Low Noise Charge Pump/Linear Regulator LED Driver

Features

- Low noise regulator with integrated charge pump voltage-booster
- 5V output with input voltage as low as 3.0V
- Charge pump can also power external LDO
- Low noise in 20Hz to 20kHz audio band
- Up to 200mA continuous output current
- Low operating and shutdown currents
- Stable with low-ESR ceramic or tantalum capacitors
- 10-lead MSOP package
- Lead-free version available

Applications

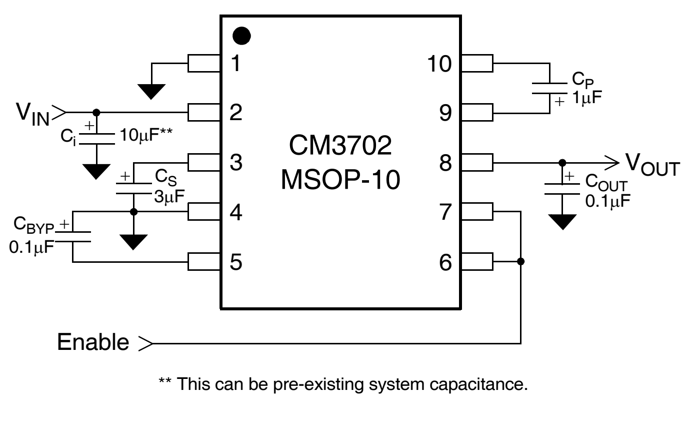
- Backlight white LEDs in wireless handsets and LCD modules
- 3.3V to 5V conversion in PCMCIA cards, PCI Express Cards, other applications needing 5V
- 5V analog supply for audio codec in notebook computers, PDAs, MP3 players, etc.

Product Description

The CM3702 low-noise charge pump LDO regulator is designed to provide accurate and "clean" power to a subsystem, e.g an LED driver, audio codec or flash memory. The 5V output provides up to 100mA continuous current for input voltages from 3.0V to 5.5V, and up to 200mA for a narrower range. This is accomplished with an integrated charge pump that boosts the input voltage before feeding it to an internal LDO linear regulator. The charge pump is designed to maintain a nominal 0.8V differential between the input and output of the LDO regulator. This allows the LDO regulator to operate with good power supply ripple rejection across the audio band while maintaining good power efficiency. The charge pump works with two external capacitors and operates at 250kHz, well outside the audible frequency band. In addition, separate analog and digital ground pins are provided for the charge pump and the rest of the circuitry to eliminate ground noise feed-through from the charge pump to the regulated output.

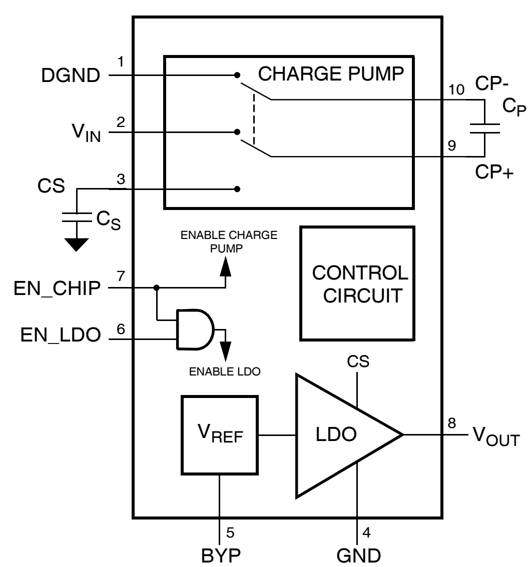
The CM3702 is fully protected, offering both overload current limiting and high temperature thermal shutdown. *(cont'd next page)*

Typical Application



** This can be pre-existing system capacitance.

Simplified Block Diagram



Product Description (cont'd)

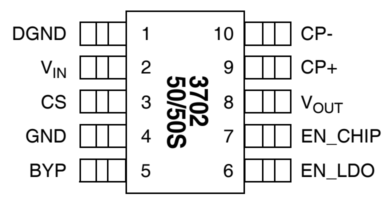
Two enable inputs provide flexibility in powering down the device. For maximum power saving in shutdown, both the charge pump and LDO regulator should be disabled. For applications that require the 5V output to be re-established with minimum delay after shutdown, the charge pump can be left enabled while the regulator is disabled. This avoids the delay that may otherwise be required for the charge pump to reach full operating voltage after being disabled. The CMOS LDO regulator features low quiescent current even at full load, making it very suitable for power sensitive applications.

A bandgap reference bypass pin is provided to further minimize noise by connecting an external capacitor between this pin and ground. Another, external, regulator can be connected to the charge pump output pin CS, if required.

The CM3702 is available in a 10-lead MSOP package, with optional lead-free finishing and is ideal for space critical applications.

PACKAGE / PINOUT DIAGRAM

Top View



10-Lead MSOP-10

CM3702-50MS/MR
10 Lead MSOP Package

Note: This drawing is not to scale.

PIN DESCRIPTIONS

LEAD(S)	NAME	DESCRIPTION
1	DGND	Ground for the charge pump circuit. This should be connected to the system (noisy) ground.
2	V_{IN}	Input power source for the device. Since the charge pump draws current in pulses at the 250kHz internal clock frequency, a low-ESR input decoupling capacitor is usually required close to this pin to ensure low noise operation.
3	CS	Charge pump output which is connected to the external reservoir capacitor C_S. This should be a low-ESR capacitor. When the voltage on this pin reaches about 5.8V then the charge pump pauses until the voltage on this pin drops to about 5.7V. This gives rise to at least 100mV of 'ripple' (the frequency and amplitude of this ripple depends upon values of C_P and C_S and also the ESR of C_S).
4	GND	Ground reference for all internal circuits except the charge pump. This pin should be connected to a "clean" low-noise analog ground
5	BYP	Bypass input connected to the internal voltage reference of the LDO regulator. An external bypass capacitor C_{BYP} of 0.1uF may be added to minimize internal voltage reference noise and maximize power supply ripple rejection.

PIN DESCRIPTIONS (CONT'D)		
6, 7	EN_LDO, EN_CHIP	EN_LDO (pin 6) and EN_CHIP (pin 7) are active-high TTL-level logic inputs to enable the linear regulator and charge pump according to the following truth table:
8	V_{OUT}	The regulated output. An output capacitor may be added to improve noise and load-transient response. When the LDO regulator is disabled, an internal pull-down with a nominal resistance of 500 ohms is activated to discharge the V_{OUT} rail to GND
9, 10	CP+, CP-	CP+ (pin 9) and CP- (pin 10) are used to connect the external "flying" capacitor C_P to the charge pump. The charge stored in C_P is transferred to the reservoir capacitor C_S at the 250kHz internal clock rate.

EN_CHIP (Pin 7)	EN_LDO (Pin 6)	CHARGE PUMP	REGULATOR
1	1	Enabled	Enabled
1	0	Enabled	Disabled
0	1	Disabled	Disabled
0	0	Disabled	Disabled

Ordering Information

PART NUMBERING INFORMATION					
		Standard Finish		Lead-free Finish	
Leads	Package	Ordering Part Number[1]	Part Marking	Ordering Part Number[1]	Part Marking
10	MSOP-10	CM3702-50MS	3702 50S	CM3702-50MR	3702 50

Note 1: Parts are shipped in Tape & Reel form unless otherwise specified.

Specifications

ABSOLUTE MAXIMUM RATINGS		
PARAMETER	**RATING**	**UNITS**
ESD Protection (HBM)	2000	V
V_{EN} Logic Input Voltage	(V_{IN} + 0.5) to (GND - 0.5)	V
$V_{IN,}$ V_{OUT} Pin Voltages	+5.5 to (GND - 0.5)	V
Storage Temperature Range	-40 to +150	°C
Operating Temperature Range Ambient Junction	 0 to +70 0 to +170	 °C °C

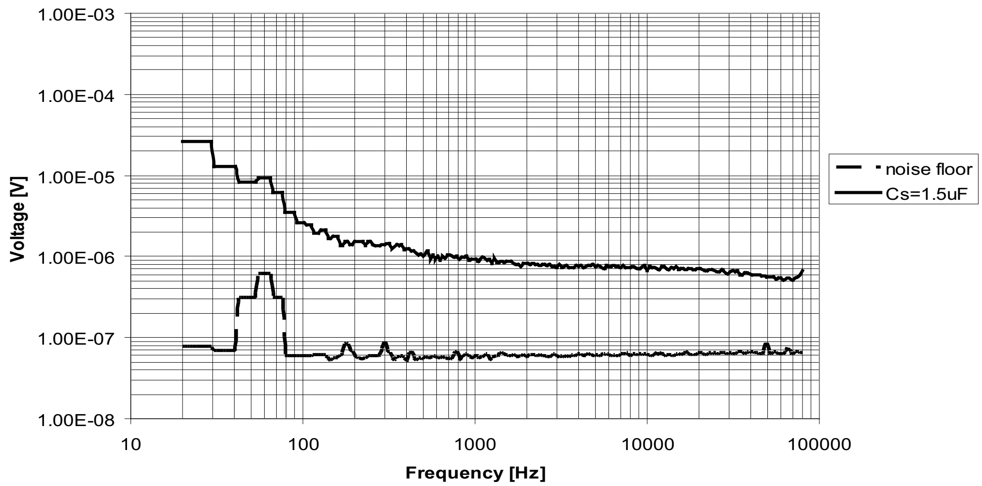
STANDARD OPERATING CONDITIONS		
PARAMETER	**VALUE**	**UNITS**
Input Voltage Range (V_{IN})	3.0 to 5.5	V
Ambient Operating Temperature	0 to +70	°C
θ_{JA} of MSOP package on PCB	200 (approx.)	°C/W
Output Load Current (I_{OUT})	0 to 200	mA
C_{BYP}	0 to 0.1	μF
C_{OUT}	0 to 100	μF

Specifications (cont'd)

ELECTRICAL OPERATING CHARACTERISTICS (SEE NOTE 1)						
SYMBOL	**PARAMETER**	**CONDITIONS**	**MIN**	**TYP**	**MAX**	**UNITS**
V_{CP}	Charge Pump Output Voltage	V_{IN} = 4V, V_{OUT} = 5V, 1mA ≤ I_{OUT} ≤ 100mA	5.5	5.8	7	V
V_{OUT}	Regulator Output Voltage	V_{IN} = 4.0V, 1mA ≤ I_{OUT} ≤ 100mA	4.85		5.15	V
$V_{R\ LOAD}$	Load Regulation	I_{OUT} = 1mA to 100mA		0.2		%
$V_{R\ LINE}$	Line Regulation	Vary V_{IN} from 3.0V to 5.0V		0.02		%
R_{DISCHG}	V_{OUT} Discharge Resistance	LDO regulator disabled, EN_LDO grounded, V_{IN} = 5V		500		Ω
I_{GND}	LDO Regulator Ground Current via the GND pin	Shutdown (EN_LDO grounded)		1	10	μA
		Regulator Enabled, I_{OUT} = 0mA		180		μA
		Regulator Enabled, I_{OUT} = 100mA		180		μA
I_{DGND}	Charge Pump Shutdown Current via DGND pin	EN_CHIP grounded, V_{IN} = 5V		1	10	μA
PSRR	Power Supply Ripple Rejection	I_{OUT} = 100mA, C_{BYP} =0.1μF, Note 2 *f* = 100Hz *f* = 10kHz		 42 42		 dB dB
e_{NO}	Output Voltage Noise	BW=22Hz-22kHz, C_{OUT} = 10μF, C_{BYP} = 0.1μF, I_{OUT} = 100mA, Note 2		35		μVrms
		BW=22Hz-22kHz, C_P = 1μF, C_S =3μF, C_{OUT} = C_{BYP} = 0.1μF, I_{OUT} = 100mA, Note 2		38		μVrms
V_{IH}	EN_CHIP, EN_LDO Input High Threshold	V_{IN} = 5.0V	2.0			V
V_{IL}	EN_CHIP, EN_LDO Input Low Threshold	V_{IN} = 5.0V			0.5	V
I_{LIM}	Overload Current Limit	LDO Only, Note 2	200	300		mA
I_{SC}	Output Short Circuit Current	LDO Only, Note 2		50		mA
T_{JSD}	Thermal Shutdown Junction Temperature	Note 2		170		°C
T_{HYS}	Thermal Shutdown Hysteresis	Note 2		25		°C

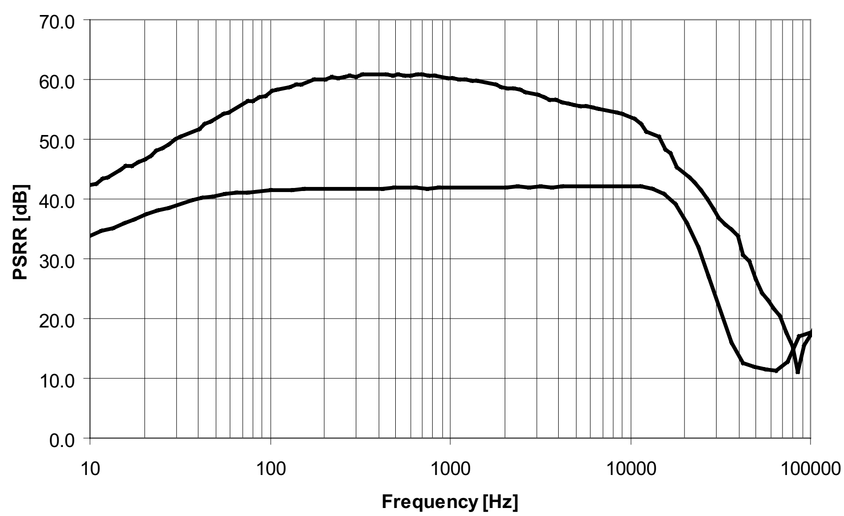
Note 1: Unless otherwise noted, electrical operating characteristics are specified with T_A = 0 to 70°C, V_{IN} = 5.0V, I_{OUT} =100mA, C_{OUT}=10μF, C_P = 1μF, C_S = 2.2μF.
Note 2: These parameters are guaranteed by design and characterization.

Performance Information



Note: Noise peaks may appear for different values of C_P, C_S & I_{OUT}, and are due to the ripple frequency of the charge pump (see later).

Figure 1. CM3702 Noise Spectrum (T_A = 25°C, C_P=0.47µF, C_S = 1.5µF, C_O = C_{BYP} = 0.1µF, I_{OUT} =100mA)



Measured by forcing V_{IN} voltage to 3.3V & 5.0V dc, then sweeping 100mV ac on V_{IN}. C_{OUT} = 10µF, C_{BYP} = 0.1µF.

Figure 2. CM3702 PSRR (upper curve with V_{IN} = 3.3V, lower curve with V_{IN} = 5V, I_{OUT} = 100mA both cases)

Performance Information (cont'd)

Typical DC Characteristics (T_A=25°C, C_P=1.0µF, C_S=10µF, C_{BYP}=0.1µF, C_{OUT}=10µF unless otherwise noted)

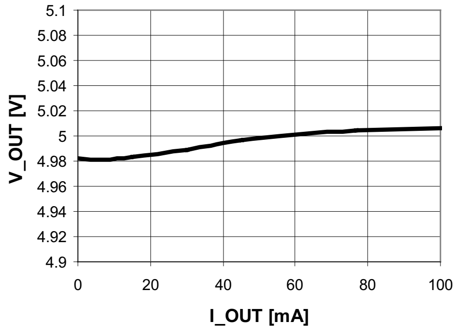


Figure 3. V_{OUT} vs. I_{OUT} (V_{IN} = 5V)

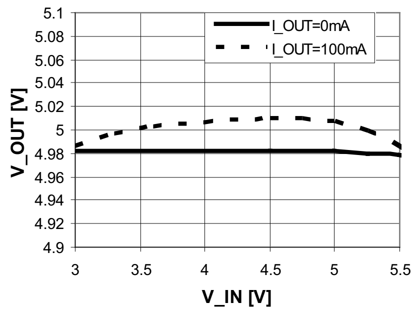


Figure 4. V_{OUT} vs. V_{IN}

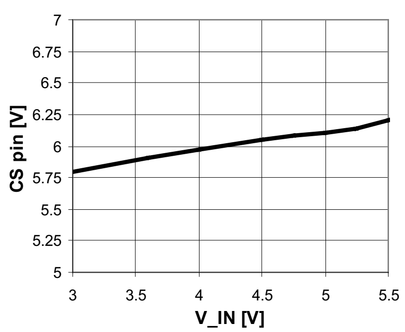


Figure 5. CS Pin vs. V_{IN}

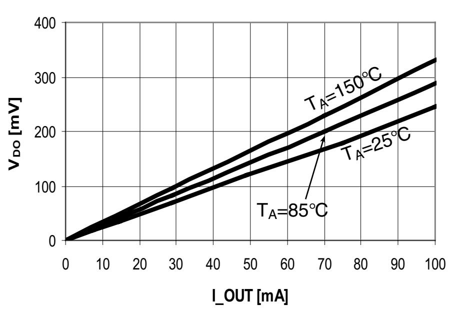


Figure 6. Dropout Voltage (LDO Only)

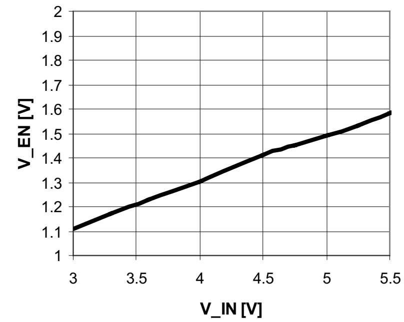


Figure 7. V_{EN} Threshold vs. V_{IN}

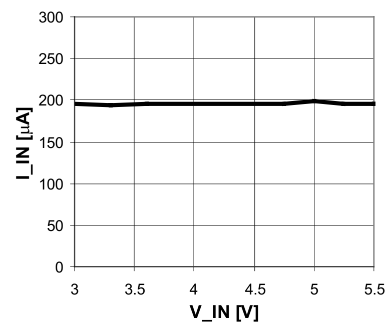


Figure 8. I_{IN} vs. V_{IN}

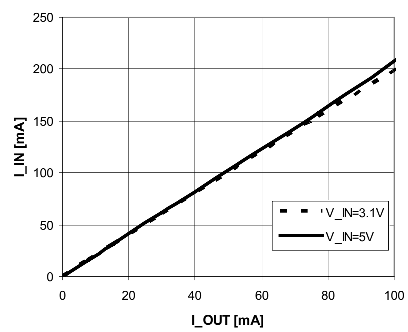


Figure 9. I_{IN} vs. I_{OUT}

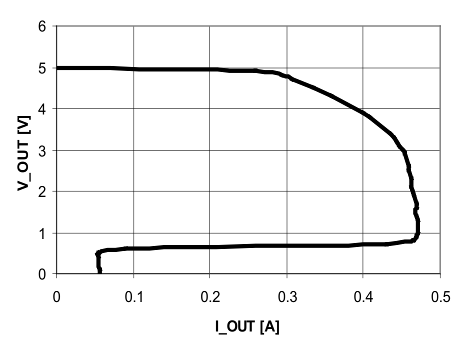


Figure 10. Overcurrent Characteristic (LDO only)

Performance Information (cont'd)

Transient Characteristics (T_A=25°C, C_P=1.0µF, C_S=10µF, C_{BYP}=0.1µF, C_{OUT}=10µF unless otherwise noted)

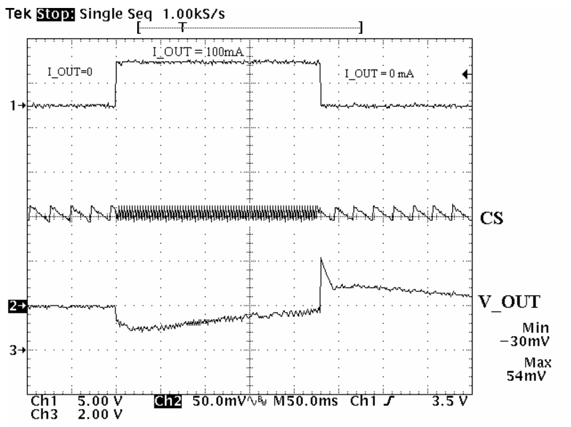


Figure 11. Load Regulation (0mA to 100mA)

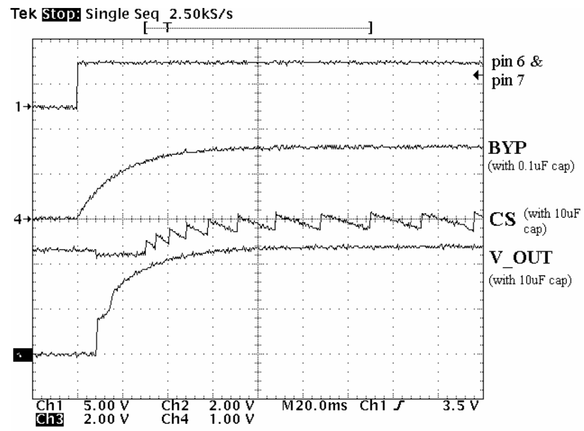


Figure 14. Cold Start / Power-Up

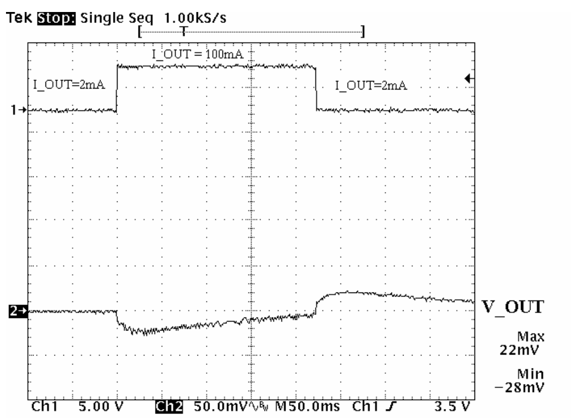


Figure 12. Load Regulation (2mA to 100mA)

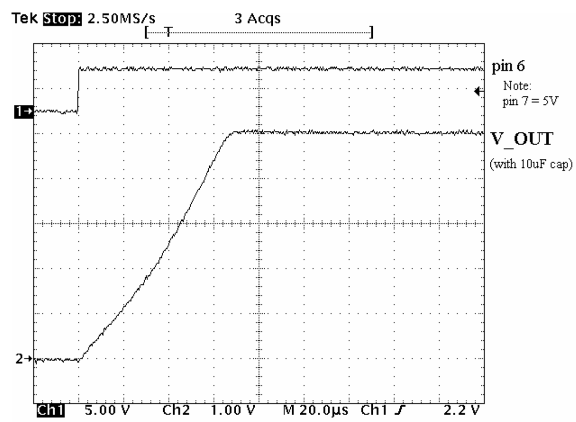


Figure 15. LDO Power-Up

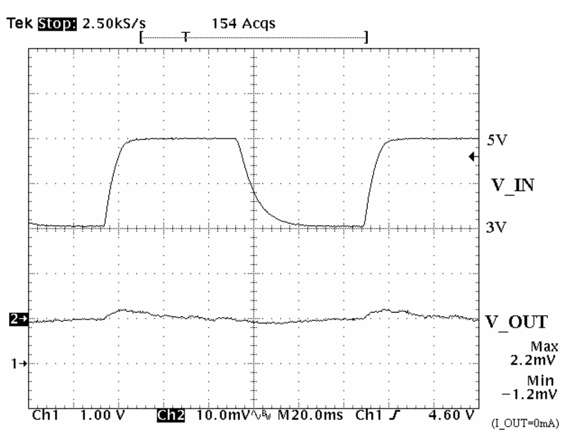


Figure 13. Line Regulation

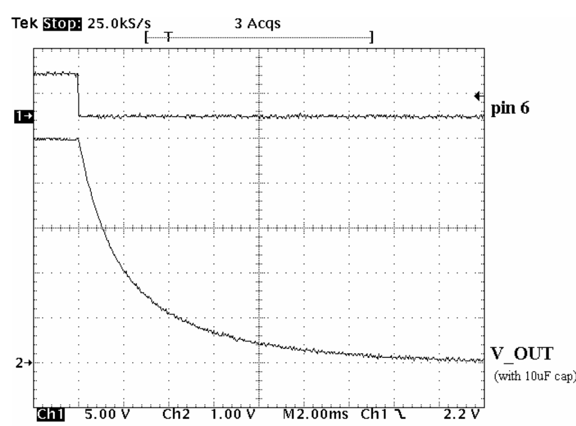


Figure 16. LDO Power-Down

Performance Information (cont'd)

Transient Characteristics (T_A=25°C, V_{IN}=5V, C_P=1.0μF, C_S=10μF, C_{BYP}=0.1μF, C_{OUT}=10μF unless otherwise noted)

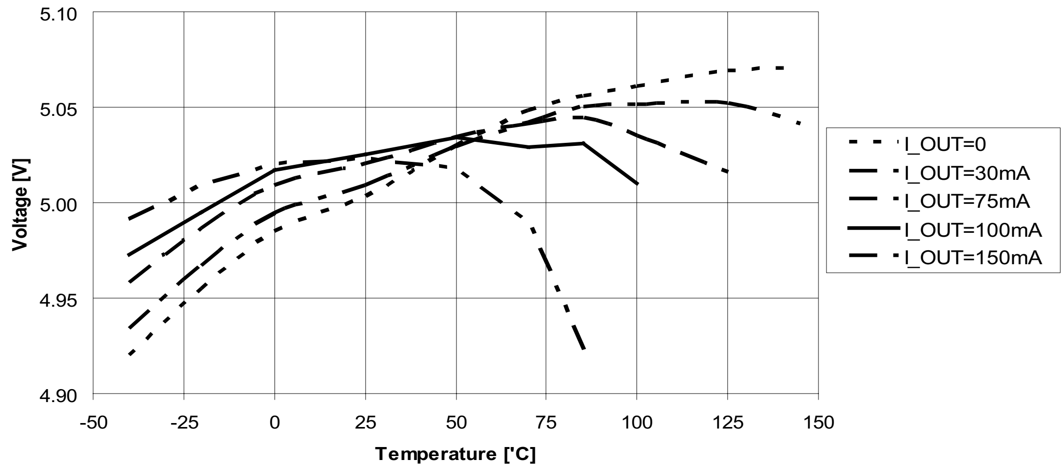


Figure 17. V_{OUT} with V_{IN} = 5V

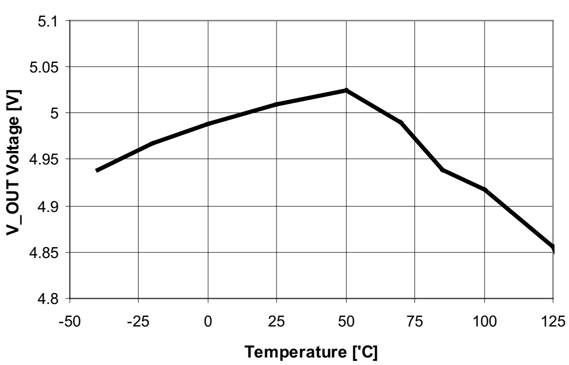


Figure 18. V_{OUT} with V_{IN}=3.0V, I_{OUT}=100mA

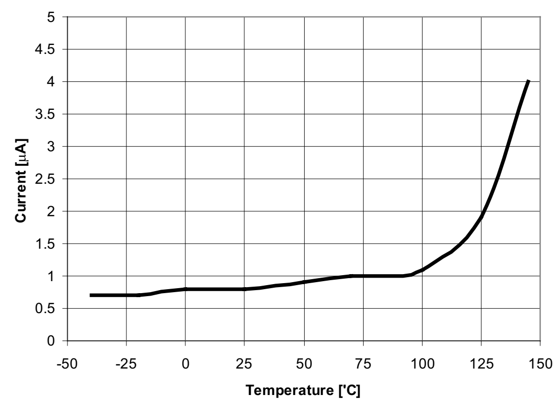


Figure 20. I_{IN} Leakage Current (Pins 6,7=0V)

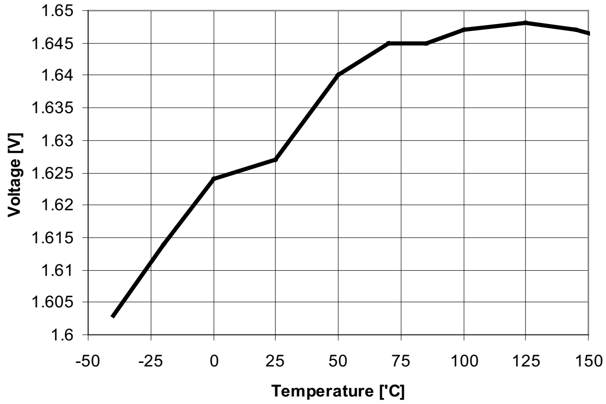


Figure 19. Bypass Pin Voltage

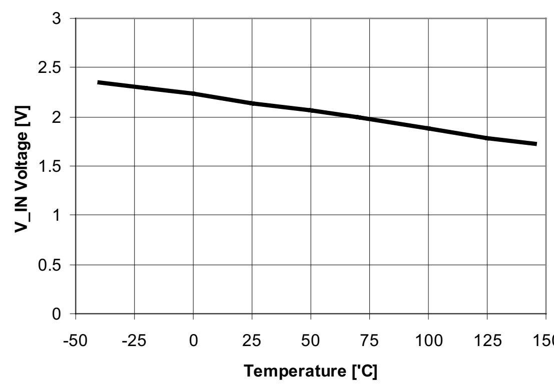


Figure 21. Undervoltage Lockout

Application Information

Ripple Frequency

The charge pump internal oscillation frequency is about 250kHz. However, this is the continuous, free-running frequency, which is usually only seen while the charge pump is powering up. After the charge pump output voltage (CS) reaches approximately 5.8V, the charge pump pauses until the CS voltage drops to approximately 5.7V. Then the charge pump restarts and runs until the CS voltage is greater than approximately 5.8V, when it pauses again, and this process repeats. This gives rise to a sawtooth 'ripple' waveform on CS which can have a much lower frequency than 250kHz. This mode of operation is necessary to conserve power - if it were not done this way then a much larger package with heatsink would be required.

The frequency of this 'ripple' is affected by V_{IN}, I_{OUT}, C_S capacitor value and C_P capacitor value.

Guidelines for Choosing Values for External Capacitors

(1) To find C_P: specify value of V_{IN}, and highest value of I_{OUT}:

If V_{IN}= 3.3V +/- 5%, then minimum value of C_P (µF) = I_{OUT} (mA) / 85.

If V_{IN}= 5.0V +/- 10%, then minimum value of C_P (µF) = I_{OUT} (mA) / 700

(2) C_i, the V_{IN} decoupling capacitor, should typically be much greater than C_P to prevent voltage droop during C_P charging.

Excessive glitches on V_{IN} will affect the output voltage V_{OUT}.

Typically C_i is 10X greater than C_P. But usually there are already some capacitors on this supply, so adding extra capacitors is not necessary - simply move an already-present low-ESR capacitor close to the CM3702.

This is especially important for V_{IN} = 5V.

(3) Choose value of C_S. C_S should be small to ensure that the ripple frequency is high, but C_S should be at least 2x greater than C_P otherwise the ripple amplitude will be very high. Reducing the value of C_S will increase the ripple frequency.

Examples of CS ripple frequencies (C_S=10µF, T_A=25°C) are shown in following tables:

C_P = 0.47µF		
V_{IN}	I_{OUT}	CS Frequency
3.14	15mA	46kHz
3.60	15mA	35kHz
4.50	70mA	76kHz
5.50	70mA	56kHz

C_P = 1.0µF		
V_{IN}	I_{OUT}	CS Frequency
3.14	100mA	250kHz
3.60	100mA	110kHz
4.50	100mA	67kHz
5.50	100mA	49kHz

(4) C_O, the optional V_{OUT} decoupling capacitor, helps minimize noise and improve load regulation. 0.1µF - 100µF is recommended.

(5) C_{BYP}, the optional bypass capacitor helps reduce noise in the LDO. 0.1µF is recommended.

After choosing external component values, check in-system performance (at min/max V_{IN}, max temperature, and min/max I_{OUT}). See the troubleshooting guide on next page for tips if there are problems.

Charge Pump Noise

The charge pump is 'digital' in operation and can produce digital noise at both the free-running frequency and at the ripple frequency.

To minimize noise, PCB grounding is important! This part requires short, low-impedance ground connections for DGND (pin 1), GND (pin 4), the V_{IN} decoupling capacitor (pin 2), the C_S capacitor (pin 3), the Bypass decoupling capacitor (pin 5) and the V_{OUT} decoupling capacitor (pin 8). All decoupling capacitors and the C_S capacitor should be low-ESR ceramics. The C_P capacitor does NOT need to be low-ESR.

Efficiency

The power efficiency in % of the combined charge pump and LDO is approximately:

$$100 \times (V_{OUT}) \ / \ (V_{IN} \times 2)$$

Power Dissipation

The dissipation of the part is approximately:

$$((V_{IN} \times 2) - V_{OUT}) \times I_{OUT}$$

The MSOP-10 package heats at a rate of about 200°C/W (θ_{JA}). Note that this value is approximate because it depends upon the copper tracks and ground planes on the pcb. If V_{IN} = 5V and I_{OUT} = 100mA then the power dissipation will be approximately 500mW. Multiplying this by the θ_{JA} of 200, the part's internal temperature will be about 100°C higher than the ambient temperature. If the ambient temperature is 70°C then the internal temperature will be approximately 170°C which will typically trigger the overtemperature circuit and depower the part.

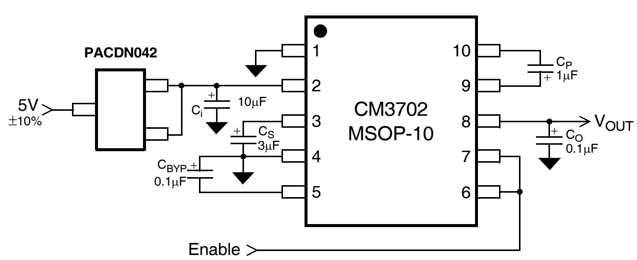
Internal temperature = Ambient temperature + (θ_{JA} x Power dissipation)

(Must be less than 170°C)

How to Reduce the Power Dissipation of the Part and How to Get More Than 100mA

If V_{IN} = 5V typ., then the charge pump / LDO combination is capable of providing more than 100mA. The only problem is power dissipation.

If the input voltage is lowered using an external diode then the output current can be increased without causing the part to overheat. The circuit below illustrates an example of how to increase the output current.



Using this circuit, I_{OUT} can be 200mA if V_{IN} = 4.75V, and yet the part will not overheat even if V_{IN} = 5.25V, I_{OUT}=200mA and the ambient temperature is 85°C.

Warnings

The charge pump output CS (pin 3) must not be shorted to GND or held below its internally-set voltage while the part is powered. This usually results in the destruction of the part.

With V_{IN} = 5V, the maximum current that can be continuously drawn from CS is approximately 100mA dc.

Never short C_P+ (pin 9) to C_P- (pin 10). This will cause large currents to flow from V_{IN} to DGND through the part, usually causing its destruction. This will happen even if EN_CHIP and EN_LDO are off.

Troubleshooting Guide

1) *Is the output voltage is drooping under heavy loads?* Perhaps the charge pump cannot provide the necessary current. Try increasing the value of C_P. If that does not work then is V_{IN} too low? Is V_{IN} dropping during the C_P charging cycle? If V_{IN} is not suitably decoupled and drops below 3.0V then the available current will be very low.

2) *Is the output voltage oscillating between 5V and 0V?* The part may be reaching its overtemperature limit. Reduce current consumption, reduce θ_{JA} or add an external diode on the input to reduce V_{IN}.

3. *Is the part too noisy?* Try increasing value (or reducing ESR) of C_S, C_i, C_O, C_{BYP}. At minimum current the charge pump ripple frequency will be low. If V_{OUT} noise is at the charge pump ripple frequency then change values of C_P and C_S. Reducing the input voltage V_{IN} will reduce the charge pump ripple frequency noise on V_{OUT}.

4. *Will the part power up?* Pin 6 must be HIGH to power up. Even if pin 7 is HIGH, pin 6 must also be high to power up.

5. *Can the cold start power-up time be reduced?* Yes, by reducing the value of the BYP capacitor.

Mechanical DetailsMechanical Details

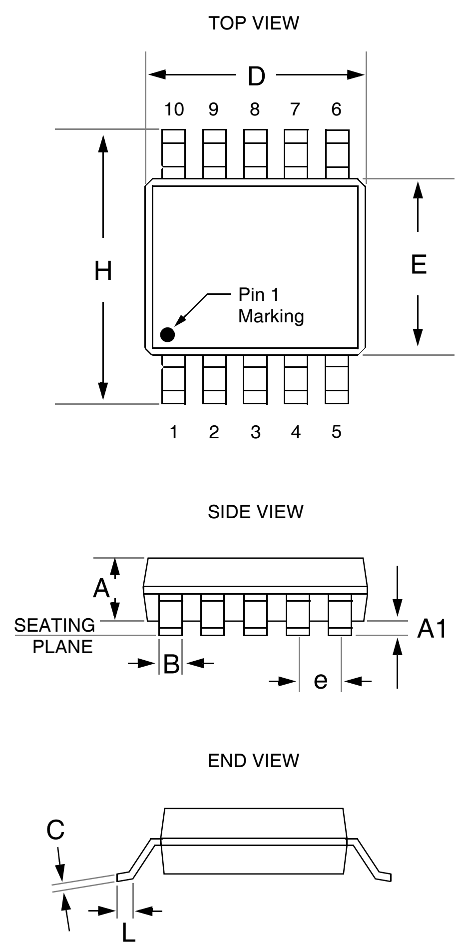
MSOP-10 Mechanical Specifications

CM3702-50MS/MR is packaged in 10-pin MSOP package. Dimensions are presented below.

For complete information on the MSOP-10 package, see the California Micro Devices MSOP Package Information document.

PACKAGE DIMENSIONS				
Package	MSOP			
Pins	10			
Dimensions	**Millimeters**		**Inches**	
	Min	**Max**	**Min**	**Max**
A	0.75	0.95	0.028	0.038
A1	0.05	0.15	0.002	0.006
B	0.17	0.27	0.007	0.011
C	0.18		0.007	
D	2.90	3.10	0.114	0.122
E	2.90	3.10	0.114	0.122
e	0.50 BSC		0.0197 BSC	
H	4.90 BSC		0.193 BSC	
L	0.40	0.70	0.0137	0.029
# per tape and reel	4000			
Controlling dimension: millimeters				

Mechanical Package Diagrams



Package Dimensions for MSOP-10