BM1701A

1.5MHz, 700mA, Synchronous Buck Regulator

Features

- 700mA Output @3.6V input
- 2.5V to 6.0V Input Voltage Range
- 1.5MHz Constant Frequency Operation
- Low Dropout Operation at 100% duty cycle
- Synchronous Topology:
  No Schottky Diode Required
- 0.6V Low Reference Voltage
- Shutdown Mode Supply Current Under 1µA
- Current Mode Operation for Excellent Line and Load Transient Response
- OTP , OCP protection
- Very low quiescent current , less than 40uA
- Small sot23-5 with 96% high efficiency
- Lead Free Available (RoHS Compliant)

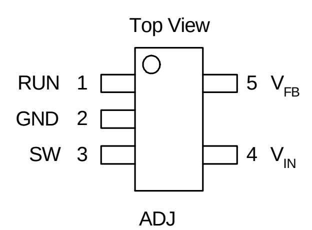
Applications

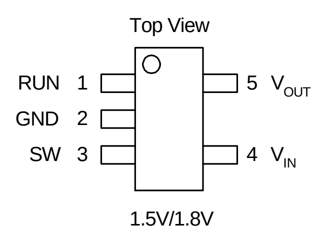
- Cellular Telephones
- Personal Information Appliances
- Wireless and DSL Modems
- MP3 Players
- Digital Still Cameras
- Portable Instruments

General Description

The BM1701A is a high efficiency monolithic synchronous buck regulator. BM1701A operates with a constant 1.5MHz switching frequency and using the inductor current as a controlled quantity in the current mode architecture. The device is available in an adjustable version and fixed output voltages of 1.5V and 1.8V. The 2.5V to 6.0V input voltage range makes the BM1701A ideally suited for single Li-Ion battery powered applications.100% duty cycle provides low dropout operation, extending battery life in portable electrical devices. The internally fixed 1.5MHz operating frequency allows the use of small surface mount inductors and capacitors. The synchronous switches included inside increase the efficiency and eliminate the need for an external Schottky diode. Low output voltages are easily supported with the 0.6V feedback reference voltage. The BM1701A is available in a low profile SOT package for saving the printed circuit board area.

Pin outs

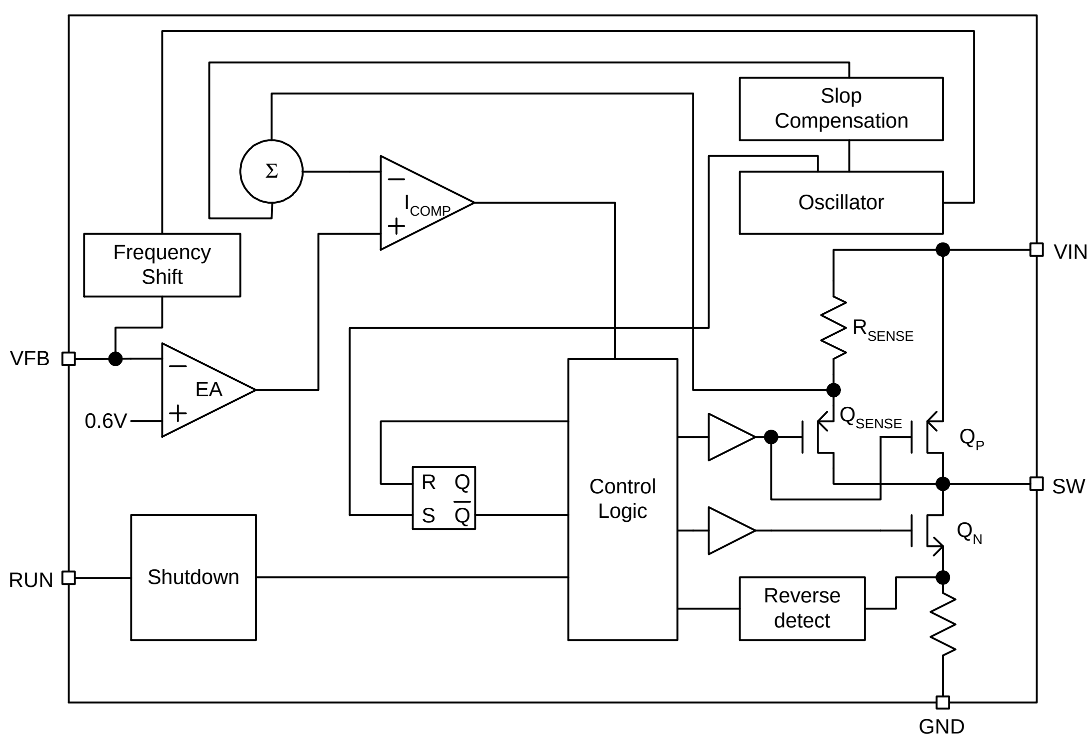




Ordering and Marking Information

BM1701A- □□□□-□□□ Lead Free Code Handling Code Temp. Range Package Code Voltage Code	Package Code B : SOT-23-5 Temp. Range I : -40 to 85°C Handling Code PB : Plastic Bag TR : Tape & Reel Voltage Code 15: 1.5V 18: 1.8V Blank : Adjustable Version Lead Free Code L : Lead Free Device Blank : Original Device
BM1701A a1XY	XY- Date Code

Block Diagram



Absolute Maximum Ratings

Symbol	Parameter	Value	Unit
V_{CC}	Input Supply Voltage (VCC to GND)	-0.3V to 6V	V
V_{RUN}	RUN Pin Voltage	-0.3V to (V_{CC}+0.3V)	V
V_{FB}	Feedback Voltage	-0.3V to (V_{CC}+0.3V)	V
V_{SW}	Switching Voltage	-0.3V to (V_{CC}+0.3V)	V
I_{SW_PEAK}	Peak SW Current	1.3	A
P_D	Average Power dissipation	0.5	W
T_J	Junction temperature, T_A < 50°	150	°C
T_{STG}	Storage temperature	-65 ~ 150	°C
T_{SDR}	Soldering temperature, 10 seconds	300	°C
V_{ESD}	Minimum ESD rating (Human body mode)	±3	KV

Pin Descrpition

No.	PIN	Description
1	RUN	Control input pin. Forcing this pin above 1.5V enables BM1701A. Forcing this pin below 0.3V shuts down BM1701A. In shutdown situation, all functions are disabled to decrease the supply current below 1µA.There is no pull high or pull low ability inside.
2	GND	Ground pin.
3	SW	Connected this pin to the inductor of the power stage. This pin connected to the drain terminals of the main and synchronous power MOSFET switches inside.
4	V_{IN}	Must be closely decoupled to GND with 4.7µF or greater ceramic capacitor.
5	V_{FB}/V_{OUT}	In the adjustable version, feedback function is available. The feedback voltage decided by an external resistive divider across the output. In the fixed version, an internal resistive divider divides the output voltage down for comparison to the internal reference voltage.

Thermal Characteristics

Symbol	Parameter	Value	Unit
θ_{JA}	Junction to ambient thermal resistance in free air	250	°C/W

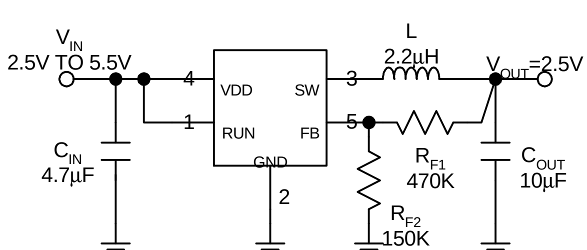
Electrical Characteristics

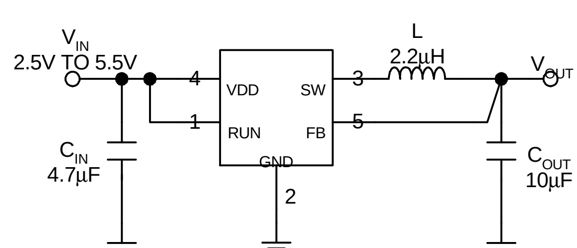
The * denotes the specifications that apply over T_A = -40°C ~ 85°C, otherwise specifications are at T_A=25°C.

Symbol	Parameter	Test condition		BM1701A			Unit
				Min	Typ	Max	
I_{VFB}	Feedback Current		*	-30		30	nA
V_{IN}	Input Voltage Range	*Note	*	2.5		6.0	V
V_{FB}	Regulated Feedback Voltage	-40°C ≤ T_A ≤ 85°C	*	0.585	0.6	0.615	V
ΔV_{FB}	Reference Voltage Line Regulation	V_{IN} = 2.5V to 5.5V	*		0.04	0.4	%/V
V_{OUT}	Regulated Output Voltage	BM1701-1.5, I_{OUT} = 100mA	*	1.455	1.500	1.545	V
		BM1701-1.8, I_{OUT}= 100mA	*	1.746	1.800	1.855	V
ΔV_{OUT}	Output Voltage Line Regulation	V_{IN} = 2.5V to 5.5V	*		0.04	0.4	%/V
I_{PK}	Peak Inductor Current	V_{IN} = 3V, V_{FB} = 0.5V or V_{OUT} = 90% Duty < 35%		0.75	1	1.25	A
V_{LOADR}	Output Voltage Load Regulation				0.5		%
I_Q	Quiescent Current	Duty Cycle = 0; V_{FB} = 1.5V				40	µA
I_{Q_SD}	Quiescent Current in Shutdown				0.1	1	µA
f_{OSC}	Oscillator Frequency	V_{FB} = 0.6V or V_{OUT} = 100%		1.2	1.5	1.8	MHz
f_{OSC_FFB}	Frequency Foldback	V_{FB} = 0V or V_{OUT} = 0V			300		KHz
R_{DSON_P}	On Resistance of P MOSFET	I_{SW} = 100mA			0.4	0.5	Ω
R_{DSON_N}	On Resistance of N MOSFET	I_{SW} = -100mA			0.35	0.45	Ω
I_{LSW}	SW Leakage Current	V_{RUN} = 0V, V_{SW} = 0V or 5V, V_{IN} = 5V			±0.01	±1	µA
V_{RUN}	RUN Threashold		*	0.3	1	1.5	V
I_{RUN}	RUN Leakage Current		*		±0.01	±1	µA

Note: The Maximum output current didn't reach 600mA when the supply voltage below 2.7V.

Application Circuit





C_{IN}: Murata GRM31CR61C475K

C_{OUT}: Murata GRM31CR61A106K

L: Gotrend GTSD53

Functional Description

Main Control Loop

The BM1701A uses a constant frequency, current mode step-down architecture. Both the main and synchronous switches are internal to reduce the external components. During normal operation, the internal PMOSFET is turned on, but is turned off when the inductor current at the input of I_{COMP} to reset the RS latch. The load current increases, it causes a slight decrease in the feedback voltage, which in turn, causes the EA's output voltage to increase until the average inductor current matches the new load current. While the internal power PMOSFET is off, the internal power NMOSFET is turned on until the inductor current starts to reverse, as indicated by the current reversal comparator I_{RCMP}, or the beginning of next cycle. When the NMOSFET is turned off by I_{RCMP}, it operates in the discontinuous conduction mode.

Pulse Skipping Mode Operation

At light load with a relative small inductance, the inductor current may reach zero. The internal power NMOSFET is turned off by the current reversal comparator, I_{RCMP}, and the switching voltage will ring. This is discontinuous mode operation, and is normal behavior for the switching regulator. At very light load, the BM1701A will automatically skip some pulses in the pulse skipping mode to maintain the output regulation. The skipping process modulates smoothly depend on the load.

Short Circuit Protection

In the short circuit situation, the output voltage is almost zero volts. Output current is limited by the I_{COMP} to prevent the damage of electrical circuit. In the normal operation, the two straight line of the inductor current ripple have the same height, it means the volts-seconds product is the same. When the short circuit operation occurs, the output voltage down to zero leads to the voltage across the inductor maximum in the on period and the voltage across the inductor minimum in the off period. In order to maintain the volts-seconds balance, the off-time must be extended to prevent the inductor current run away. Frequency decay will extend the switching period to provide more times to the off-period, then the inductor current have to restrict to protect the electrical circuit in the short situation.

Dropout Operation

As the input supply voltage decreases to a value approaching the output voltage, the duty cycle increases toward the maximum on time. Further reduction of the supply voltage forces the main switch to remain on for more than one cycle until it reaches 100% duty cycle. The output voltage will then be determined by the input voltage minus the voltage drop across the PMOSFET and the inductor.

An important detail to remember is that on resistance of PMOSFET switch will increase at low input supply voltage. Therefore, the user should calculate the power dissipation when the BM3406 is used at 100% duty cycle with low input voltage.

Slope Compensation

Slope compensation provides stability in constant frequency current mode architecture by preventing sub-harmonic oscillations at high duty cycle. It is accomplished internally by adding a compensating ramp to the inductor current signal at duty cycle in excess of 40%. Normally, this results in a reduction of maximum inductor peak current for duty cycles greater than 40%. In the BM3406, the reduction of inductor peak current recovered by a special skill at high duty ratio. This allow the maximum inductor peak current maintain a constant level through all duty ratio.

Application Description

Inductor Selection

Due to the high switching frequency as 1.5MHz, the inductor value of the application field is usually from 1µH to 4.7µH. The criterion to selecting a suitable inductor is dependent on the worst current ripple throughout the inductor. The worst current ripple defines as 40% of the fully load capability. In the applications, the worst value of current ripple is 240mA, the 40% of 700mA. Evaluate L by equation (1):

$$L = \frac{(V_{IN} - V_{OUT}) \cdot V_{OUT}}{V_{IN}} \cdot \frac{1}{\Delta I_L \cdot f_S} \quad \text{......(1)}$$

where f_S is the switching frequency of BM3406 and ΔI_L is the value of the worst current ripple, it can be any value of current ripple that smaller than the worst value you can accept. In order to perform high efficiency, selecting a low DC resistance inductor is a helpful way. Another important parameter is the DC current rating of the inductor. The minimum value of DC current rating equals the full load value of 600mA, plus the half of the worst current ripple, 120mA. Choose inductors with suitable DC current rating to ensure the inductors don't operate in the saturation.

Input Capacitor Selection

The input capacitor must be able to support the maximum input operating voltage and maximum RMS input current. The Buck converter absorbs current from input in pulses.

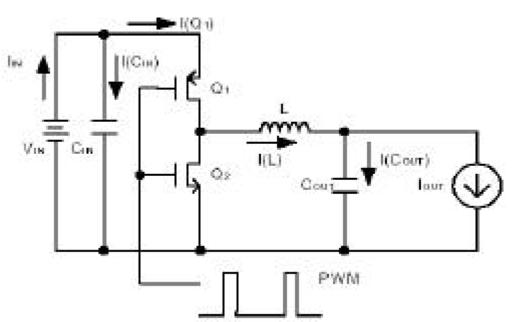


Figure-1

Figure-1 shows a schematic of a Buck structure. The waveforms show as Figure-2.

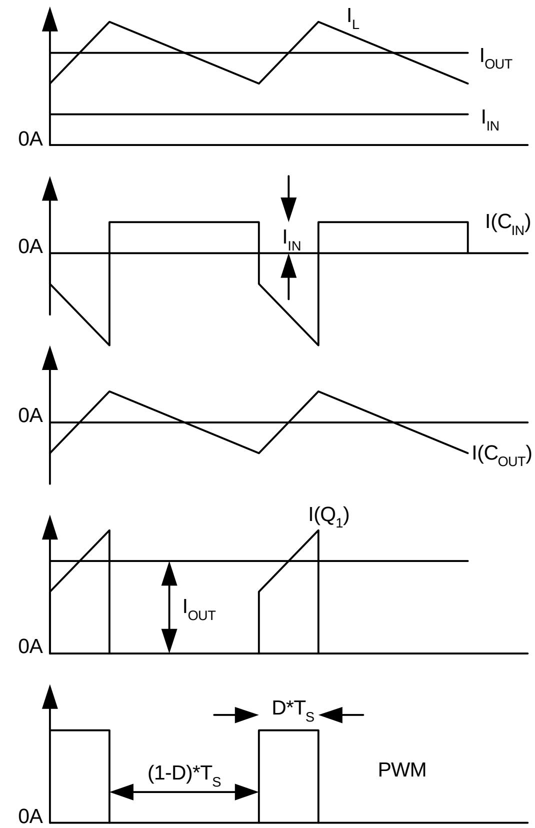


Figure-2

Observe the waveform of $I(C_{IN})$,the RMS value of $I(C_{IN})$ is

$$I(C_{IN}) = \sqrt{\left[(I_{OUT} - I_{IN})^2 \cdot \sqrt{D}\right]^2 + \left(I_{IN} \cdot \sqrt{1-D}\right)^2} \quad \text{......(2)}$$

Replace D and I_{IN} by following relation:

$$D = \frac{V_{OUT}}{V_{IN}} \quad \text{......(3)}$$

$$I_{IN} = D \cdot I_{OUT} \quad \text{......(4)}$$

The RMS value of input capacitor current equal:

$$I(C_{IN}) = I_{OUT} \cdot \sqrt{D(1-D)} \quad \text{......(5)}$$

When D=0.5 the RMS current of input capacitor will be maximum value. Use this value to choose the input capacitor with suitable current rating.

Application Description (Cont.)

Output Capacitor Selection

The output voltage ripple is a significant parameter to estimate the performance of a convertor. There are two discrete components that affect the output voltage ripple bigger or smaller. It is recommended to use the criterion has mentioned above to choose a suitable inductor. Then based on this known inductor current ripple condition, the value and properties of output capacitor will affect the output voltage ripple better or worse. The output voltage ripple consists of two portions, one is the product of ESR and inductor current ripple, the other portion is a function of the inductor current ripple and the output capacitance. Figure-3 shows the waveforms to explain the part decided by the output capacitance.

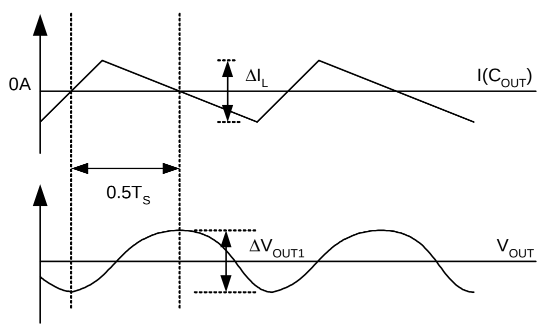


Figure-3

Evaluate the ΔV_{OUT1} by the ideal of energy equalization. According to the definition of Q,

$$Q = \frac{1}{2}\left(\frac{1}{2}\Delta I_L \cdot \frac{1}{2}T_S\right) = C_{OUT} \cdot \Delta V_{OUT1} \quad ......(6)$$

where T_S is the inverse of switching frequency and the ΔI_L is the inductor current ripple. Move the C_{OUT} to the left side to estimate the value of ΔV_{OUT1} as equation (7).

$$\Delta V_{OUT1} = \frac{\Delta I_L \cdot T_S}{8 \cdot C_{OUT}} \quad ......(7)$$

As mentioned above, one part of output voltage ripple is the product of the inductor current ripple and ESR of output capacitor. The equation (8) explains the output voltage ripple estimation.

$$\Delta V_{OUT} = \Delta I_L \cdot \left(ESL + \frac{T_S}{8 \cdot C_{OUT}}\right) \quad ......(8)$$

Thermal Considerations

BM1701A is a high efficiency switching converter, it means less power loss transferred into heat. Due to the on resistance difference between internal power PMOSFET and NMOSFET, the power dissipation in the high converting ratio is greater than low converting ratio. The worst case is in the dropout operation, the mainly conduction loss dissipate on the internal power PMOSFET. The power dissipation nearly defined as:

$$P_D = (I_{OUT})^2\left[R_{DS\_ONP} \cdot D + R_{DS\_ONN} \cdot (1-D)\right] \quad ......(9)$$

BM1701A has internal over temperature protection. When the junction temperature reaches 150 centigrade, will turn off both internal power PMOSFET and NMOSFET. The estimation of the junction temperature, T_J, defined as:

$$T_J = P_D \cdot \theta_{JA} \quad ......(10)$$

where the θ_{JA} is the thermal resistance of the package utilized by BM1701A.

Output Voltage Setting

BM1701A has the adjustable version for output volt-

Application Description (Cont.)

age setting by the users. A suggestion of maximum value of RF2 is 200KΩ to keep the minimum current that provides enough noise rejection ability through the resistor divider. The output voltage programmed by the equation:

$$V_{OUT} = 0.6 \cdot \left(1 + \frac{R_{F1}}{R_{F2}}\right) \quad ......(11)$$

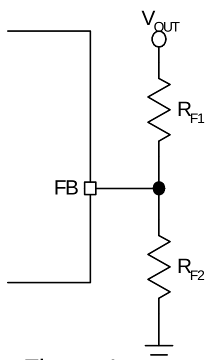


Figure-4

PCB Layout Considerations

BM1701A is a high efficiency DC-DC converter which is a noise source in the electrical circuit by its switching operating. Some PCB layout considerations suppress the effect of switching operating by itself to improve the better regulation.

<1> Keep the power trace wide and short as possible. The power trace shows in the Figure-6 as thick solid lines.

<2> Put the C_{IN} to VIN close and C_{OUT} near the inductor as possible.

<3> Keep the ground terminal of C_{IN} and C_{OUT} as close as possible to minimize the AC current loop.

<4> Put the voltage divider consist of R_{F1} and R_{F2} closely to FB, the connection path between R_{F1} and V_{OUT} must far away the SW to prevent the switch noise coupling into FB by crosstalk. If necessary, the connection path between R_{F1} and V_{OUT} must near to SW, put a ground trace between the feedback trace and SW to prevent the coupling.

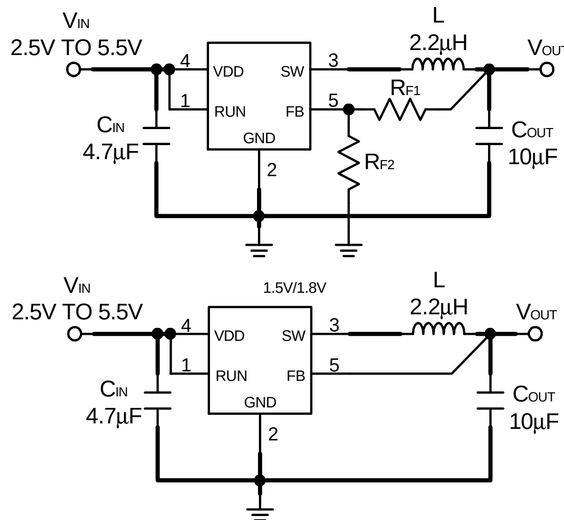
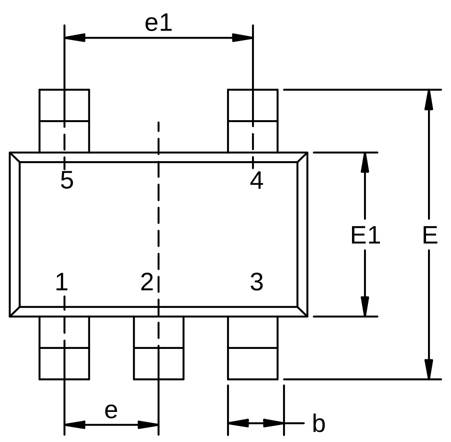
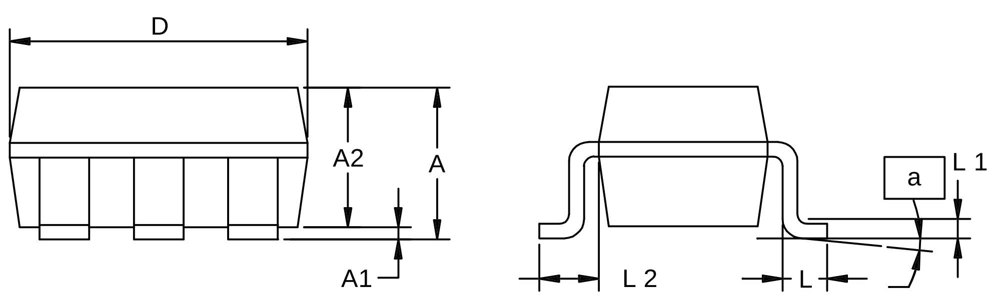


Figure-5

Packaging Information

SOT-23-5





Dim	Millimeters		Inches	
	Min.	**Max.**	**Min.**	**Max.**
A	0.95	1.45	0.037	0.057
A1	0.05	0.15	0.002	0.006
A2	0.90	1.30	0.035	0.051
b	0.35	0.55	0.0138	0.0217
D	2.8	3.00	0.110	0.118
E	2.6	3.00	0.102	0.118
E1	1.5	1.70	0.059	0.067
e	0.95		0.037	
e1	1.90		0.075	
L	0.35	0.55	0.014	0.022
L1	0.20 BSC		0.008 BSC	
L2	0.5	0.7	0.020	0.028
a	0°	10°	0°	10°