High Voltage, 2A Step-Down DC/DC Regulator

◆ DESCRIPTION

The MT1520 is a monolithic step down switch mode regulator with a built in internal power MOSFET.It achieves 2A continuous output current over a wide input supply range with excellent load and line regulation.

Current mode operation provides fast transient response and eases loop stabilization.

Fault condition protection includes cycle-by-cycle current limiting and thermal shutdown. In shutdown mode the regulator draws 20μA of supply current.

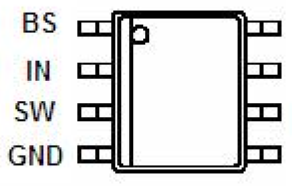
◆ FEATURES

- High Efficiency: Up to 95%
- 2A Output Current
- 4.75V to 16V Input Voltage Range
- Fixed 380KHz Frequency
- 0.15Ω Internal Power MOSFET Switch
- 20μA Shutdown Mode
- Thermal Shutdown
- Cycle-by-Cycle Over Current Protection
- Output Adjustable from 1.22 to 12V
- Stable with Low ESR Output Ceramic Capacitors
- Available in SOP-8 Pin package

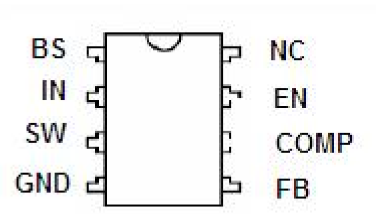
◆ APPLICATIONS

- Portable Devices
- LCD Monitors
- Vehicle Application
- Battery Charger
- Distributed Power Systems

◆ PIN CONFIGURATIONS



MT1520M



MT1520T

◆ PIN CONFIGURATION

Pin Number	Name	Function
1	BS	High-Side Gate Drive Boost Input. BS supplies the drive for the high-side n-channel MOSFET switch. Connect a 10nF or greater capacitor from SW to BS to power the high-side switch.
2	IN	Power Input. IN supplies the power to the IC, as well as the step-down converter switch. Drive IN with a 4.75V to 16V power source. Bypass IN to GND with a suitably large capacitor to eliminate noise on the input to the IC. ***See Input Capacitor.***
3	SW	Power Switching Output. SW is the switching node that supplies power to the output. Connect the output LC filter from SW to the output load. Note that a capacitor is required from SW to BS to power the high-side switch.
4	GND	Ground.
5	FB	Feedback Input. FB senses the output voltage to regulate that voltage. Drive with a resistive voltage divider from the output voltage. The feedback threshold is 1.2V. ***See Setting the Output Voltage.***
6	COMP	Compensation Node. COMP is used to compensate the regulation control loop. Connect a series RC network from COMP to GND to compensate the regulation control loop. ***See Compensation.***
7	EN	Enable Input. EN is a digital input that turns the regulator on or off. Drive EN high to turn on the regulator, drive EN low to turn it off. For automatic startup, leave EN unconnected.
8	NC	No Connect.

◆ ABSOLUTE MAXIMUM RATINGS(Note A)

Symbol	Parameter	Maximum	Unit
Input Voltage	V_{IN}	-0.3 to 30	V
SW Pin Voltage	V_{SW}	-1 to V_{IN} +1	V
Boot strap Voltage	V_{BS}	V_{SW}-0.3 to V_{SW} +6	V
All Other I/O Pin		-0.3 to 6	V
Operating Ambient Temperature	T_A	-20 to 85	°C
Maximum Junction Temperature	T_J	150	°C
Storage Temperature	T_{STG}	-65 to 150	°C
Lead Temperature(Soldering, 10 sec)	T_{LEAD}	260	°C

Note A :To prevent permanent damage to the device, do not stress the device beyond these absolute maximum ratings.

◆ RECOMMENDED OPERATING CONDITIONS

Symbol	Parameter	Maximum	Unit
Input Voltage	V_{IN}	4.75 to 16	V

◆ POWER DISSIPATION TABLE

Package	θ_{JA} (°C /W)	$T_A \leq 25$°C Power rating(mW)	T_A=70°C Power rating(mW)	T_A= 85°C Power rating (mW)
M	90	1389	889	722
T	90	1389	889	722

Note :

1. Exceeding the maximum allowable power dissipation will result in excessive die temperature, and the regulator will go into thermal shutdown.
2. T_J: Junction Temperature Calculation:
   $T_J = T_A + (P_D \times \theta_{JA})$
   The θ_{JA} numbers are guidelines for the thermal performance of the device/PC-board system. All of the above assume no ambient airflow.
3. θ_{JA}: Thermal Resistance-Junction to Ambient.

◆ ORDERING INFORMATION

Device	Package		V_{OUT} Volts	T_A (°C)
MT1520	**M**	SOP-8	ADJ	-20 to 85
MT1520	**T**	DIP-8	ADJ	-20 to 85

◆ BLOCK DIAGRAM

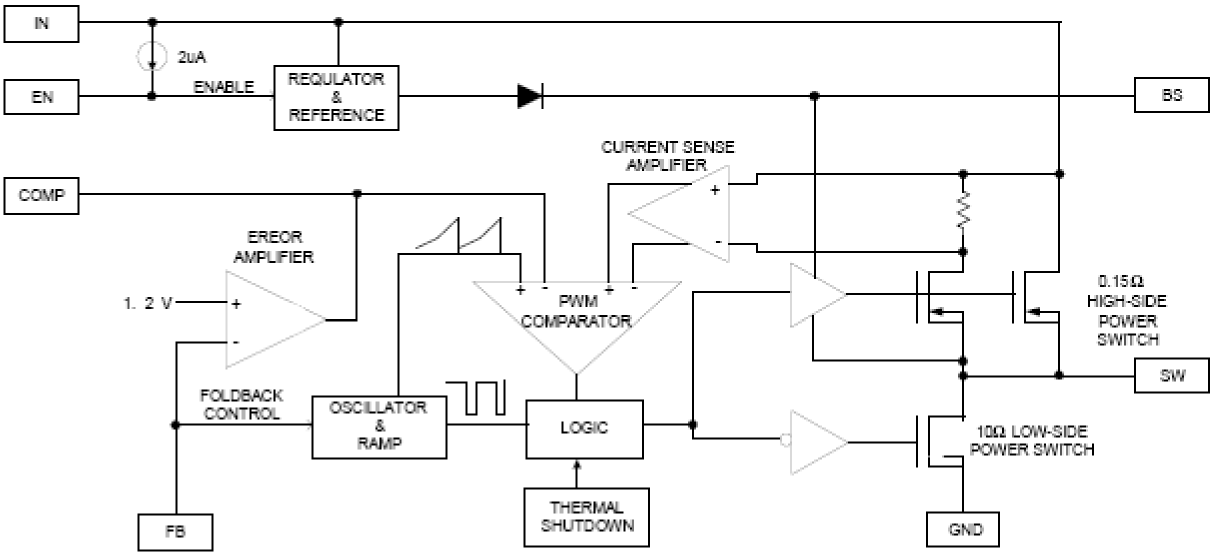


Figure 2. Functional Block Diagram

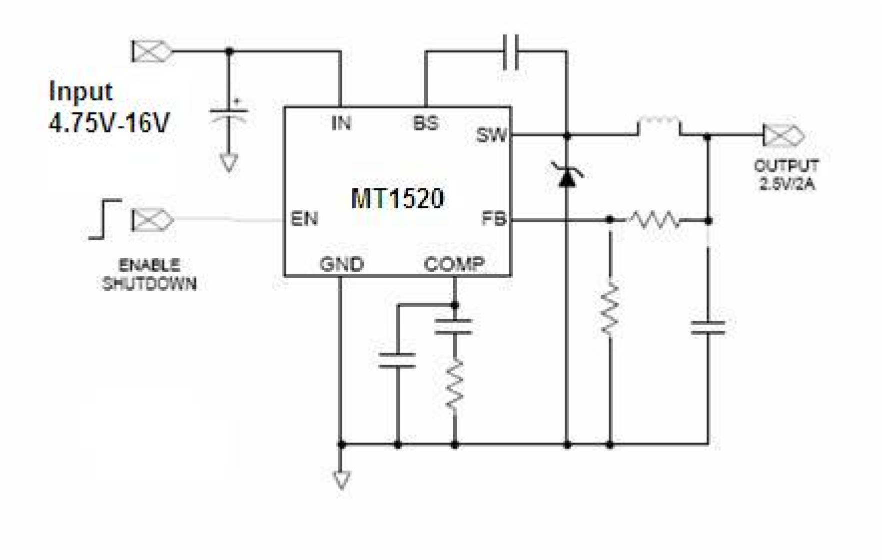
◆ FUNCTIONAL DESCRIPTION

The MT1520 is a current-mode step-down switch-mode regulator. It regulates input voltages from 4.75V to 16V down to an output voltage as low as 1.2V, and is able to supply up to 2A of load current. The MT1520 uses current -mode control to regulate the output voltage.

The output voltage is measured at FB through a resistive voltage divider and amplified through the internal error amplifier. The output current of the transconductance error amplifier is presented at COMP where a network compensates the regulation control system. The voltage at COMP is compared to the switch current measured internally to control the output voltage.

The converter uses an internal n-channel MOSFET switch to step down the input voltage to the regulated output voltage. Since the MOSFET requires a gate voltage greater than the input voltage, a boost capacitor connected between SW and BS drives the gate. The capacitor is internally charged while the switch is off. An internal 10Ω switch from SW to GND is used to insure that SW is pulled to GND when the switch is off to fully charge the BS capacitor.

◆ TYPICAL APPLICATIONS



◆ TEST CIRCUIT

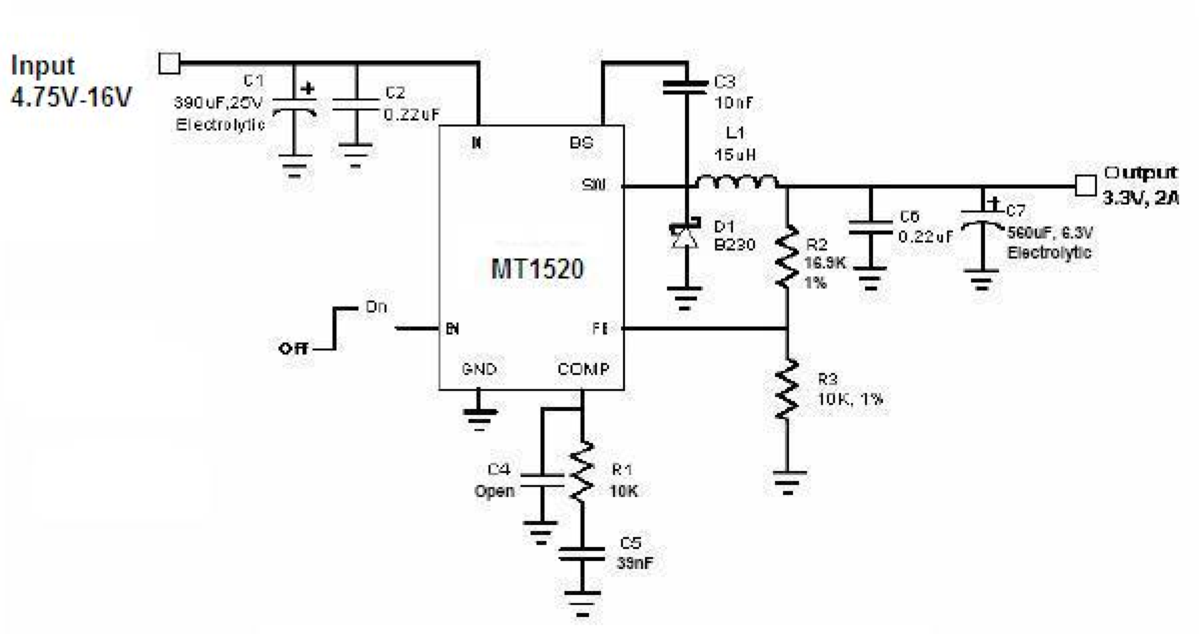


Figure 3.MT1520 Step Down from 16V to 3.3V@2A

◆ ELECTRICAL CHARACTERISTICS

(V_{IN} = 12V, V_{EN}=5V, unless otherwise specified refer to circuit of Figure3. Typical values are at T_A = 25oC.)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Feedback Pin Voltage	V_{FB}	4.75V ≤ V_{IN} ≤16V	-	1.2	-	V
Upper Switch On Resistance	R_{ON_UP}		-	0.22	-	Ω
Lower Switch On Resistance	R_{ON_LOW}		-	10	-	Ω
Upper Switch Leakage	I_{LEAK}	V_{EN} = 0V, V_{SW} = 0V	-	-	10	μA
Current Limit	I_{LIMIT}		-	3	-	A
Oscillator Frequency	F_{OSC}		-	380	-	KHz
Short Circuit Frequency	F_{SC}	V_{FB} = 0V	-	80	-	KHz
Maximum Duty Cycle	D_{MAX}	V_{FB} = 1V	-	90	-	%
Minimum Duty Cycle	D_{Min}	V_{FB} = 1V	-	-	-	%
EN Threshold	V_{THR}		-	1.1	-	V
Under Voltage Lockout Threshold Rising	V_{UVLO}		-	2.5	-	V
Under Voltage Lockout Threshold Hysteresis	V_{HYS}		-	200	-	mV
Shutdown Supply Current	I_{SD}	V_{EN} = 0V	-	25	1	μA
Operating Supply Current	I_{OP}	V_{EN} = 0V, V_{FB} = 1.4V	-	1.0	-	mA
Thermal Shutdown	T_{SD}		-	160	-	^{o}C

Notes:

1. Measured on 1" square of 1 oz. copper FR4 board.
2.. The device is not guaranteed to function outside its operating ratings

◆ APPLICATION INFORMATION

Setting the Output Voltage

The output voltage is set using a resistive voltage divider from the output voltage to FB (see Figure 3). The voltage divider divides the output voltage down by the ratio:

$$V_{FB} = V_{OUT} * R3 / (R2 + R3)$$

Thus the output voltage is:

$$V_{OUT} = 1.2 * (R2 + R3) / R3$$

R3 can be as high as 100KΩ, but a typical value is 10KΩ. Using that value, R2 is determined by:

$$R2 \cong 8.18 * (V_{OUT} - 1.2)(K\Omega)$$

For example, for a 3.3V output voltage, R3 is 10KΩ, and R2 is 16.9KΩ.

Input Capacitor

The input current to the step-down converter is discontinuous, and therefore an input capacitor C1 is required to supply the AC current to the step-down converter while maintaining the DC input voltage. A low ESR capacitor is required to keep the noise at the IC to a minimum. Ceramic capacitors are preferred, but tantalum or low- ESR electrolytic capacitors may also suffice.

The input capacitor value should be greater than 10µF. The capacitor can be electrolytic, tantalum or ceramic. However since it absorbs the input switching current it requires an adequate ripple current rating. Its RMS current rating should be greater than approximately 1/2 of the DC load current.

For insuring stable operation C2 should be placed as close to the IC as possible. Alternately a smaller high quality ceramic 0.1µF capacitor
may be placed closer to the IC and a larger capacitor placed further away. If using this technique, it is recommended that the larger capacitor be a tantalum or electrolytic type. All ceramic capacitors should be placed close to the MT1520.

Output Capacitor

The output capacitor is required to maintain the DC output voltage. Low ESR capacitors are preferred to keep the output voltage ripple low. The characteristics of the output capacitor also affect the stability of the regulation control system. Ceramic, tantalum, or low ESR electrolytic capacitors are recommended. In the case of ceramic capacitors, the impedance at the switching frequency is dominated by the capacitance, and so the output voltage ripple is mostly independent of the ESR. The output voltage ripple is estimated to be:

$$V_{RIPPLE} \cong 1.4 * V_{IN} * (f_{LC} / f)^2$$

Where V_{RIPPLE} is the output ripple voltage, V_{IN} is the input voltage, f_{LC} is the resonant frequency of the LC filter, f is the

◆ APPLICATION INFORMATION (Continue)

switching frequency. In the case of tanatalum or low-ESR electrolytic capacitors, the ESR dominates the impedance at the switching frequency, and so the output ripple is calculated as:

$$V_{RIPPLE} \cong \Delta I * R_{ESR}$$

Where V_{RIPPLE} is the output voltage ripple, ΔI is the inductor ripple current, and R_{ESR} is the equivalent series resistance of the output capacitors.

Inductor

The inductor is required to supply constant current to the output load while being driven by the switched input voltage. A larger value inductor results in less ripple current that in turn results in lower output ripple voltage. However, the larger value inductor has a larger physical size, higher series resistance, and/or lower saturation current. Choose an inductor that does not saturate under the worst-case load conditions. A good rule for determining the inductance is to allow the peak-to-peak ripple current in the inductor to be approximately 30% of the maximum load current. Also, make sure that the peak inductor current (the load current plus half the peak-to-peak inductor ripple current) is below the 2.4A minimum current limit. The inductance value can be calculated by the equation:

$$L = V_{OUT} * (V_{IN} - V_{OUT}) / (V_{IN} * f * \Delta I)$$

Where V_{OUT} is the output voltage, V_{IN} is the input voltage, f is the switching frequency, and ΔI is the peak-to-peak inductor ripple current. Table 2 lists a number of suitable inductors from various manufacturers.

Table 2: Inductor Selection Guide

Vendor / Model	Core Type	Core Material	Package Dimensions (mm) W	L	H
Sumida					
CR25	Open	Ferrite	7.0	7.8	5.5
CDH74	Open	Ferrite	7.3	8.0	5.2
CDRH5D28	Shielded	Ferrite	5.5	5.7	5.5
CDRH6D28	Shielded	Ferrite	6.7	6.7	3.0
CDRH104R	Shielded	Ferrite	10.1	10.0	3.0
Toko					
D53LC Type A	Shielded	Ferrite	5.0	5.0	3.0
D75C	Shielded	Ferrite	7.6	7.6	5.1
D104C	Shielded	Ferrite	10.0	10.0	4.3
D10FL	Open	Ferrite	9.7	11.5	4.0
Coilcraft					
DO3308	Open	Ferrite	9.4	13.0	3.0
DO3316	Open	Ferrite	9.4	13.0	5.1

◆ APPLICATION INFORMATION (Continue)

Output Rectifier Diode

The output rectifier diode supplies the current to the inductor when the high-side switch is off. To reduce losses due to the diode forward voltage and recovery times, use a Schottky rectifier. Choose a rectifier who's maximum reverse voltage rating is greater than the maximum input voltage, and who's current rating is greater than the maximum load current.

Table 3 provides the Schottky rectifier part numbers based on

Table 3: Schottky Rectifier Selection Guide

VIN (Max)	2A Load Current	
	Part Number	Vendor
15V	30BQ015	4
20V	B220	1
	SK23	6
	SR32	6

Table 4 lists some rectifier manufacturers.

Table 4: Schottky Diode Manufacturers.

#	Vendor	Web Site
1	Diodes, Inc.	www.diodes.com
2	Fairchild Semiconductor	www.fairchildsemi.com
3	General Semiconductor	www.gensemi.com
4	International Rectifier	www.irf.com
5	On Semiconductor	www.onsemi.com
6	Pan Jit International	www.panjit.com.tw

Compensation

The system stability is controlled through the COMP pin. COMP is the output of the internal transconductance error amplifier. A series capacitor-resistor combination sets a pole-zero combination to control the characteristics of the control system.

The DC loop gain is:

$$A_{VDC} = (V_{FB} / V_{OUT}) * A_{VEA} * G_{CS} * R_{LOAD}$$

Where:

V_{FB} is the feedback threshold voltage, 1.2V. V_{OUT} is the desired output regulation voltage. A_{VEA} is the transconductance error amplifier voltage gain, 400 V/V. G_{CS} is the current sense gain, (roughly the output current divided by the voltage at COMP), 1.95 A/V. R_{LOAD} is the load resistance (V_{OUT} / I_{OUT} where I_{OUT} is the output load current) The system has 2 poles of importance, one is due to the compensation capacitor (C5), and the other is due to the output capacitor (C7).

◆ APPLICATION INFORMATION (Continue)

These are:

$$f_{P1} = G_{EA} / (2\pi * A_{VEA} * C5)$$

Where P1 is the first pole, and G_{EA} is the error amplifier transconductance (770μA/V). and

$$f_{P2} = 1/(2\pi * R_{LOAD} * C7)$$

The system has one zero of importance, due to the compensation capacitor (C5) and the compensation resistor (R1). The zero is:

$$f_{Z1} = 1/(2\pi * R1 * C5)$$

If a large value capacitor (C7) with relatively high equivalent-series-resistance (ESR) is used, the zero due to the capacitance and ESR of the output capacitor can be compensated by a third pole set by R1 and C4. The pole is:

$$f_{P3} = 1/(2\pi * R1 * C4)$$

The system crossover frequency (the frequency where the loop gain drops to 1, or 0dB) is important. A good rule of thumb is to set the crossover frequency to approximately 1/10 of the switching frequency. In this case, the switching frequency is 380KHz, therefore use a crossover frequency, f_C, of 40KHz. Lower crossover frequencies result in slower response and worse transient load recovery. Higher crossover frequencies can result in instability.

Table 5: Compensation Values for Typical Output Voltage/Capacitor Combinations

V_{OUT}	C7	R1	C5	C4
2.5V	22μF Ceramic	7.5KΩ	2.2nF	None
3.3V	22μF Ceramic	10KΩ	1.5nF	None
5V	22μF Ceramic	10KΩ	2.2nF	None
12V	22μF Ceramic	10KΩ	5.6nF	None
2.5V	560μF/6.3V (30mΩ ESR)	10K.	30nF	None
3.3V	560μF/6.3V (30mΩ ESR)	10K.	39nF	None
5V	470μF/10V (30mΩ ESR)	10K	47nF	None
12V	220μF/25V (30mΩ ESR)	10K.	56nF	None

Choosing the Compensation Components

The values of the compensation components given in Table 5 yield a stable control loop for the output voltage and capacitor given. To optimize the compensation components for conditions not listed in Table 5, use the following procedure: Choose the compensation resistor to set the desired crossover frequency. Determine the value by the following equation:

$$R1 = 2\pi * C7 * V_{OUT} * f_C / (G_{EA} * G_{CS} * V_{FB})$$

◆ APPLICATION INFORMATION (Continue)

Putting in the known constants and setting the crossover frequency to the desired 40KHz:

$$R1 \approx 1.37 * 10^{8} * C7 * V_{OUT}$$

The value of R1 is limited to 10KΩto prevent output overshoot at startup, therefore if the value calculated for R1 is greater than 10KΩ, use 10KΩ. In this case, the actual crossover frequency is less than the desired 40KHz, and is calculated by:

$$f_C = R1 * G_{EA} * G_{CS} * V_{FB} / \left(2\pi * C7 * V_{OUT}\right)$$

Or:

$$f_C \approx \left(2.92 * 10_{-} * R1\right) / \left(C7 * V_{OUT}\right)$$

Choose the compensation capacitor to set the zero to 1/4 of the crossover frequency. Determine the value by the following equation:

$$C5 = \left(0.22 * C7 * V_{OUT}\right) / R1$$

Determine if the second compensation capacitor, C4 is required. It is required if the ESR zero of the output capacitor happens at less than four times the crossover frequency.

$$8\pi * C7 * R_{ESR} * f_C \geq 1$$

Or:

$$\left(7.34 * 10^{-5} * R1 * R_{ESR}\right) / V_{OUT} \geq 1$$

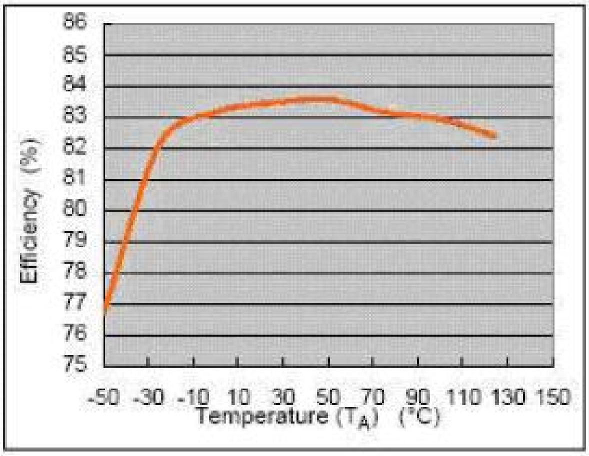
where RESR is the equivalent series resistance of the output capacitor. If this is the case, add the second compensation capacitor. Determine the value by the equation:

$$C4 = C7 * R_{ESR(MAX)} / R1$$

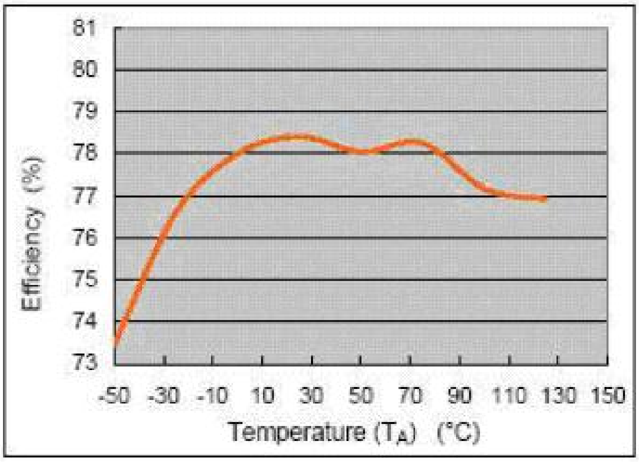
Where $R_{ESR(MAX)}$ is the maximum ESR of the output capacitor.

◆ TYPICAL PERFORMANCE CHARACTERISTICS

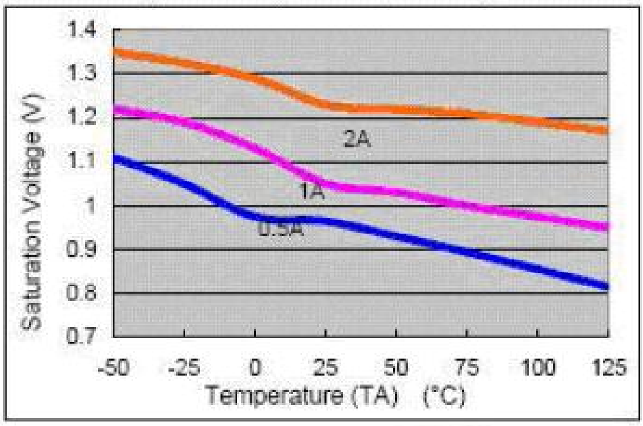
MT1520 Efficiency vs. Temperature (Vin=12V, Vout=5V, Io=2A)



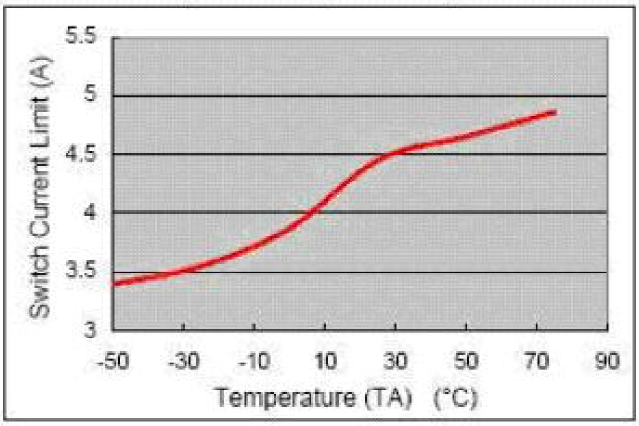
MT1520 Efficiency vs. Temperature (Vin=12V, Vout=3.3V, Io=2A)



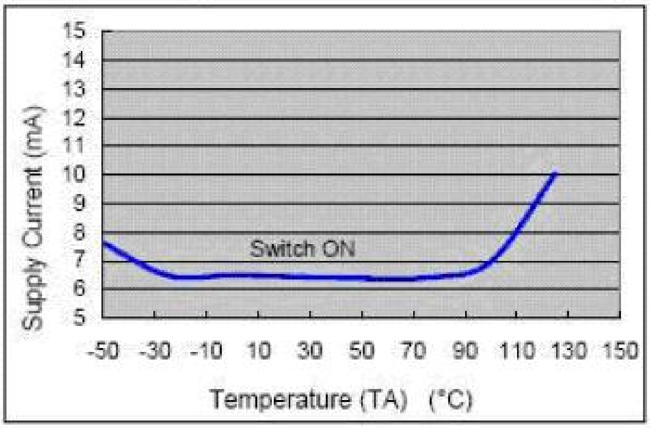
MT1520 Saturation Voltage vs. Temperature (Vcc=12V, Vfb=0V, VSD=0)

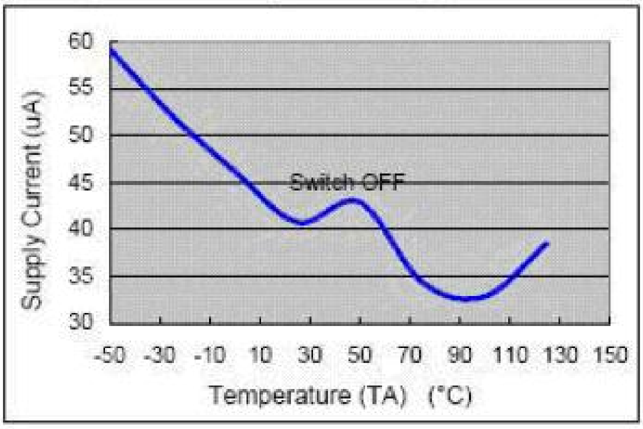


MT1520 Switch Current Limit vs. Temperature (Vcc = 12V, Vfb = 0V)



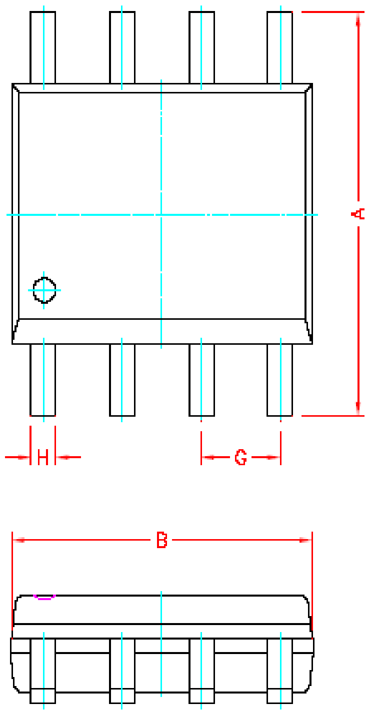
MT1520 Supply Current vs. Temperature (Vcc=12V, No Load, Von/off =0V(Switch ON) ,Von/off =5V(Switch OFF))



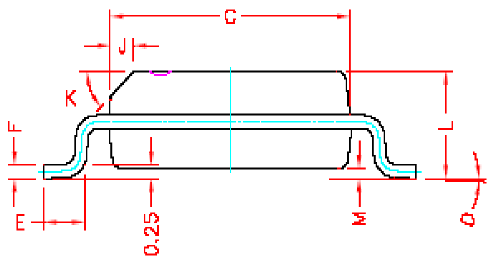


◆ PHYSICAL DIMENSIONS:

8-Pin Plastic S.O.I.C(M)

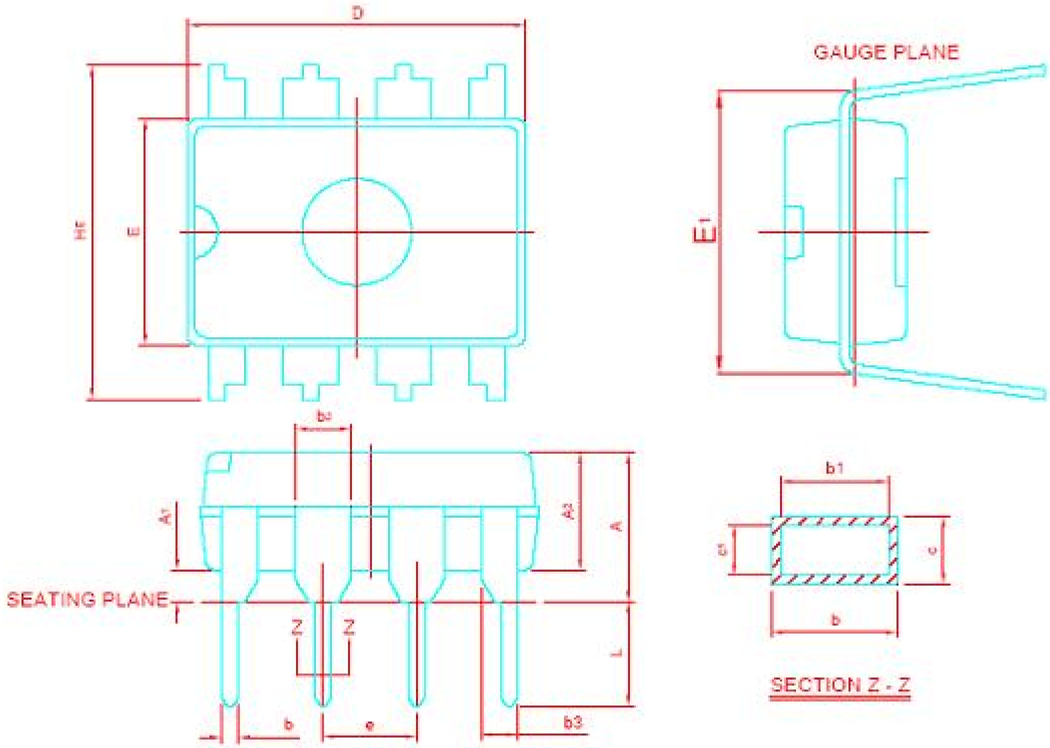


REF.	DIMENSIONS	
	Millimeters	
	Min.	Max.
A	5.80	6.20
B	4.80	5.00
C	3.80	4.00
D	0°	8°
E	0.40	0.90
F	0.19	0.25
M	0.10	0.25
H	0.35	0.49
L	1.35	1.75
J	0.375 REF.	
K	45°	
G	1.27 TYP.	



◆ PHYSICAL DIMENSIONS:

8-Pin Plastic DIP (T)



REF.	Millimeter		REF.	Millimeter	
	Min.	Max.		Min.	Max.
A	-	5.334	c1	0.203	0.279
A1	0.381	-	D	9.017	10.16
A2	2.921	4.953	E	6.096	7.112
b	0.356	0.559	E1	7.620	8.255
b1	0.356	0.508	e	2.540 BSC	
b2	1.143	1.778	H_E	-	10.92
b3	0.762	1.143	L	2.921	3.810
c	0.203	0.356			