ML4873

Battery Power Control IC

GENERAL DESCRIPTION

The ML4873 is a complete solution for DC to DC conversion and power management in multi-cell battery powered portable computers and instruments. Several advanced techniques are incorporated in the IC for the highest possible system efficiency and lowest battery drain.

The 5.0V and 3.3V main regulators in the ML4873 each control synchronous rectified buck regulators and drive N-channel MOSFETs. This allows high conversion efficiencies (90% or greater). The drive for the upper N-channel MOSFETs in the system is provided via a separate input from a charge pump.

A special "burst mode" for efficient low current operation is provided on one of the regulators for suspend mode.

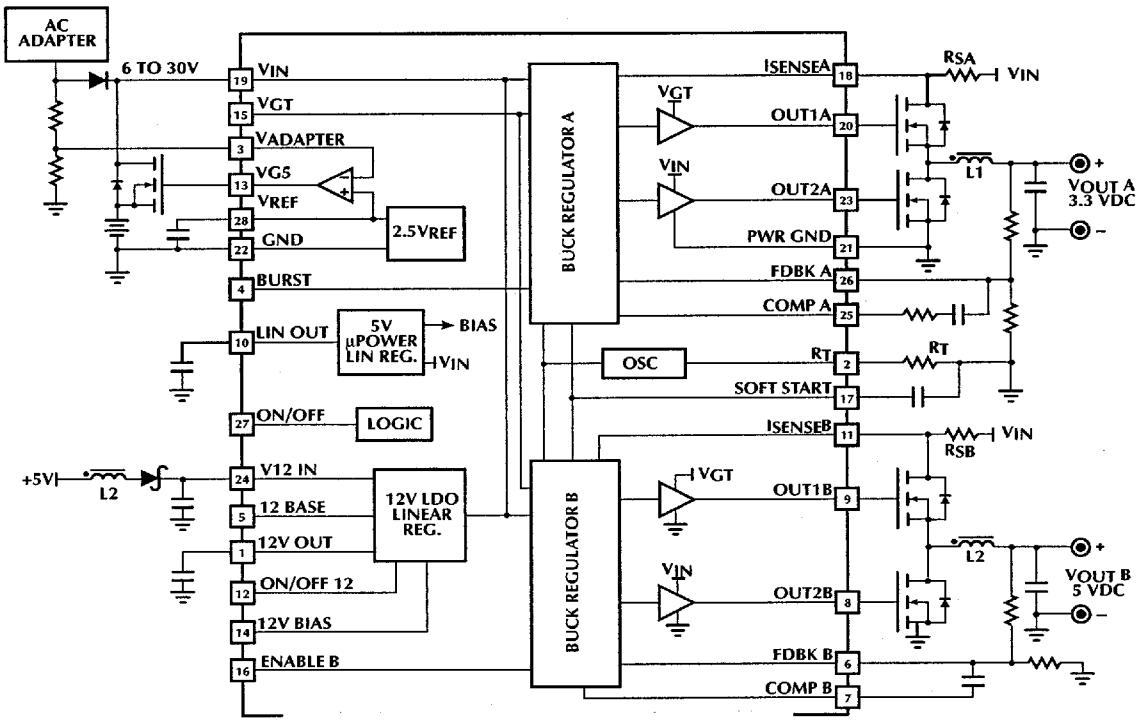
A low drop-out 12V linear regulator for programming EEPROMs or PCMCIA is provided on chip with a separate input, provided by either a winding on the main inductor or from the battery pack.

A µPower 5V linear regulator is provided for the power monitoring logic. The IC can be turned off with only the 5V regulator operating.

FEATURES

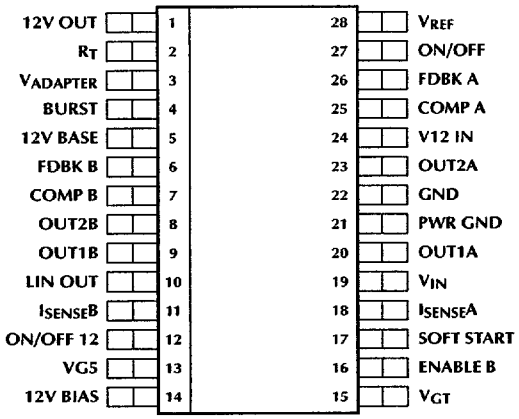
- Two synchronously rectified, 100kHz buck regulators for 5V and 3.3V outputs
- Regulation to ±3% maximum: provides 2% PCMCIA switch matrix margin.
- N-channel MOSFET drive for lowest cost
- Burst mode for efficient operation at light load
- µPower 5V standby linear regulator for power management logic
- 12V low drop out linear regulator with high output (to 300mA) capability
- Automatic charger disconnect switch comparator and N-channel driver
- Wide input voltage range (5.5V to 30V)
- 28-Lead SOIC or SSOP packages

BLOCK DIAGRAM



PIN CONFIGURATION

ML4873
28-PinSOIC (S28W)
or 28-Pin SSOP (R28)



TOP VIEW

PIN DESCRIPTION

PIN#	NAME	FUNCTION
1	12V OUT	12V Low Drop-Out regulator output
2	R_T	Timing Resistor which sets oscillator frequency
3	$V_{ADAPTER}$	Input to sense whether adapter is active. VG5 goes high when this pin is above V_{REF}.
4	BURST	A logic 1 sets Buck Regulator A into burst mode (see table 1)
5	12V BASE	Connection to increase 12V regulator output current with external NPN pass transistor
6	FDBK B	Voltage Feedback for buck regulator B
7	COMP B	Buck Regulator B frequency compensation terminal
8	OUT2B	5V Buck Regulator Switch Output
9	OUT1B	5V Buck Regulator Synchronous Rectifier Output
10	LIN OUT	Output of the µPower 5V regulator. Normally used to power external management circuits and logic
11	$I_{SENSE}B$	Current Sensing for buck regulator B Current limit
12	ON/OFF 12	A logic 1 turns on the 12V regulator
13	VG5	Output to drive N-Channel MOSFET gate to switch battery out when adapter is present
14	12V BIAS	Bias supply for 12V Regulator
15	V_{GT}	N-Channel high side gate drive
16	ENABLE B	A logic 1 enables buck regulator B
17	SOFT START	Soft Start Capacitor
18	$I_{SENSE}A$	Current Sensing for buck regulator A current limit
19	V_{IN}	Input from Battery or AC Adapter
20	OUT1A	3.3V Buck Regulator Switch Output
21	PWR GND	Power Ground
22	GND	Logic and signal Ground
23	OUT2A	3.3V Buck Regulator Synchronous Rectifier Output
24	V12 IN	Power Input for the 12V regulator
25	COMP A	Buck Regulator A frequency compensation terminal
26	FDBK A	Voltage Feedback for buck regulator A
27	ON/OFF	A low on this pin disables all IC functions except the linear 5V regulator and the 2.5V reference, and puts the IC onto a low current consumption mode
28	V_{REF}	Buffered 2.5V reference output

ABSOLUTE MAXIMUM RATINGS

Absolute maximum ratings are those values beyond which the device could be permanently damaged. Absolute maximum ratings are stress ratings only and functional device operation is not implied.

Voltage on any pin 36V
Output Current Source or Sink (Pins 8, 9, 20, 23) .....
Pulsed 300mA
VG5 Source Current 20mA
VG5 Sink Current 200mA
12V Linear Regulator Output Current 200mA
5V Linear Regulator Output Current 50mA
Inputs (Pins 3, 4, 12, 16, 27) .....–0.3 to 5.5V
I_{SENSE} Inputs (Pins 11, 18) ..... V_{IN}
Junction Temperature ..... 150°C
Storage Temperature Range ..... –65°C to 150°C
Lead Temperature (Soldering 10 Sec.) ..... 260°C
Thermal Resistance (θ_{JA}) Plastic SOIC ..... 70°C/W
Thermal Resistance (θ_{JA}) Plastic SSOP ..... 80°C/W

OPERATING CONDITIONS

Temperature Range
Commercial ..... 0°C to 70°C
V_{IN} Voltage Range ..... 5.4V to 30V
V_{GT} Voltage Range ..... V_{IN} –0.5 to 35V

ELECTRICAL CHARACTERISTICS

Unless otherwise specified, T_A = Operating Temperature Range, V_{IN} = 12V, V12 IN = 14V, V_{GT} = 22V, R_T = 200kΩ (Note 1)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Oscillator					
Initial Accuracy		95	100	105	kHz
Dead Time	50K ≤ R_T ≤ 300K	600	800	1000	ns
Maximum Duty Cycle		90		97	%
Voltage Stability	6V ≤ V_{IN} ≤ 20V		2		%
Error Amplifiers					
Input Offset Voltage			2	10	mV
Input Bias Current			10	200	nA
Output High Voltage	I_{OUT} = –2mA	2.7	2.95		V
Output Low Voltage	I_{OUT} = 20µA			0.5	V
Source Current	V_{OUT} = 2.5V	–5	–7		mA
Sink Current	V_{OUT} = 2.5V		500		µA
Gain Bandwidth Product			675		kHz
High Side (Out 1) Outputs (Pins 9, 20)					
Output High Voltage	I_{OUT} = –20mA	19	21.3		V
Output Low Voltage	I_{OUT} = 20mA		0.2	0.5	V
Low Side (Out 2) Outputs (Pins 8, 23)					
Output High Voltage	I_{OUT} = –20mA	10			V
Output Low Voltage	I_{OUT} = 20mA		0.2	0.5	V
Soft Start and Current Limit (Pins 11, 17, 18)					
Voltage Threshold	From V_{IN}	–250	–200	–150	mV
Bias Current	V_{ISENSE} = V_{IN} –200mV		27	75	µA
Soft Start I_{CHARGE}		–6	–13	–20	µA
Soft Start $I_{DISCHARGE}$		3	6.2		mA

ELECTRICAL CHARACTERISTICS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Burst Regulator					
Start Threshold			V_{REF} – 25		mV
Stop Threshold			V_{REF} + 25		mV
Reference					
Output Voltage	T_A = 25°C, I_{PIN28} = –100µA	2.45	2.5	2.55	V
Line Regulation	5.4V < V_{IN} < 20V, I_{PIN28} ≤ –mA		0.3	1.2	mV/V
12V Linear Regulator					
Output Voltage	I_O = 60mA	11.5	12	12.5	V
Line Regulation	14V < V12 IN < 24V		0.01		%/V
Drop Out Voltage (V12 IN – 12V OUT)	I_O = 60mA		0.4		V
Load Regulation	10µA < I_O < 60mA		0.8	2.5	%
5V Linear Regulator					
Output Voltage	I_{OUT} = 100µA	4.8	5.0	5.2	V
Input Voltage	V_{OUT} ≥ 4.85V, I_O = 1mA	5.5			V
Line Regulation	5.4V < V_{IN} < 20V, I_O = 1mA		0.75	1.5	%
Load Regulation	10µA < I_O < 10mA		0.25	0.5	
$V_{ADAPTER}$ Comparator					
Input Bias Current				100	nA
Input Offset Voltage		–30		+30	mV
VG5 Source Current	V_{VG5} = 12V	–5	–10		mA
VG5 Sink Current	V_{VG5} = 12V	85			mA
Logic Inputs (Pins 4, 12, 16, 27)					
Logic Low (V_{IL})	I_{IN} ≥ –5µA			1.1	V
Logic High (V_{IH})	I_{IN} ≥ 5µA	2.5			V
Supply Current					
I_{VIN} + I_{VGT}	Sleep Mode, T_A = 25°C		190	250	µ
I_{VIN} + I_{VGT}	Bust Mode, T_A = 25°C		250		µ
I_{VIN}	Run Mode, T_A = 25°C		7	10	mA
I_{VGT}	Run Mode, T_A = 25°C		2	4	mA

Note 1: Limits are guaranteed by 100% testing, sampling, or correlation with worst case test conditions.

FUNCTIONAL DESCRIPTION

POWER DOWN MODES

The ML4873 operates in either a powered down mode or a run mode according to the state of the ON/OFF pin (Table 1). When the ON/OFF pin is high, the IC is in the run mode and all IC sections are functioning. When the ON/OFF pin is low, the IC is in the standby mode and only the µPower 5V linear regulator and 2.5V reference are on. All gate drive outputs are low. The 5V linear regulator then provides the power to run the system's power management logic. When the BURST pin is high, and the output is above the lower threshold of the burst comparator, the IC is also in standby mode, but with the burst comparator logic also running.

BUCK REGULATORS

The two buck regulators (Figure 3) are synchronously rectifying voltage mode PWM regulators capable of being used over a wide variety of loads and input voltages. The use of synchronous rectification improves system efficiency by reducing the fixed drop associated with the "freewheeling" diode in conventional regulators. These regulators also drive all N-Channel power MOSFETs, significantly improving system efficiency at a low cost. In order to drive the MOSFET gates adequately, a V_{GT} supply must be provided which is higher than the battery voltage by an amount sufficient to provide full enhancement voltage to the MOSFETs. This can be generated as shown in figure 2.

TABLE 1. ML4873 POWER DOWN MODES

Mode	On/Off	Enable B	Burst	Function	Total Supply Current
Sleep	0	X	X	5V Linear Reg Only	130µA
Suspend	1	X	1	Buck Reg A in Burst Mode 5V Linear Reg on	250µA*
Partial Run	1	0	0	Reg. B Disabled, All Other Functions Running	8mA
Run	1	1	0	All Functions Enabled	10mA

*Note This figure represents the total quiescent current for the Bust and 5V regulator. Actual current consumed will vary in proportion to load current.

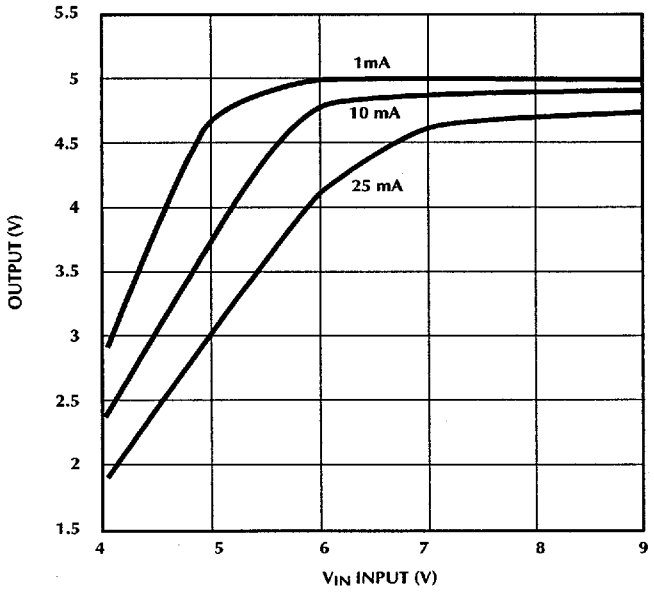


Figure 1. 5V Linear Regulator Output at low V_{IN}

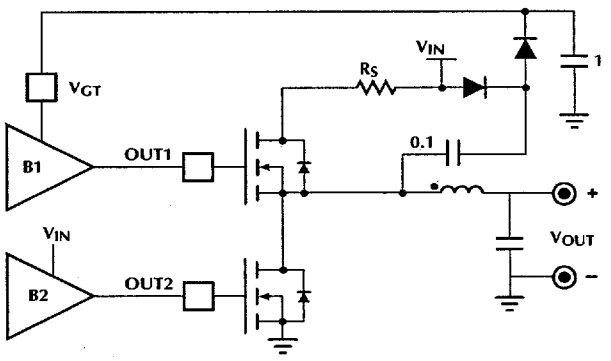


Figure 2. Generating V_{GT} Bias Voltage

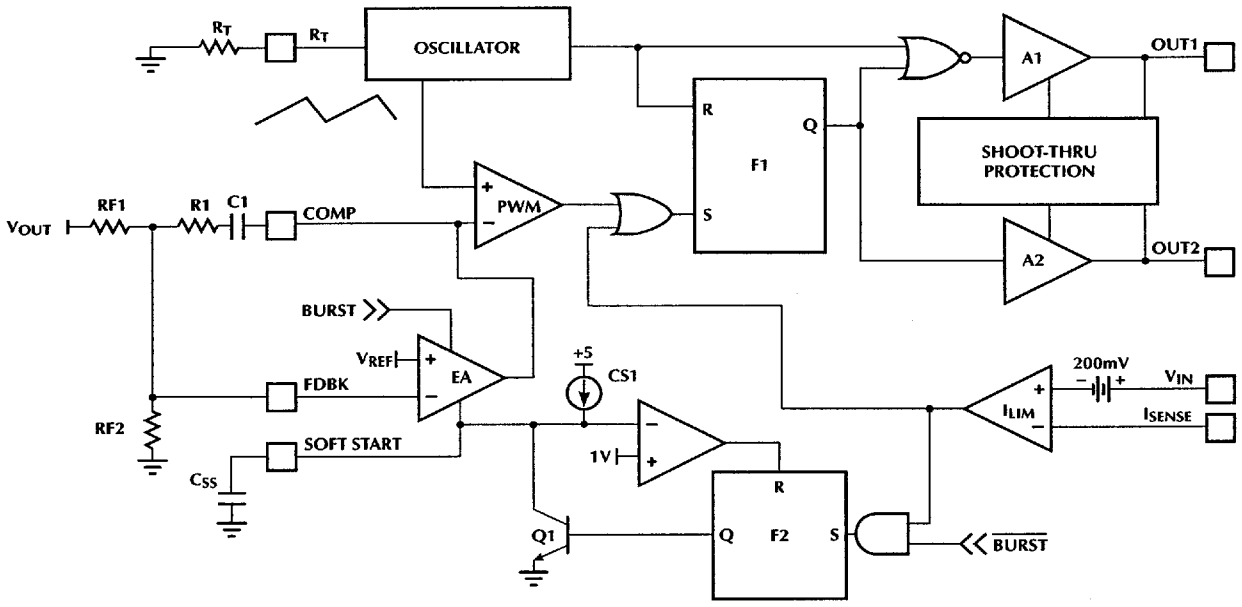


Figure 3. Buck Regulator Block Diagram

Regulator A includes a pin which puts Regulator A into "Burst mode". When in "Burst mode" the regulator comes on when the burst comparator is below its lower threshold and goes off again when the output capacitor has charged to the burst comparator's upper threshold. Burst mode is useful for running the regulator at light modes, such as memory keep-alive or "suspend" mode.

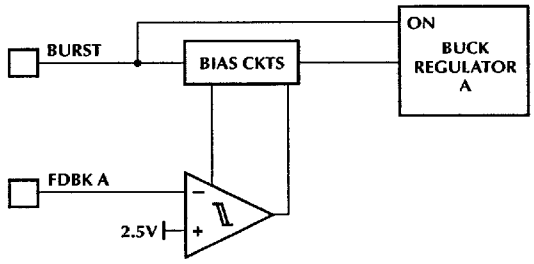


Figure 4. Burst Mode Comparator and Logic

When burst mode is enabled the C_{SS} discharge circuit (Figure 3) is disabled. C_{SS} is floating until CS1 is enabled when a burst occurs. When probing the C_{SS} pin in burst mode, use a high impedance probe to prevent discharge of the C_{SS} pin from disturbing the circuit operation.

Selection of the external MOSFETs, output inductor and capacitor determine the output capabilities of the regulator. Output voltage is set by RF1 and RF2 where.

$$V_{OUT} = \frac{2.5 \times (RF1 + RF2)}{RF2} \qquad (1)$$

The short circuit limit is set by external resistor R_S.

$$I_{SHORT\ CKT} \approx \frac{0.2}{R_S} \qquad (2)$$

C_{SS} is discharged when the regulator is off or when the voltage across R_S exceeds 200mV. F2 ensures that C_{SS} is fully discharged. This circuit provides reliable output short circuit protection with very little power wasted in the sensing element. The error amplifier's output voltage is limited to the voltage on the SOFT START pin. When C_{SS} is discharged, the regulator's duty cycle is 0.

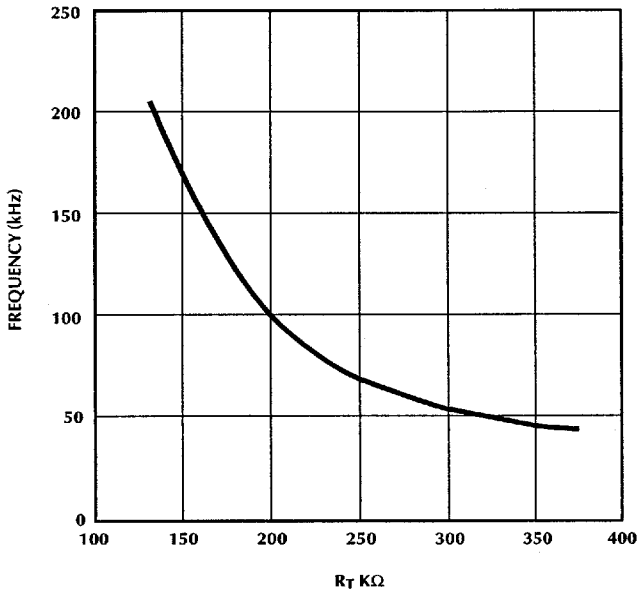


Figure 5. Oscillator Frequency vs. R_T

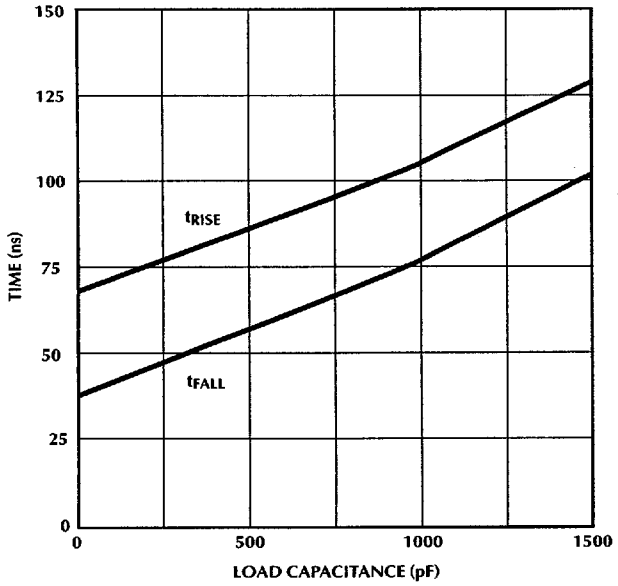


Figure 6. OUT1 Rise and Fall Time vs. Load C_{LOAD}

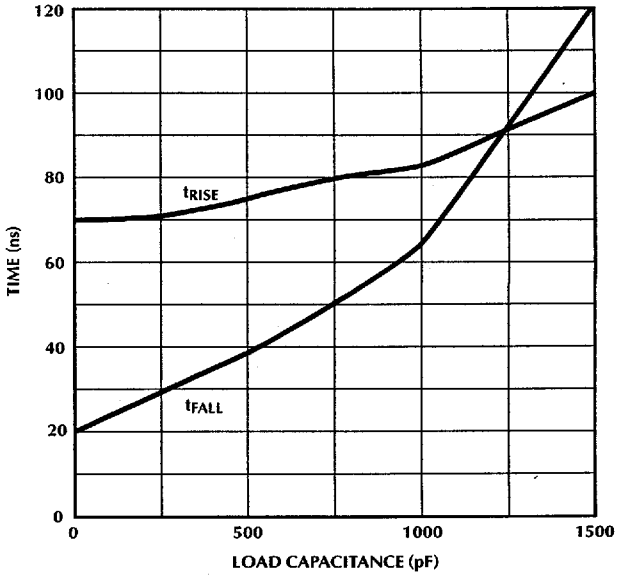


Figure 7. OUT2 Rise and Fall Time vs. Load C_{LOAD}

ADAPTER SWITCH

This function is provided by a comparator whose output (VG5) is pulled to V_{GT} when $V_{ADAPTER}$ goes above 2.5V. By connecting an N-Channel MOSFET gate to VG5, the system can run from the battery without the loss associated with a diode. When the AC adapter is plugged in, the voltage on pin 3 goes high, VG5 swings low, and the system runs from the AC adapter. This circuit functions in all modes of IC operation except SLEEP, when the VG5 output goes low.

12V LINEAR REGULATOR

The 12V regulator includes a shut-off pin. To operate the regulator as a low drop-out regulator, a separate 12VBIAS pin is provided. If this pin is 1.5V higher than V12 IN, the output transistor can be driven to saturation. Input for this regulator may come from either V_{IN} (for high voltage battery packs) or from a coupled inductor winding as shown in Figure 8. If the low drop-out feature is not necessary, V12 BIAS can be tied to V12 IN.

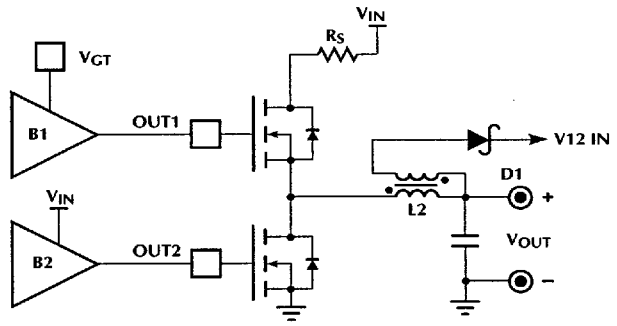


Figure 8. Coupled Inductor to generated V12 IN

APPLICATIONS

BUCK REGULATOR INDUCTOR

Inductors are specified with three main parameters; inductance (L), maximum current ($I_{OUT(MAX)}$), and DC resistance (R_L).

Inductance for a given set of requirements can be calculated using the following:

$$L = \frac{(V_{IN} - V_{OUT}) \times \left(\frac{D}{F}\right)}{(2) \times (I_{OUT(MIN)})} \quad (3)$$

In this equation, D is the duty cycle, and F is the switching frequency.

Selecting the inductor value using this formula ensures that the inductor stays in the continuous current mode, and never goes discontinuous at light loads ($I_{OUT(MIN)}$). This is important, as high current spikes occur and losses go up when operating in the discontinuous mode.

A good rule of thumb for choosing inductor core size is to make sure that the maximum output current of the regulator doesn't exceed 80% of the maximum current rating of the inductor. Otherwise, core saturation may occur. This is especially important for ferrites, which have a harder saturation characteristic than powdered iron cores.

In order to distribute conduction losses evenly among all components, the DC resistance should be selected to be 1/4 of the sum of the RDS_{ON}s of the power MOSFETs.

Core losses, which contribute significantly to overall efficiency losses, should be minimized by using an inductor designed for minimum losses at the chosen operating frequency. This is a function of the core material, and is lowest in "Kool Mu" and molyperm cores. Of course, efficiency and cost are often inversely related when it comes to magnetic materials.

FREQUENCY SELECTION

Frequency is set by the resistor R_T, which establishes the charge current for the internal capacitor. Since the discharge current is a constant, the dead time of the oscillator is constant, the maximum duty cycle increases as the oscillator frequency decreases. For low input voltage applications, a lower switching frequency may be required to maintain regulation at minimum input voltage.

Losses are heavily comprised of AC losses from the switching characteristic of the power MOSFETs and inductor core losses. Hence, reducing the switching frequency may result in higher efficiencies. As inductor conduction losses will increase at lower frequencies (size goes up, hence there are more copper losses), there will be a point at which this effect cancels the beneficial effect on the AC losses and further reductions no longer increase efficiencies. Also, reductions in operating frequency will result in larger magnetics, and a larger overall supply.

COMPENSATION

Proper compensation is the most critical part of designing a working supply. The compensation network must ensure stability over the full range of input voltage and load conditions, as well as maximize the available bandwidth for good transient response.

If an appreciable ESR exists such that ResrC > LC/5, then we can get away with adding one additional zero to the error amplifier's feedback network, and make use of the other zero created by the combination of the ESR and the output capacitance. We must also add an additional resistance in parallel with the zero we have added, this will give us increased bandwidth and lower the DC gain. Its size is determined by the gain necessary to bring the system to 0dB at the desired crossover point. As a rule of thumb, this point should be no more than 1/5 the switching frequency.

In cases where the ESR of the output capacitors is minimal, we no longer have a zero for free.

Now, we must use a zero on the input of the error amplifier in addition to the zero in the feedback network. The parallel feedback resistor is also still required; the gain is now the parallel combination of the feedback zero resistor and this resistor.

The internal error amplifier has an open loop gain of 90 dB, and a single pole at 31Hz. These must be taken into account in order to adequately compensate the supply.

TYPICAL PERFORMANCE CHARACTERISTICS

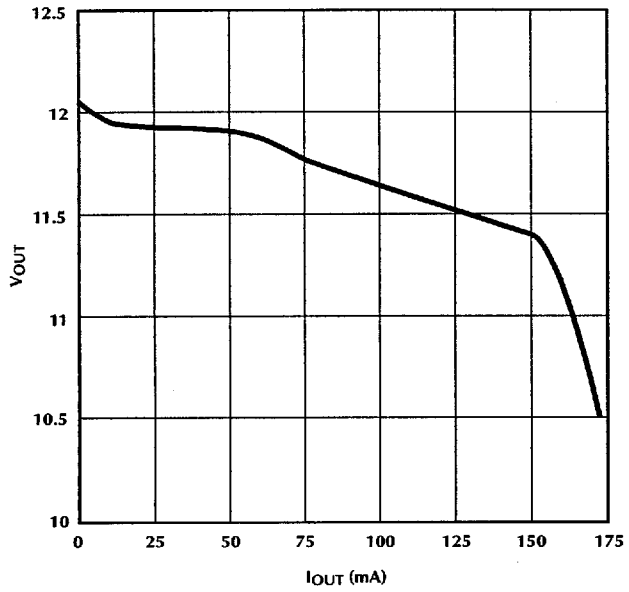


Figure 9. 12V Regulator Load Regulation

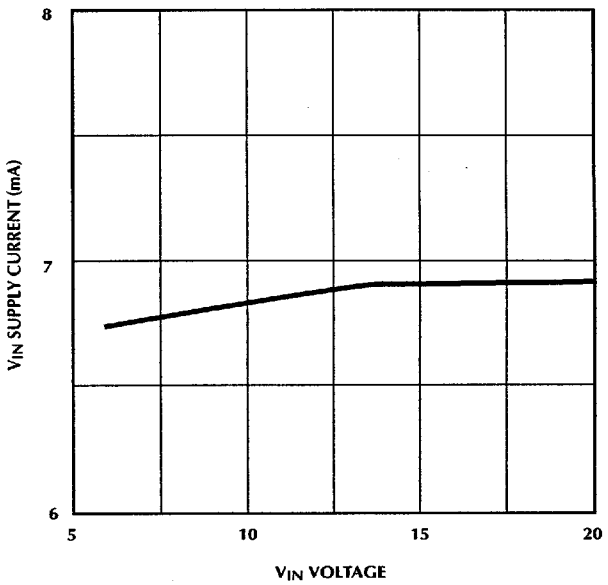


Figure 10. Supply Current (V_{IN}) vs. V_{IN} Voltage

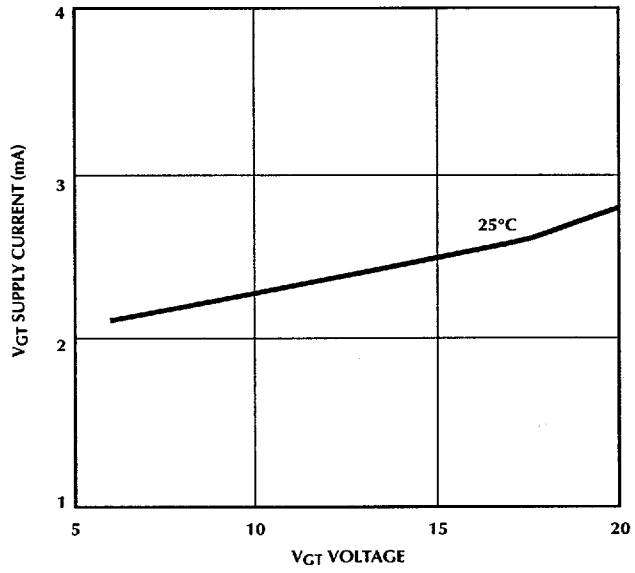


Figure 11. Supply Current (V_{GT}) vs V_{GT} Voltage

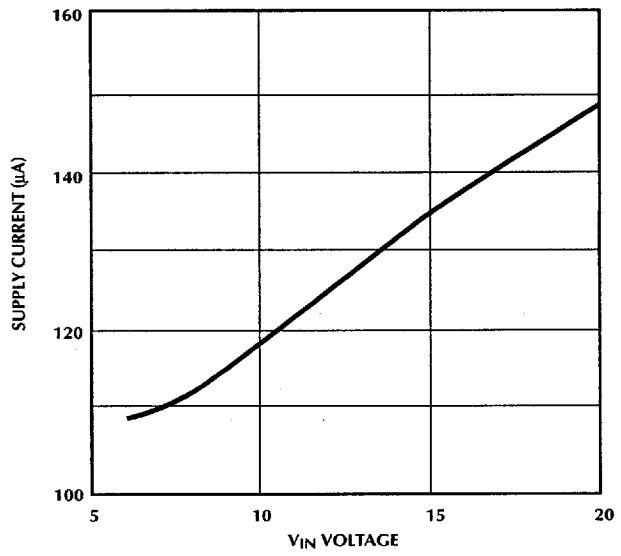
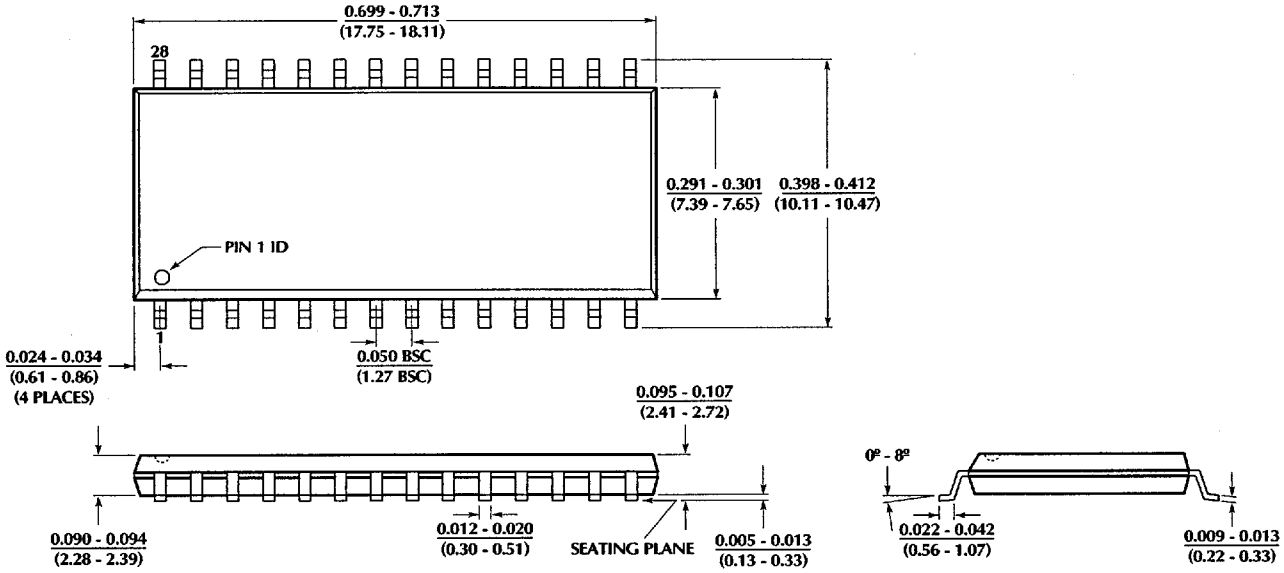


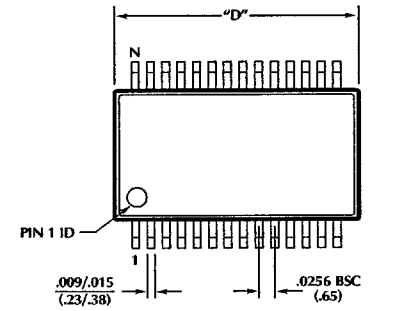
Figure 12. SLEEP Mode Current (V_{IN}) vs. V_{IN} Voltage

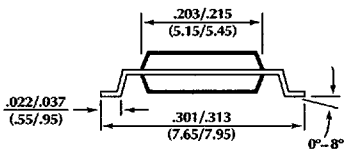
PHYSICAL DIMENSIONS inches (millimeters)

Package: S28
28-Pin SOIC



Package: R28
28–Pin SSOP





"N" LEADS	DIM. "D" inches	(mm)	PACKAGE I.D.
20	.274/.294	(6.95/7.45)	R20
24	.313/.333	(7.95/8.45)	R24
28	.392/.412	(9.95/10.45)	R28

ORDERING INFORMATION

PART NUMBER	TEMPERATURE RANGE	PACKAGE
ML4873CS	0°C to 70°C	28-PIN SOIC (S28W)
ML4873CR	0°C to 70°C	28-PIN SSOP (R28)

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San Jose, CA 95131
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