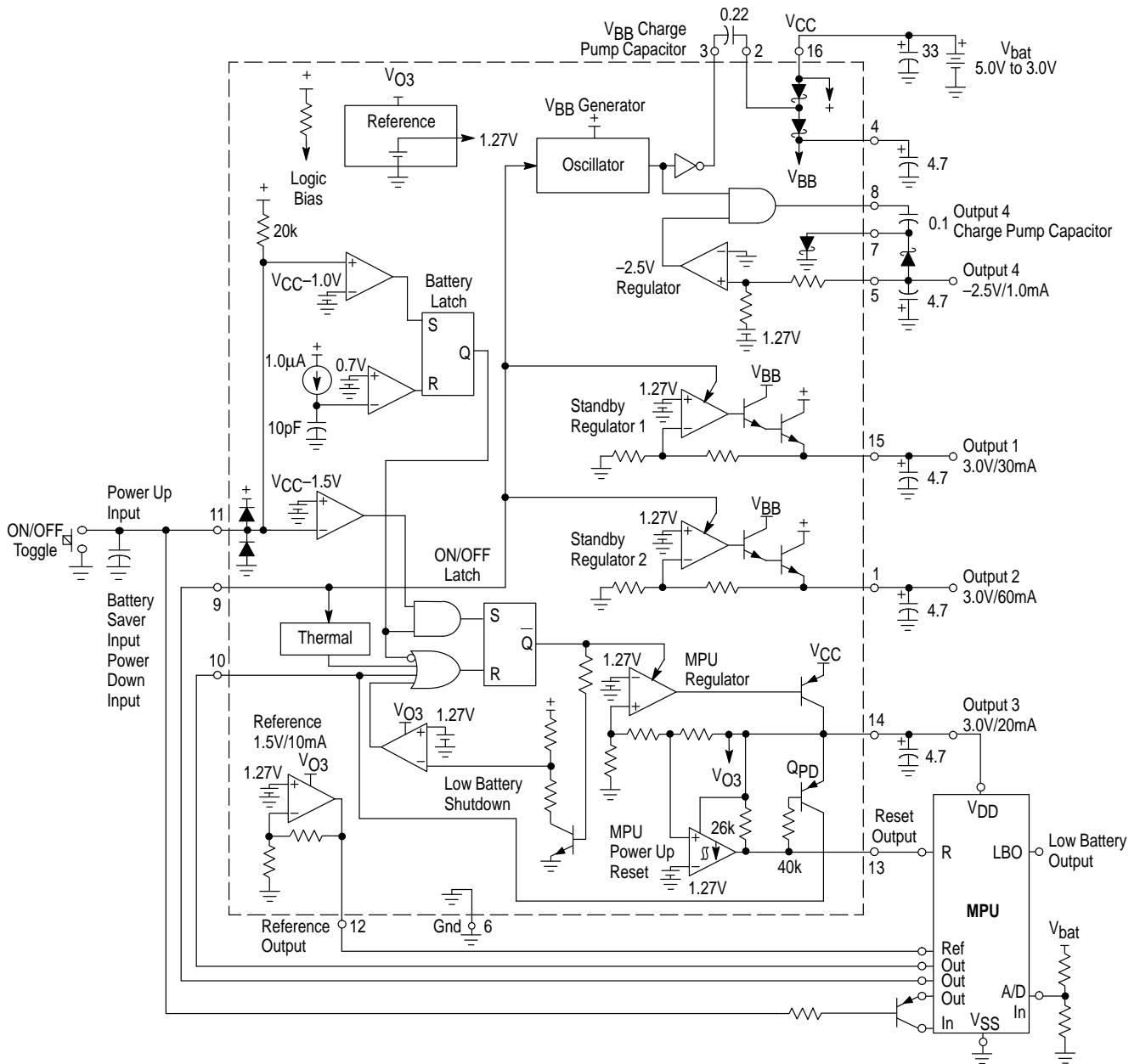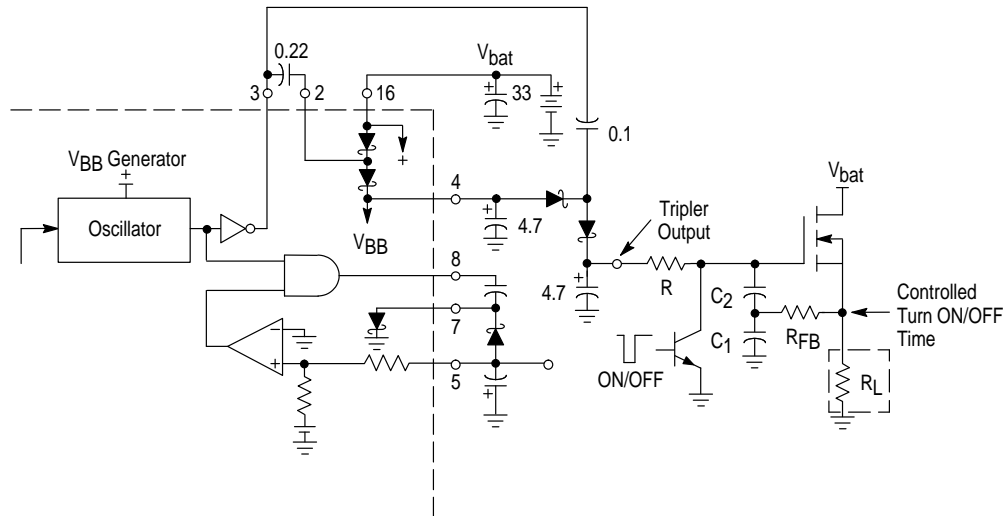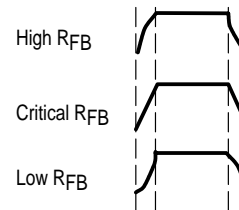**Figure 6. Voltage Tripler and Switch Driver**

Tripler Output Voltage

Load Current (mA)	V_{CC} = 3.15 V	V_{CC} = 4.5 V
0	7.96	12.01
0.5	7.48	11.54
1.0	7.24	11.29
1.5	6.99	11.04
2.0	6.62	10.69

Load Turn ON/OFF Time

External Switch

A low threshold N–channel MOSFET can be used to switch the transmitting power amplifier (R_L) ON and OFF. To ensure that all of the available battery voltage appears across the load, the MOSFET must be fully enhanced over the system's required operating voltage range. With the addition of two Schottky diodes and two capacitors, the V_{BB} Generator can be made to function as a voltage tripler. The table in Figure 6 shows the output voltage characteristics of the tripler circuit.

In order to minimize adjacent channel splatter, the RF power amplifier must be turned ON and OFF in a controlled (soft) manner. The applied voltage rise and fall time, as well as the rate of change in rise and fall time, must be tailored to the amplifiers characteristics. The circuit consisting of resistors R, R_{FB}, and capacitors C_1 and C_2 is a simple solution allowing the system designer a means to control the ON and OFF time as well as the waveshape. Feedback resistor R_{FB} controls the waveshape. Capacitors C_1 and C_2 are usually of equal value.

MC33128

OUTLINE DIMENSIONS

D SUFFIX
PLASTIC PACKAGE
CASE 751B–05
(SO–16)
ISSUE J
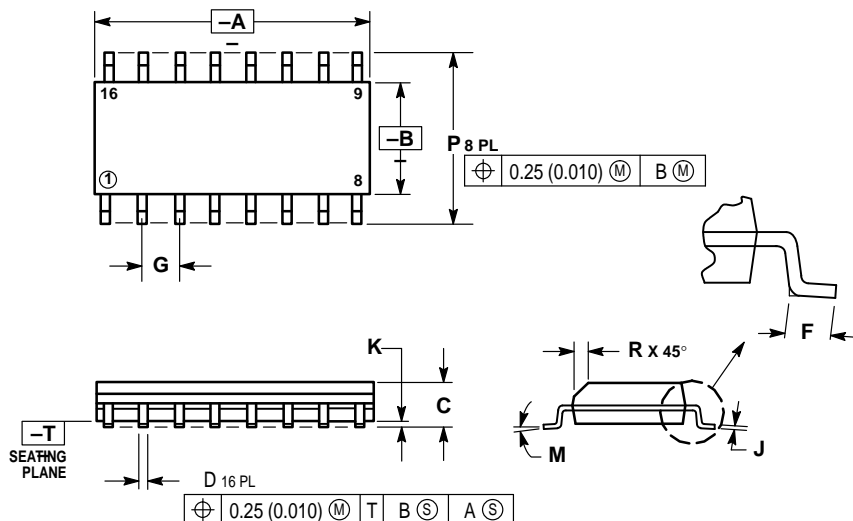
NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
5. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	9.80	10.00	0.386	0.393
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

MOTOROLA

◊