19-1217; Rev 0; 4/97

MAXIM

Regulated 3.3V Charge Pump

General Description

The MAX679 step-up, regulated charge pump generates a 3.3V ±4% output voltage from a 1.8V to 3.6V input voltage (two alkaline, NiCd, or NiMH; or one Lithium-Ion battery). Output current is 20mA (min) from a 2.0V input. Only three external capacitors are needed to build a complete DC-DC converter.

The MAX679's switching frequency is pin selectable at 330kHz or 1MHz to allow trade-offs between lowest supply current and smallest-size capacitors. The logic shutdown function reduces the supply current to 5µA (max) and disconnects the load from the input. Special soft-start circuitry prevents excessive current from being drawn from the battery during start-up. This DC-DC converter requires no inductors and has low EMI. It is available in the ultra-small µMAX package, which is only 1.11mm high and half the area of an 8-pin SO.

Features

- **Regulated 3.3V ±4% Output**
- **Ultra-Small: 1.1mm-High, 8-Pin µMAX Package**
- **No Inductors Required**
- **Up to 1MHz Operation (small external components)**
- **Fits into 0.05 in.^{2}**
- **Up to 85% Efficiency**
- **1.8V to 3.6V Input Voltage Range**
- **50µA Quiescent Supply Current**
- **1µA Shutdown Current**

Applications

Battery-Powered Applications

Miniature Equipment

Backup-Battery Boost Converters

Translators

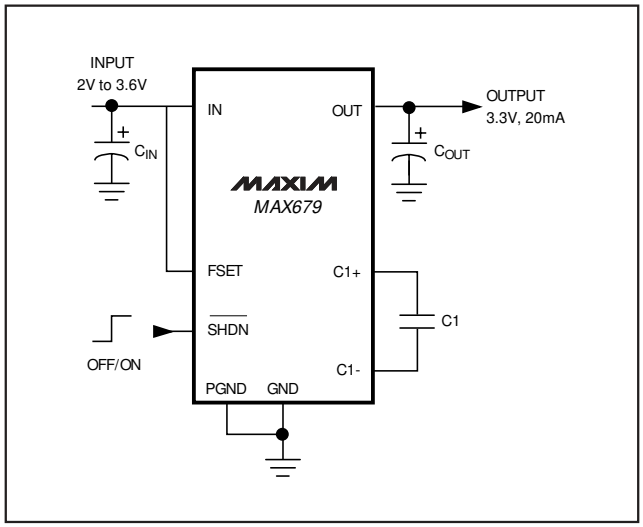
Two-Way Pagers

Ordering Information

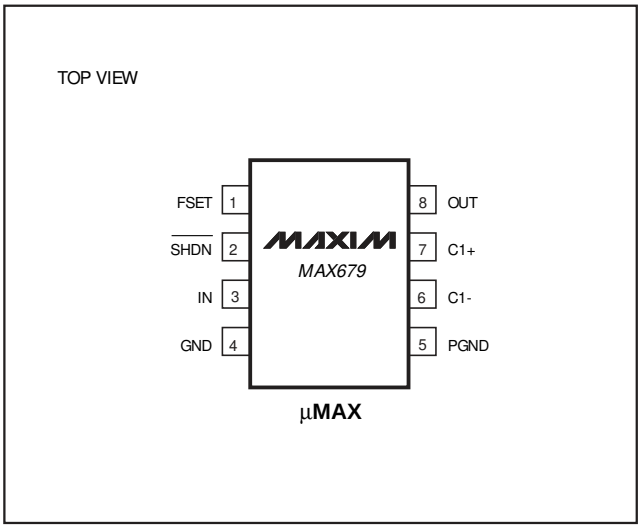
PART	TEMP. RANGE	PIN-PACKAGE
MAX679C/D	0°C to +70°C	Dice*
MAX679EUA	-40°C to +85°C	8 µMAX

**Dice are tested at T_A = +25°C only.*

Typical Operating Circuit



Pin Configuration



Regulated 3.3V Charge Pump

ABSOLUTE MAXIMUM RATINGS

IN, OUT, $\overline{SHDN}$, FSET to GND .....-0.3V to 6V
PGND to GND .....±0.3V
C1- to GND .....-0.3V to (V_{IN} + 0.3V)
C1+ to GND .....-0.3V to (V_{OUT} + 0.3V)
OUT Short to GND 10sec

Continuous Power Dissipation (T_A = +70°C)
µMAX (derate 4.1mW/°C above +70°C) 330mW
Operating Temperature Range .....-40°C to +85°C
Storage Temperature Range .....-65°C to +160°C
Lead Temperature (soldering, 10sec) .....+300°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

(V_{IN} = $V_{\overline{SHDN}}$ = V_{FSET} = 2V, C_{IN} = 4.7µF, C1 = 0.33µF, C_{OUT} = 10µF, **T_A = -40°C to +85°C**, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

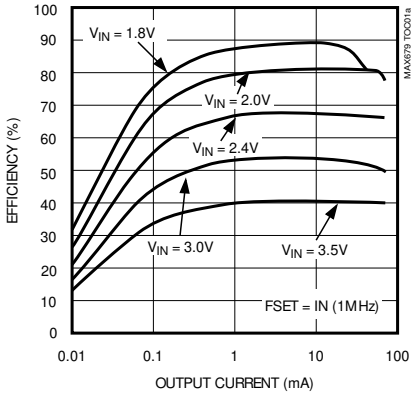
PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Input Voltage			1.8		3.6	V
Input Undervoltage Lockout Voltage			0.8		1.6	V
Output Voltage	2V < V_{IN} < 3.3V, 0mA < I_{OUT} < 20mA	T_A = 0°C to +85°C	3.17	3.3	3.43	V
		T_A = -40°C to +85°C	3.15		3.45	
Output Current	V_{IN} = 1.8V, V_{OUT} > 3.17V			20		mA
No-Load Supply Current	V_{IN} = 2.5V, FSET = IN or GND			50	80	µA
Leakage Current into OUT in Shutdown	V_{OUT} = 3.6V, $\overline{SHDN}$ = GND			15	25	µA
Supply Current in Shutdown	V_{IN} = 3.3V			1	5	µA
FSET, $\overline{SHDN}$ Input Voltage Low	V_{IN} = 1.8V			0.5 x V_{IN}	0.3 x V_{IN}	V
FSET, $\overline{SHDN}$ Input Voltage High	V_{IN} = 3.6V		0.7 x V_{IN}	0.5 x V_{IN}		V
FSET, $\overline{SHDN}$ Input Leakage Current	FSET, $\overline{SHDN}$ = GND or V_{IN}			0.1	1	µA
Switching Frequency	FSET = GND		260	330	450	kHz
	FSET = IN		700	1000	1300	
Output Short-Circuit Current	OUT = GND, V_{IN} = 3.3V			100	200	mA
Efficiency	V_{IN} = 2V, I_{OUT} = 10mA			80		%

Note 1: Specifications to -40°C are guaranteed by design, not production tested.

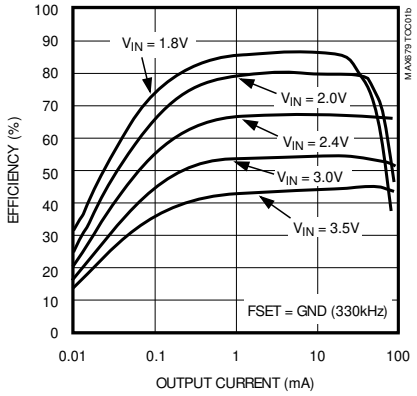
Typical Operating Characteristics

(Typical Operating Circuit with: V_{IN} = $V_{\overline{SHDN}}$ = 2V, C_{IN} = 4.7µF, C1 = 0.33µF, C_{OUT} = 10µF, tested in-circuit, T_A = +25°C, unless otherwise noted.)

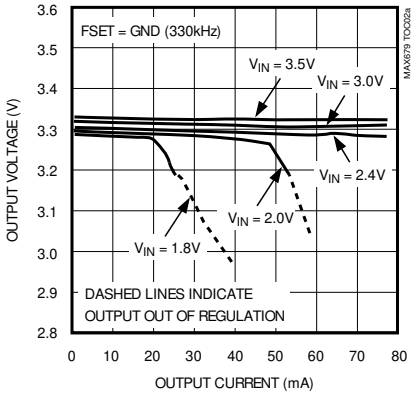
EFFICIENCY vs. OUTPUT CURRENT



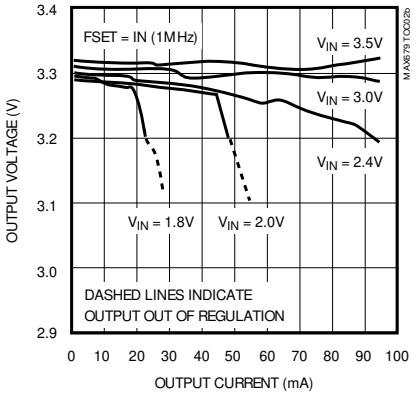
EFFICIENCY vs. OUTPUT CURRENT



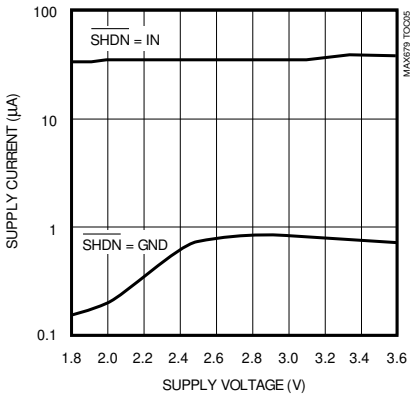
OUTPUT VOLTAGE vs. OUTPUT CURRENT



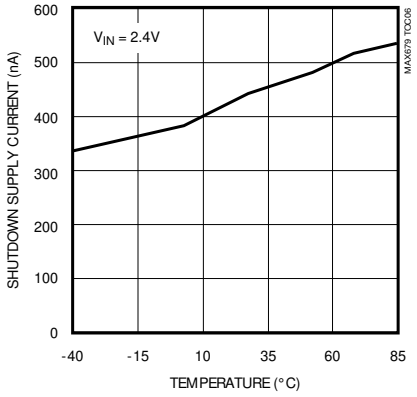
OUTPUT VOLTAGE vs. OUTPUT CURRENT



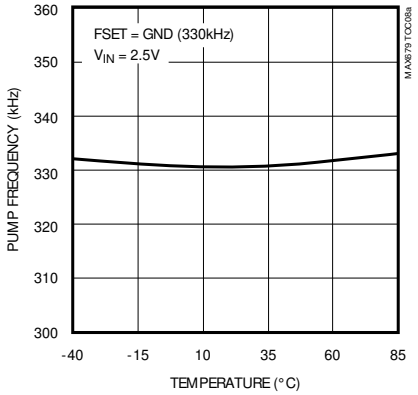
SUPPLY CURRENT vs. SUPPLY VOLTAGE



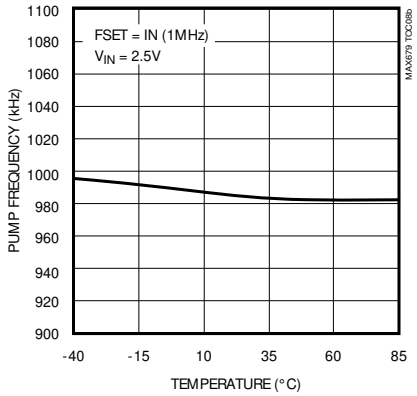
SHUTDOWN SUPPLY CURRENT vs. TEMPERATURE



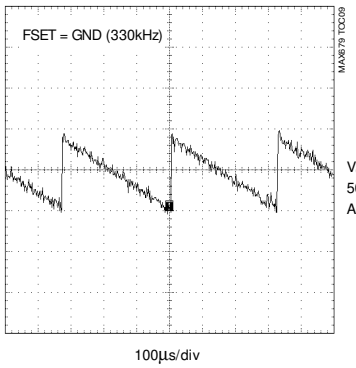
PUMP FREQUENCY vs. TEMPERATURE



PUMP FREQUENCY vs. TEMPERATURE



OUTPUT RIPPLE (2mA LOAD)

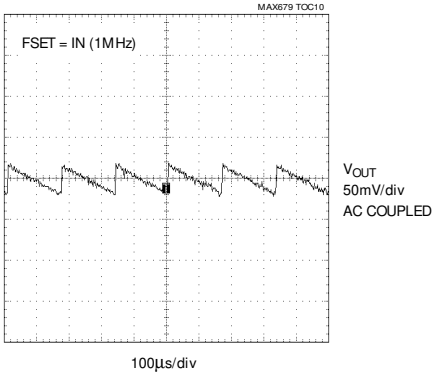


Regulated 3.3V Charge Pump

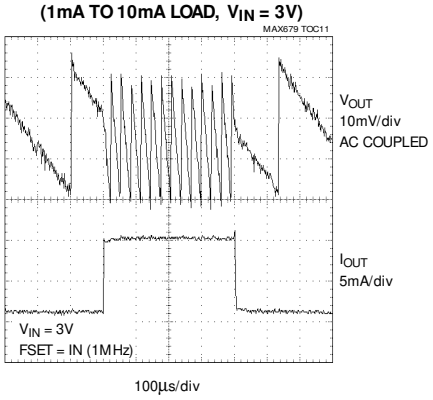
Typical Operating Characteristics (continued)

(Typical Operating Circuit with: $V_{IN} = V_{\overline{SHDN}} = 2V$, $C_{IN} = 4.7\mu F$, C1 = 0.33µF, $C_{OUT} = 10\mu F$, tested in-circuit, $T_A = +25°C$, unless otherwise noted.)

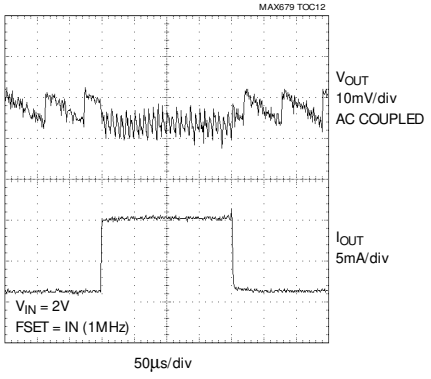
OUTPUT RIPPLE (2mA LOAD)



LOAD-TRANSIENT RESPONSE (1mA TO 10mA LOAD, V_{IN} = 3V)



LOAD-TRANSIENT RESPONSE (1mA TO 10mA LOAD, V_{IN} = 2V)



Pin Description

PIN	NAME	FUNCTION
1	FSET	Set Charge-Pump Frequency Input. FSET = GND selects 330kHz and FSET = IN selects 1MHz. Do not leave FSET unconnected.
2	$\overline{SHDN}$	Shutdown Input. The device shuts down, the output disconnects from the input, and the supply current decreases to 1µA when $\overline{SHDN}$ is a logic low. Connect $\overline{SHDN}$ to IN for normal operation.
3	IN	Supply Input. Connect to an input supply in the 1.8V to 3.6V range. Bypass IN to GND with a (C_{OUT} / 2)µF capacitor.
4	GND	Ground. Analog ground for internal reference and control circuitry.
5	PGND	Power Ground. Charge-pump current flows through this pin.
6	C1-	Negative Terminal of the Charge-Pump Capacitor
7	C1+	Positive Terminal of the Charge-Pump Capacitor
8	OUT	3.3V Power Output. Bypass OUT to GND with an output filter capacitor (see the *Design Procedure* section).

Detailed Description

The MAX679 regulated charge pump has a 50% duty-cycle clock. In phase one (charge phase), the charge-transfer capacitor (C1) charges to the input voltage, and output current is delivered by the output filter capacitor (C_{OUT}). In phase two (transfer phase), C1 is placed in series with the input and connects to the output, transferring its charge to C_{OUT}. If the clock were to run continuously, this process would eventually generate an output voltage equal to two times the input voltage (hence the name “doubler”).

The charge pump regulates by gating the oscillator on and off as needed to maintain output regulation. This method has low quiescent current, but to achieve acceptable output ripple, C1 must be significantly lower in value than C_{OUT}.

Start-Up Sequence

The MAX679 soft-start circuitry prevents excessive current from being drawn from the battery at start-up or when the output is shorted. This is done by limiting the charge pump to 1/10 the normal current until either the output is in regulation or the first 4096 charge-pump

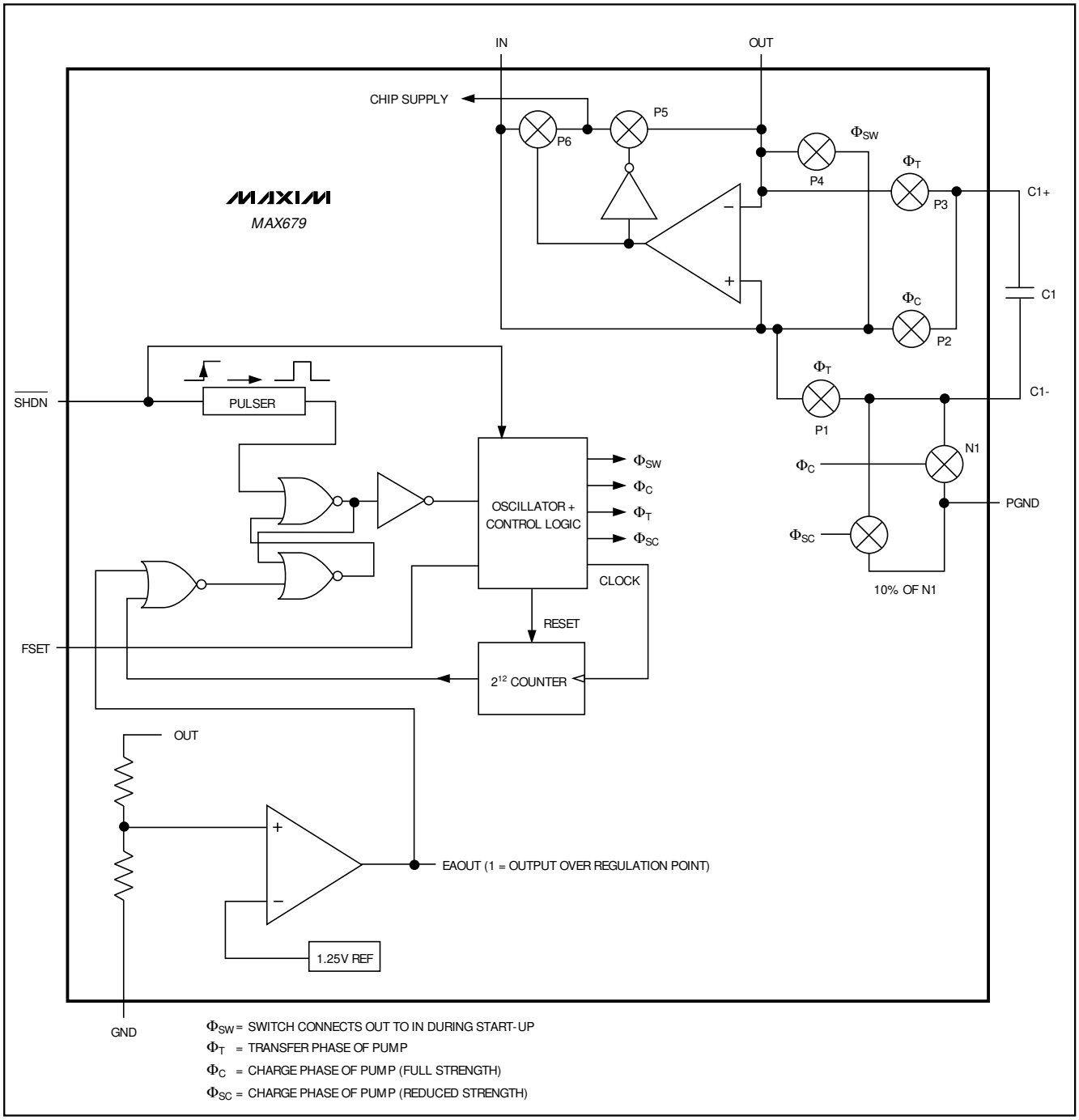


Figure 1. Block Diagram

Regulated 3.3V Charge Pump

cycles (about 4ms) have elapsed. The start-up sequence begins at power-up, when exiting shutdown, or when recovering from a short circuit. If V_{IN} is less than the 1.6V UVLO threshold, the device remains shut down and ignores a high $\overline{SHDN}$ input.

Design Procedure

Optimize the charge-pump circuit for size, quiescent current, and output ripple by properly selecting the operating frequency and capacitors C_{IN}, C1, and C_{OUT}.

For lowest output ripple, select 1MHz operation (FSET = IN). In addition, increasing C_{OUT} relative to C1 will further reduce ripple. For highest efficiency, select 330kHz operation (FSET = GND) and select the largest practical values for C_{OUT} and C1 while maintaining a 30-to-1 ratio. See Table 1 for some suggested values and the resulting output ripple.

Note that the capacitors must have low ESR (<20mΩ) to maintain low ripple. Currently, only ceramic capacitors can provide such low ESR; therefore, the output filter capacitors should be a combination of a 1µF ceramic capacitor and a 10µF tantalum capacitor.

Smallest Size

Set the frequency to 1MHz by connecting FSET to IN. Table 1 shows typical external component values.

Table 1. External Component Selection

V_{IN} (V)	C1 (µF)	C_{OUT} (µF)	FSET (Hz)	Vp-p (mV)
2	0.33	10	1M	7
2	0.33	10	330k	14
2	0.1	3.3	1M	16
2	0.1	3.3	330k	22
3	0.33	10	1M	27
3	0.33	10	330k	56
3	0.1	3.3	1M	72
3	0.1	3.3	330k	89

PC Board Layout

Place C1, C_{OUT}, and C_{IN} close to the IC. Connect PGND and GND with a short trace.

Efficiency

Charge-pump efficiency is best at low frequency (330kHz). The theoretical maximum efficiency is given in the following equation:

Theoretical maximum efficiency = V_{OUT} / (2 x V_{IN})

Gate-charge losses amount to approximately 1mA from the output at full switching frequency (about 5% to 7% loss).

Table 2. Manufacturers of Low-ESR Capacitors

PRODUCTION METHOD	MANUFACTURER	CAPACITORS	PHONE	FAX
Surface-Mount Tantalum Capacitors	AVX	TPS series	(803) 946-0690	(803) 626-3123
	Matsuo	267 series	(714) 969-2491	(714) 960-6492
	Sprague	593D, 595D series	(603) 224-1961	(603) 224-1430
Surface-Mount Ceramic Capacitors	AVX	X7R	(803) 946-0690	(803) 626-3123
	Matsuo	X7R	(714) 969-2491	(714) 960-6492

Chip Information

TRANSISTOR COUNT: 819

SUBSTRATE CONNECTED TO GND