HM1615

Micropower Step-Up DC/DC Converters in ThinSOT

FEATURES

- **Low Quiescent Current:**
  20µA in Active Mode
  <1µA in Shutdown Mode
- **Operates with V_{IN} as Low as 1V**
- Low V_{CESAT} Switch: 250mV at 300mA
- Uses Small Surface Mount Components
- High Output Voltage: Up to 34V
- Low Profile (1mm) ThinSOT™ Package

APPLICATIO S

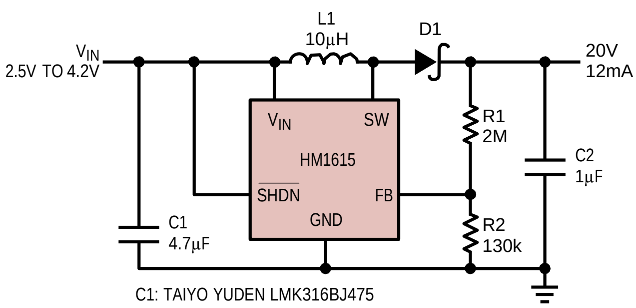
- LCD Bias
- Handheld Computers
- Battery Backup
- Digital Cameras

DESCRIPTION

The HM1615/HM1615-1 are micropower step-up DC/DC converters in a 5-lead low profile (1mm) ThinSOT package. The HM1615 is designed for higher power systems with a 350mA current limit and an input voltage range of 1.2V to 15V, whereas the HM1615-1 is intended for lower power and single-cell applications with a 100mA current limit and an extended input voltage range of 1V to 15V. Otherwise, the two devices are functionally equivalent. Both devices feature a quiescent current of only 20µA at no load, which further reduces to 0.5µA in shutdown. A current limited, fixed off-time control scheme conserves operating current, resulting in high efficiency over a broad range of load current. The 36V switch allows high voltage outputs up to 34V to be easily generated in a simple boost topology without the use of costly transformers. The HM1615's low off-time of 400ns permits the use of tiny, low profile inductors and capacitors to minimize footprint and cost in space-conscious portable applications.

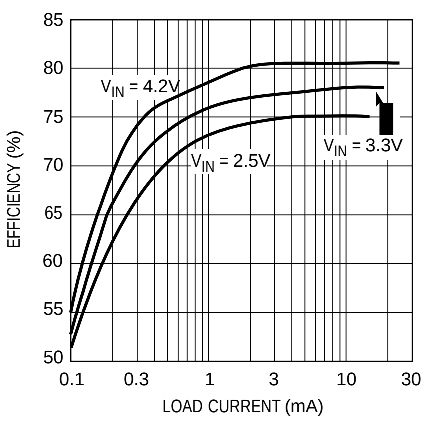
TYPICAL APPLICATION

1-Cell Li-Ion to 20V Converter for LCD Bias



C1: TAIYO YUDEN LMK316BJ475
C2: TAIYO YUDEN TMK316BJ105
D1: MOTOROLA MBR0530
L1: MURATA LQH3C100K24

Efficiency



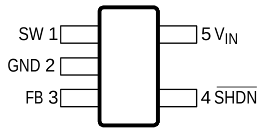
ABSOLUTE MAXIMUM RATINGS

(Note 1)

V_{IN}, $\overline{SHDN}$ Voltage 15V
SW Voltage 36V
FB Voltage .... V_{IN}
Current into FB Pin 1mA
Junction Temperature .... 125°C
Operating Temperature Range (Note 2) .. – 40°C to 85°C
Storage Temperature Range .... – 65°C to 150°C
Lead Temperature (Soldering, 10 sec).................. 300°C

PACKAGE/ORDER I FOR ATIO

TOP VIEW



S5 PACKAGE
5-LEAD PLASTIC SOT-23

T_{JMAX} = 125°C, θ_{JA} = 256°C/W

ORDER PART NUMBER
HM1615ES5 HM1615ES5-1 HM1615IS5
S5 PART MARKING
YTIZ YTKH YTXZ

Consult LTC Marketing for parts specified with wider operating temperature ranges.

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_{IN} = 1.2V, $V_{\overline{SHDN}}$ = 1.2V unless otherwise noted.

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Minimum Input Voltage	HM1615-1 HM1615				1.0 1.2	V V
Quiescent Current	Not Switching $V_{\overline{SHDN}}$ = 0V			20	30 1	µA µA
FB Comparator Trip Point		●	1.205	1.23	1.255	V
FB Comparator Hysteresis				8		mV
Output Voltage Line Regulation	1.2V < V_{IN} < 12V			0.05	0.1	%/V
FB Pin Bias Current (Note 3)	V_{FB} = 1.23V	●		30	80	nA
Switch Off Time	V_{FB} > 1V V_{FB} < 0.6V			400 1.5		ns µs
Switch V_{CESAT}	I_{SW} = 70mA (HM1615-1) I_{SW} = 300mA (HM1615)			85 250	120 350	mV mV
Switch Current Limit	HM1615-1 HM1615		75 300	100 350	125 400	mA mA
$\overline{SHDN}$ Pin Current	$V_{\overline{SHDN}}$ = 1.2V $V_{\overline{SHDN}}$ = 5V			2 8	3 12	µA µA
$\overline{SHDN}$ Input Voltage High			0.9			V
$\overline{SHDN}$ Input Voltage Low					0.25	V
Switch Leakage Current	Switch Off, V_{SW} = 5V			0.01	5	µA

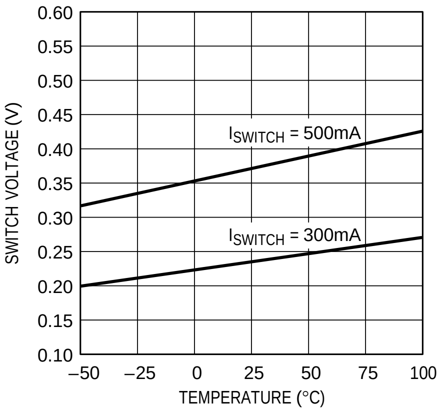
Note 1: Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

Note 2: The HM1615E and HM1615E-1 are guaranteed to meet performance specifications from 0°C to 70°C. Specifications over the –40°C to 85°C operating temperature range are assured by design, characterization and correlation with statistical process controls. The HM1615I is guaranteed to meet performance specifications over the –40° C to 85°C operating temperature range.

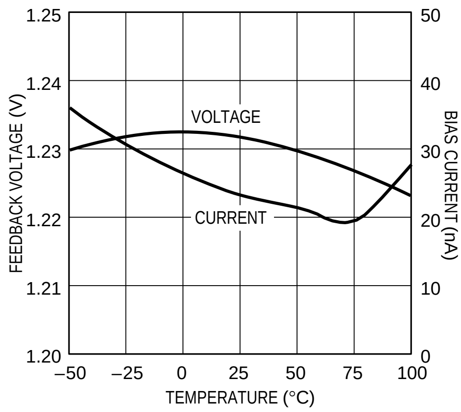
Note 3: Bias current flows into the FB pin.

TYPICAL PERFORMANCE CHARACTERISTICS

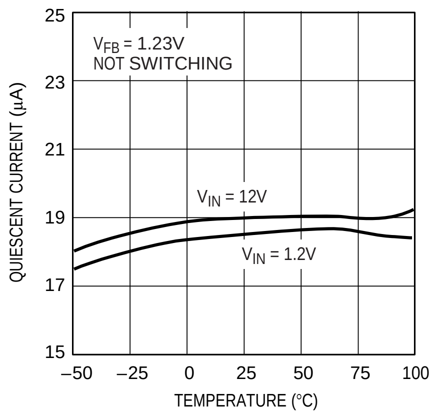
Switch Saturation Voltage (V_{CESAT})



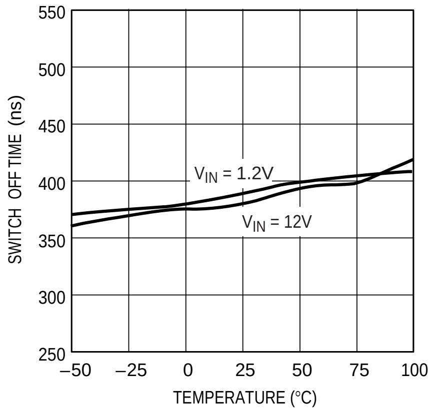
Feedback Pin Voltage and Bias Current



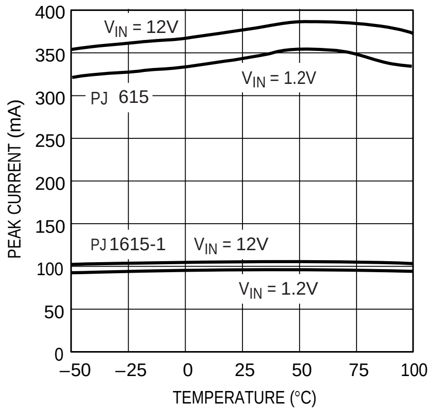
Quiescent Current



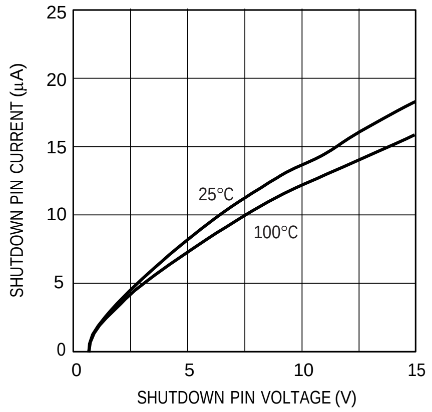
Switch Off Time



Switch Current Limit



Shutdown Pin Current



PIN FUNCTIONS

SW (Pin 1): Switch Pin. This is the collector of the internal NPN power switch. Minimize the metal trace area connected to this pin to minimize EMI.

GND (Pin 2): Ground. Tie this pin directly to the local ground plane.

FB (Pin 3): Feedback Pin. Set the output voltage by selecting values for R1 and R2 (see Figure 1):

$$R1 = R2\left(\frac{V_{OUT}}{1.23} - 1\right)$$

$\overline{SHDN}$ (Pin 4): Shutdown Pin. Tie this pin to 0.9V or higher to enable the device. Tie below 0.25V to turn off the device.

V_{IN} (Pin 5): Input Supply Pin. Bypass this pin with a capacitor as close to the device as possible.

BLOCK DIAGRAM

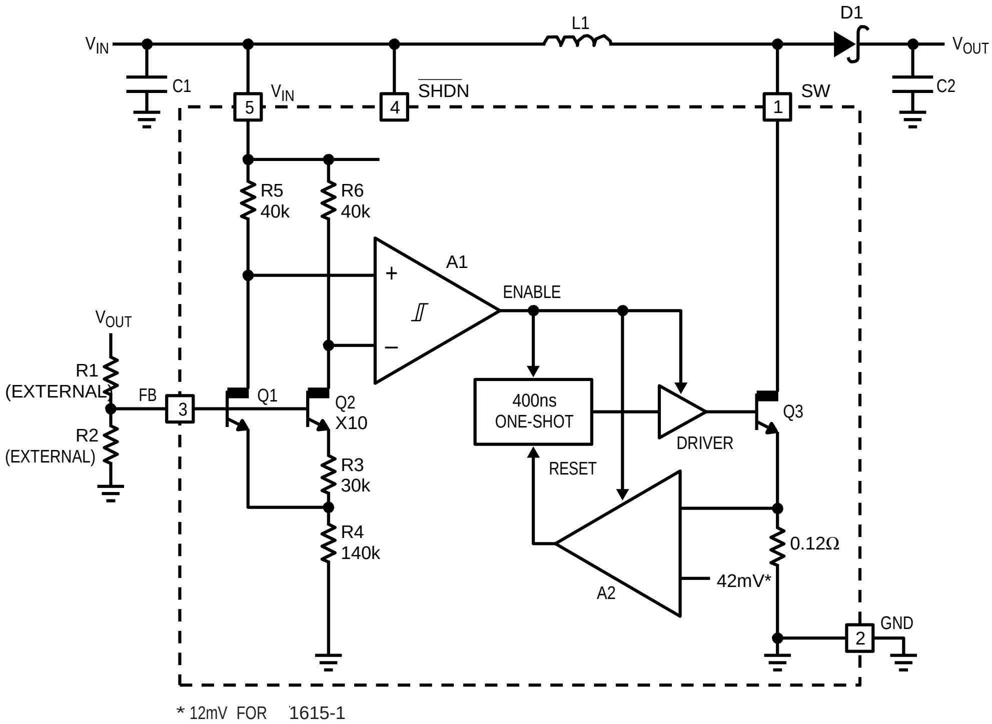


Figure 1. HM1615 Block Diagram

OPERATIO

The HM1615 uses a constant off-time control scheme to provide high efficiencies over a wide range of output current. Operation can be best understood by referring to the block diagram in Figure 1. Q1 and Q2 along with R3 and R4 form a bandgap reference used to regulate the output voltage. When the voltage at the FB pin is slightly above 1.23V, comparator A1 disables most of the internal circuitry. Output current is then provided by capacitor C2, which slowly discharges until the voltage at the FB pin drops below the lower hysteresis point of A1 (typical hysteresis at the FB pin is 8mV). A1 then enables the internal circuitry, turns on power switch Q3, and the current in inductor L1 begins ramping up. Once the switch current reaches 350mA, comparator A2 resets the one-shot, which turns off Q3 for 400ns. L1 then delivers current to the output through diode D1 as the inductor current ramps down. Q3 turns on again and the inductor current ramps back up to 350mA, then A2 resets the one-shot, again allowing L1 to deliver current to the output. This switching action continues until the output voltage is charged up (until the FB pin reaches 1.23V), then A1 turns off the internal circuitry and the cycle repeats. The HM1615 contains additional circuitry to provide protection during start-up and under short-circuit conditions. When the FB pin voltage is less than approximately 600mV, the switch off-time is increased to 1.5μs and the current limit is reduced to around 250mA (70% of its normal value). This reduces the average inductor current and helps minimize the power dissipation in the HM1615 power switch and in the external inductor and diode. The HM1615-1 operates in the same manner, except the switch current is limited to 100mA (the A2 reference voltage is 12mV instead of 42mV).

APPLICATIONS INFORMATION

Choosing an Inductor

Several recommended inductors that work well with the HM1615 and HM1615-1 are listed in Table 1, although there are many other manufacturers and devices that can be used. Consult each manufacturer for more detailed information and for their entire selection of related parts. Many different sizes and shapes are available. Use the equations and recommendations in the next few sections to find the correct inductance value for your design.

Table 1. Recommended Inductors

PART	VALUE (μH)	MAX DCR (Ω)	VENDOR
LQH3C4R7 LQH3C100 LQH3C220	4.7 10 22	0.26 0.30 0.92	Murata (814) 237-1431 www.murata.com
CD43-4R7 CD43-100 CDRH4D18-4R7 CDRH4D18-100	4.7 10 4.7 10	0.11 0.18 0.16 0.20	Sumida (847) 956-0666 www.sumida.com
DO1608-472 DO1608-103 DO1608-223	4.7 10 22	0.09 0.16 0.37	Coilcraft (847) 639-6400 www.coilcraft.com

Inductor Selection—Boost Regulator

The formula below calculates the appropriate inductor value to be used for a boost regulator using the HM1615 or HM1615-1 (or at least provides a good starting point). This value provides a good tradeoff in inductor size and system performance. Pick a standard inductor close to this value. A larger value can be used to slightly increase the available output current, but limit it to around twice the value calculated below, as too large of an inductance will increase the output voltage ripple without providing much additional output current. A smaller value can be used (especially for systems with output voltages greater than 12V) to give a smaller physical size. Inductance can be calculated as:

$$L = \frac{V_{OUT} - V_{IN(MIN)} + V_D}{I_{LIM}} t_{OFF}$$

where $V_D = 0.4V$ (Schottky diode voltage), $I_{LIM} = 350mA$ or 100mA, and $t_{OFF} = 400ns$; for designs with varying V_{IN} such as battery powered applications, use the minimum V_{IN} value in the above equation. For most systems with output voltages below 7V, a 4.7μH inductor is the best choice, even though the equation above might specify a smaller value. This is due to the inductor current overshoot that occurs when very small inductor values are used (see Current Limit Overshoot section).

For higher output voltages, the formula above will give large inductance values. For a 2V to 20V converter (typical LCD Bias application), a 21μH inductor is called for with the above equation, but a 10μH inductor could be used without excessive reduction in maximum output current.

Inductor Selection—SEPIC Regulator

The formula below calculates the approximate inductor value to be used for a SEPIC regulator using the HM1615. As for the boost inductor selection, a larger or smaller value can be used.

$$L = 2\left(\frac{V_{OUT} + V_D}{I_{LIM}}\right) t_{OFF}$$

Current Limit Overshoot

For the constant off-time control scheme of the HM1615, the power switch is turned off only after the 350mA (or 100mA) current limit is reached. There is a 100ns delay between the time when the current limit is reached and when the switch actually turns off. During this delay, the inductor current exceeds the current limit by a small amount. The peak inductor current can be calculated by:

$$I_{PEAK} = I_{LIM} + \left(\frac{V_{IN(MAX)} - V_{SAT}}{L}\right) 100\ ns$$

Where $V_{SAT} = 0.25V$ (switch saturation voltage). The current overshoot will be most evident for systems with high input voltages and for systems where smaller inductor values are used. This overshoot can be beneficial as it helps increase the amount of available output current for smaller inductor values. This will be the peak current seen by the inductor (and the diode) during normal operation. For designs using small inductance values (especially at

APPLICATIONS INFORMATION

input voltages greater than 5V), the current limit overshoot can be quite high. Although it is internally current limited to 350mA, the power switch of the HM1615 can handle larger currents without problem, but the overall efficiency will suffer. Best results will be obtained when I_{PEAK} is kept below 700mA for the HM1615 and below 400mA for the HM1615-1.

Capacitor Selection

Low ESR (Equivalent Series Resistance) capacitors should be used at the output to minimize the output ripple voltage. Multilayer ceramic capacitors are the best choice, as they have a very low ESR and are available in very small packages. Their small size makes them a good companion to the HM1615's SOT-23 package. Solid tantalum capacitors (like the AVX TPS, Sprague 593D families) or OS-CON capacitors can be used, but they will occupy more board area than a ceramic and will have a higher ESR. Always use a capacitor with a sufficient voltage rating.

Ceramic capacitors also make a good choice for the input decoupling capacitor, which should be placed as close as possible to the HM1615. A 4.7µ F input capacitor is suffi- cient for most applications. Table 2 shows a list of several capacitor manufacturers. Consult the manufacturers for more detailed information and for their entire selection of related parts.

Diode Selection

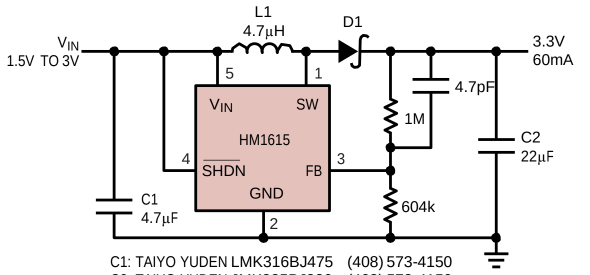
For most HM1615 applications, the Motorola MBR0520 surface mount Schottky diode (0.5A, 20V) is an ideal choice. Schottky diodes, with their low forward voltage drop and fast switching speed, are the best match for the HM1615. For higher output voltage applications the 30V MBR0530 can be used. Many different manufacturers make equivalent parts, but make sure that the component is rated to handle at least 0.35A. For HM1615-1 applications, a Philips BAT54 or Central Semiconductor CMDSH-3 works well.

Lowering Output Voltage Ripple

Using low ESR capacitors will help minimize the output ripple voltage, but proper selection of the inductor and the output capacitor also plays a big role. The HM1615 pro- vides energy to the load in bursts by ramping up the inductor current, then delivering that current to the load. If too large of an inductor value or too small of a capacitor value is used, the output ripple voltage will increase because the capacitor will be slightly overcharged each burst cycle. To reduce the output ripple, increase the output capacitor value or add a 4.7pF feed-forward capaci- tor in the feedback network of the HM1615 (see the circuits in the Typical Applications section). Adding this small, inexpensive 4.7pF capacitor will greatly reduce the output voltage ripple.

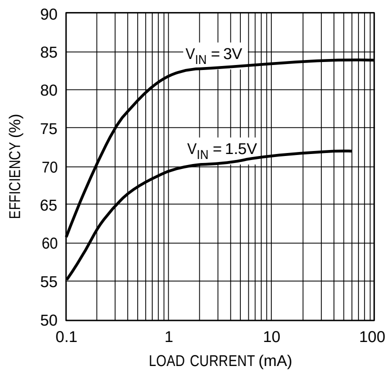
TYPICAL APPLICATIONS

2-Cell to 3.3V Boost Converter

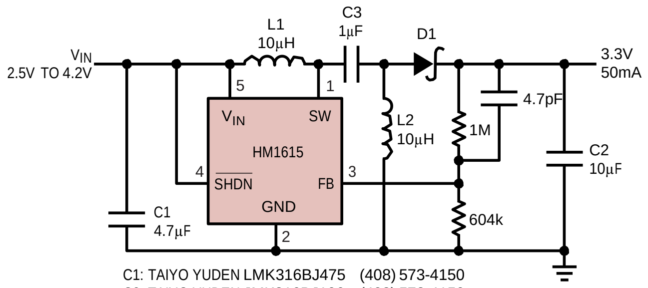


C1: TAIYO YUDEN LMK316BJ475 (408) 573-4150
C2: TAIYO YUDEN JMK325BJ226 (408) 573-4150
L1: MURATA LQH3C4R7M24 (814) 237-1431
D1: MOTOROLA MBR0520 (800) 441-2447

2-Cell to 3.3V Converter Efficiency

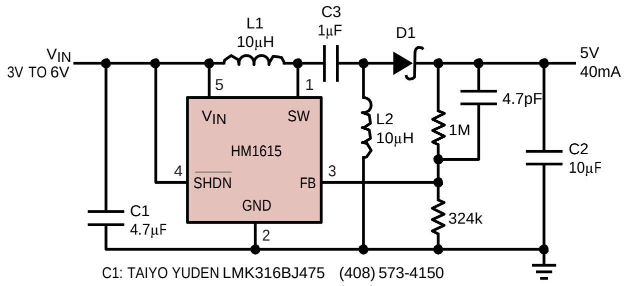


1-Cell Li-Ion to 3.3V SEPIC Converter



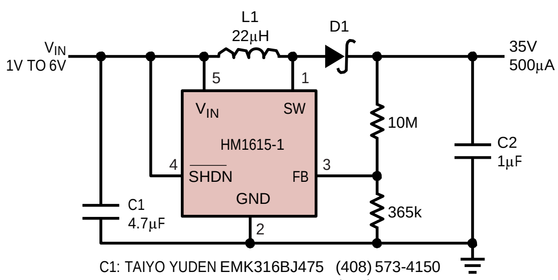
C1: TAIYO YUDEN LMK316BJ475 (408) 573-4150
C2: TAIYO YUDEN JMK316BJ106 (408) 573-4150
C3: TAIYO YUDEN JMK107BJ105 (408) 573-4150
L1, L2: MURATA LQH3C100K24 (814) 237-1431
D1: MOTOROLA MBR0520 (800) 441-2447

4-Cell to 5V SEPIC Converter



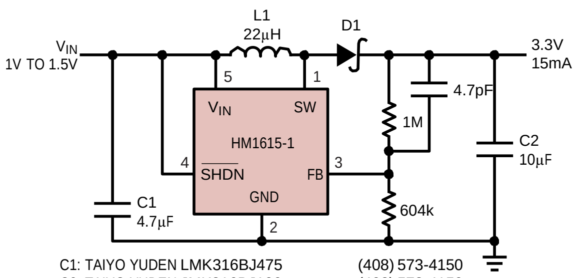
C1: TAIYO YUDEN LMK316BJ475 (408) 573-4150
C2: TAIYO YUDEN JMK316BJ106 (408) 573-4150
C3: TAIYO YUDEN JMK107BJ105 (408) 573-4150
L1, L2: MURATA LQH3C100K24 (814) 237-1431
D1: MOTOROLA MBR0520 (800) 441-2447

PIN Diode Driver



C1: TAIYO YUDEN EMK316BJ475 (408) 573-4150
C2: TAIYO YUDEN GMK316BJ105 (408) 573-4150
L1: MURATA LQH3C220K24 (814) 237-1431
D1: MOTOROLA MBR0540 (800) 441-2447

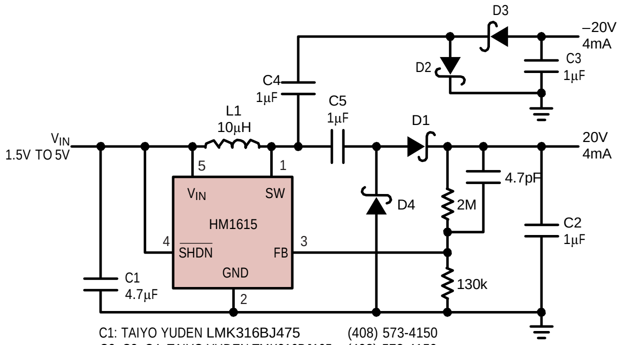
1-Cell to 3.3V Boost Converter



C1: TAIYO YUDEN LMK316BJ475 (408) 573-4150
C2: TAIYO YUDEN JMK316BJ106 (408) 573-4150
L1: MURATA LQH3C220K24 (814) 237-1431
D1: CENTRAL SEMICONDUCTOR CMDSH-3 (516) 435-1110

TYPICAL APPLICATIONS

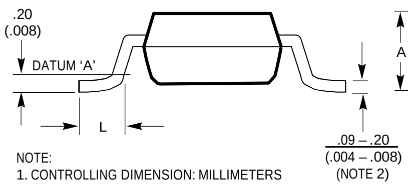
±20V Dual Output Converter with Output Disconnect

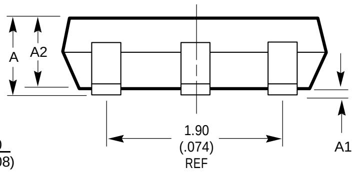


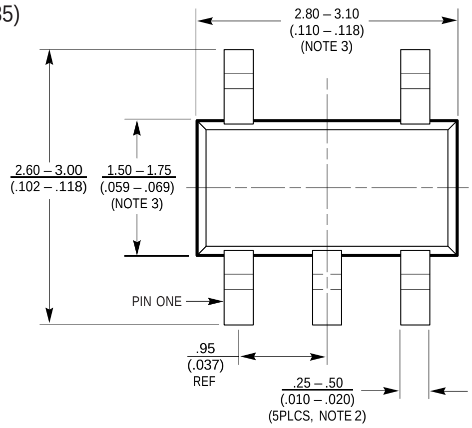
C1: TAIYO YUDEN LMK316BJ475 (408) 573-4150
C2, C3, C4: TAIYO YUDEN TMK316BJ105 (408) 573-4150
C5: TAIYO YUDEN LMK212BJ105 (408) 573-4150
L1: MURATA LQH3C100K24 (814) 237-1431
D1, D2, D3, D4: MOTOROLA MBR0530 (800) 441-2447

PACKAGE DESCRIPTION

S5 Package
5-Lead Plastic SOT-23
(Reference LTC DWG # 05-08-1633)
(Reference LTC DWG # 05-08-1635)







NOTE:
1. CONTROLLING DIMENSION: MILLIMETERS
2. DIMENSIONS ARE IN $\frac{\text{MILLIMETERS}}{\text{(INCHES)}}$
3. DRAWING NOT TO SCALE
4. DIMENSIONS ARE INCLUSIVE OF PLATING
5. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH AND METAL BURR
6. MOLD FLASH SHALL NOT EXCEED .254mm
7. PACKAGE EIAJ REFERENCE IS:
SC-74A (EIAJ) FOR ORIGINAL
JEDEL MO-193 FOR THIN

	SOT-23 (Original)	SOT-23 (ThinSOT)
A	.90 – 1.45 (.035 – .057)	1.00 MAX (.039 MAX)
A1	.00 – .15 (.00 – .006)	.01 – .10 (.0004 – .004)
A2	.90 – 1.30 (.035 – .051)	.80 – .90 (.031 – .035)
L	.35 – .55 (.014 – .021)	.30 – .50 REF (.012 – .019 REF)