

5A and 2.5A High Efficiency Switching Regulators

FEATURES

- Wide Input Voltage Range: 3V to 60V
- Low Quiescent Current: 6mA
- Internal 5A Switch (2.5A for LT1071)
- Very Few External Parts Required
- Self Protected Against Overloads
- Operates in Nearly All Switching Topologies
- Shutdown Mode Draws Only 50 μ A Supply Current
- Flyback Regulated Mode Has Fully Floating Outputs
- Comes in Standard 5-Pin TO-220 Package
- Can be Externally Synchronized (Consult Factory)

APPLICATIONS

- Logic Supply 5V at 10A
- 5V Logic to ± 15 V Op Amp Supply
- Off-Line Converter Up to 200W
- Battery Upconverter
- Power Inverter (+ to -) or (- to +)
- Fully Floating Multiple Outputs
- For Lower Current Applications, See the LT1072

USER NOTE:

This data sheet is only intended to provide specifications, graphs and a general functional description of the LT1070/LT1071. Application circuits are included to show the capability of the LT1070/LT1071. A complete design manual (AN19) should be obtained to assist in developing new designs. This manual contains a comprehensive discussion of both the LT1070 and the external components used with it, as well as complete formulas for calculating the values of these components. The manual can also be used for the LT1071 by factoring in the lower switch current rating. A second Application Note, AN25, which details off-line applications is available.

DESCRIPTION

The LT[®]1070/LT1071 are monolithic high power switching regulators. They can be operated in all standard switching configurations including buck, boost, flyback, forward, inverting and "Cuk". A high current, high efficiency switch is included on the die along with all oscillator, control and protection circuitry. Integration of all functions allows the LT1070/LT1071 to be built in a standard 5-pin TO-220 power package. This makes it extremely easy to use and provides "bust proof" operation similar to that obtained with 3-pin linear regulators.

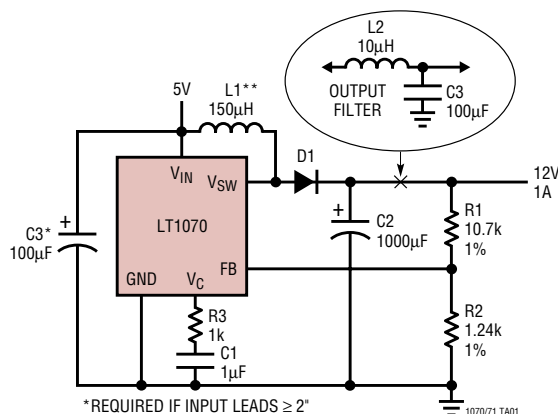
The LT1070/LT1071 operate with supply voltages from 3V to 60V, and draw only 6mA quiescent current. They can deliver load power up to 100W with no external power devices. By utilizing current mode switching techniques, they provide excellent AC and DC load and line regulation.

The LT1070/LT1071 have many unique features not found even on the vastly more difficult to use low power control chips presently available. They use adaptive antisat switch drive to allow very wide ranging load currents with no loss in efficiency. An externally activated shutdown mode reduces total supply current to 50 μ A typical for standby operation. Totally isolated and regulated outputs can be generated by using the optional "flyback regulation mode" built into the LT1070/LT1071, without the need for optocouplers or extra transformer windings.

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TYPICAL APPLICATION

Boost Converter (5V to 12V)

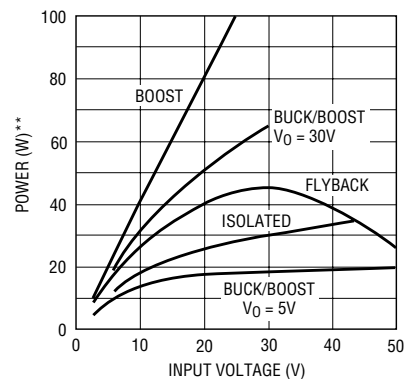


*REQUIRED IF INPUT LEADS $\geq 2^\circ$

**PULSE ENGINEERING 92113

1070/71 TA01

Maximum Output Power*



1070/71 TA02

*ROUGH GUIDE ONLY. BUCK MODE $P_{OUT} = 5A \cdot V_{OUT}$. SPECIAL TOPOLOGIES DELIVER MORE POWER

**DIVIDE VERTICAL POWER SCALE BY 2 FOR LT1071

LT1070/LT1071

ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage		Operating Junction Temperature Range	
LT1070/LT1071 (Note 2)	40V	Commercial (Operating)	0°C to 100°C
LT1070HV/LT1071HV (Note 2)	60V	Commercial (Short Circuit)	0°C to 125°C
Switch Output Voltage		Industrial	–40°C to 125°C
LT1070/LT1071	65V	Military (OBSOLETE)	–55°C to 150°C
LT1070HV/LT1071HV	75V	Storage Temperature Range	–65°C to 150°C
Feedback Pin Voltage (Transient, 1ms)	±15V	Lead Temperature (Soldering, 10 sec)	300°C

PACKAGE/ORDER INFORMATION

BOTTOM VIEW K PACKAGE 4-LEAD TO-3 METAL CAN $T_{JMAX} = 100^{\circ}\text{C}$, $\theta_{JA} = 35^{\circ}\text{C/W}$, $Q_{JC} = 2^{\circ}\text{C}$ (LT1070C, I) $T_{JMAX} = 150^{\circ}\text{C}$, $\theta_{JA} = 35^{\circ}\text{C/W}$, $Q_{JC} = 2^{\circ}\text{C}$ (LT1070M) $T_{JMAX} = 100^{\circ}\text{C}$, $\theta_{JA} = 35^{\circ}\text{C/W}$, $Q_{JC} = 4^{\circ}\text{C}$ (LT1071C, I) $T_{JMAX} = 150^{\circ}\text{C}$, $\theta_{JA} = 35^{\circ}\text{C/W}$, $Q_{JC} = 4^{\circ}\text{C}$ (LT1071M) OBSOLETE PACKAGE Consider the T5 Package for Alternate Source	ORDER PART NUMBER LT1070CK LT1070HVCK LT1070HVMK LT1070IK LT1070MK LT1071CK LT1071HVCK LT1071HVMK LT1071MK	FRONT VIEW T PACKAGE 5-LEAD PLASTIC TO-220 $T_{JMAX} = 100^{\circ}\text{C}$, $\theta_{JA} = 75^{\circ}\text{C/W}$, $Q_{JC} = 2^{\circ}\text{C}$ (LT1070C, I) $T_{JMAX} = 100^{\circ}\text{C}$, $\theta_{JA} = 75^{\circ}\text{C/W}$, $Q_{JC} = 4^{\circ}\text{C}$ (LT1071C)	ORDER PART NUMBER LT1070CT LT1070HVCT LT1070HVIT LT1070IT LT1071CT LT1071HVCT LT1071HVIT LT1071IT
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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 $T_A = 25^{\circ}\text{C}$. $V_{IN} = 15\text{V}$, $V_C = 0.5\text{V}$, $V_{FB} = V_{REF}$, output pin open unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{REF}	Reference Voltage	Measured at Feedback Pin, $V_C = 0.8\text{V}$	● 1.224 1.214	1.244 1.244	1.264 1.274	V V
I_B	Feedback Input Current	$V_{FB} = V_{REF}$	●	350	750 1100	nA nA
g_m	Error Amplifier Transconductance	$\Delta I_C = \pm 25\mu\text{A}$	● 3000 2400	4400	6000 7000	μmho μmho
	Error Amplifier Source or Sink Current	$V_C = 1.5\text{V}$	● 150 120	200	350 400	μA μA
	Error Amplifier Clamp Voltage	Hi Clamp, $V_{FB} = 1\text{V}$ Lo Clamp, $V_{FB} = 1.5\text{V}$	1.80 0.25	0.38	2.30 0.52	V V
	Reference Voltage Line Regulation	$3\text{V} \leq V_{IN} \leq V_{MAX}$, $V_C = 0.8\text{V}$	●		0.03	%/V
A_V	Error Amplifier Voltage Gain	$0.9\text{V} \leq V_C \leq 1.4\text{V}$		500	800	V/V
	Minimum Input Voltage		●	2.6	3.0	V
I_Q	Supply Current	$3\text{V} \leq V_{IN} \leq V_{MAX}$, $V_C = 0.6\text{V}$		6	9	mA
	Control Pin Threshold	Duty Cycle = 0	● 0.8 0.6	0.9	1.08 1.25	V V
	Normal/Flyback Threshold on Feedback Pin			0.4	0.45	0.54 V

10701fe

ELECTRICAL CHARACTERISTICS The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^\circ\text{C}$. $V_{IN} = 15\text{V}$, $V_C = 0.5\text{V}$, $V_{FB} = V_{REF}$, output pin open unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{FB}	Flyback Reference Voltage	$I_{FB} = 50\mu\text{A}$	15 14	16.3	17.6 18.0	V V
	Change in Flyback Reference Voltage	$0.05 \leq I_{FB} \leq 1\text{mA}$	4.5	6.8	8.5	V
	Flyback Reference Voltage Line Regulation	$I_{FB} = 50\mu\text{A}$, $3\text{V} \leq V_{IN} \leq V_{MAX}$ (Note 3)		0.01	0.03	%/V
	Flyback Amplifier Transconductance (g_m)	$\Delta I_C = \pm 10\mu\text{A}$	150	300	650	μmho
	Flyback Amplifier Source and Sink Current	$V_C = 0.6\text{V}$, $I_{FB} = 50\mu\text{A}$ (Source)	15	32	70	μA
		$V_C = 0.6\text{V}$, $I_{FB} = 50\mu\text{A}$ (Sink)	25	40	70	μA
B_V	Output Switch Breakdown Voltage	$3\text{V} \leq V_{IN} \leq V_{MAX}$, $I_{SW} = 1.5\text{mA}$ (LT1070/LT1071)	65	90		V
		(LT1070HV/LT1071HV)	75	90		V
V_{SAT}	Output Switch "On" Resistance (Note 4)	LT1070		0.15	0.24	Ω
		LT1071		0.30	0.50	Ω
	Control Voltage to Switch Current Transconductance	LT1070		8		A/V
		LT1071		4		A/V
I_{LIM}	Switch Current Limit (LT1070)	Duty Cycle $\leq 50\%$, $T_J \geq 25^\circ\text{C}$	5		10	A
		Duty Cycle $\leq 50\%$, $T_J < 25^\circ\text{C}$	5		11	A
		Duty Cycle = 80% (Note 5)	4		10	A
	Switch Current Limit (LT1071)	Duty Cycle $\leq 50\%$, $T_J \geq 25^\circ\text{C}$	2.5		5.0	A
		Duty Cycle $\leq 50\%$, $T_J < 25^\circ\text{C}$	2.5		5.5	A
		Duty Cycle = 80% (Note 5)	2.0		5.0	A
$\frac{\Delta I_{IN}}{\Delta I_{SW}}$	Supply Current Increase During Switch "On" Time			25	35	mA/A
f	Switching Frequency		35	40	45	kHz
			33		47	kHz
DC (Max)	Maximum Switch Duty Cycle		90	92	97	%
	Flyback Sense Delay Time			1.5		μs
	Shutdown Mode Supply Current	$3\text{V} \leq V_{IN} \leq V_{MAX}$, $V_C = 0.05\text{V}$		100	250	μA
	Shutdown Mode Threshold Voltage	$3\text{V} \leq V_{IN} \leq V_{MAX}$	100	150	250	mV
			50		300	mV

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

Note 2: Minimum switch "on" time for the LT1070/LT1071 in current limit is $\approx 1\mu\text{s}$. This limits the maximum input voltage during short-circuit conditions, in the buck and inverting modes only, to $\approx 35\text{V}$. Normal (unshorted) conditions are not affected. Mask changes are being implemented which will reduce minimum "on" time to $\leq 1\mu\text{s}$, increasing maximum short-circuit input voltage above 40V. If the present LT1070/LT1071 (contact factory for package date code) is being operated in the buck or inverting mode at high input voltages and short-circuit conditions are expected, a resistor must be placed in series with the inductor, as follows:

The value of the resistor is given by:

$$R = \frac{t \cdot f \cdot V_{IN} - V_F}{I_{LIMIT}} - R_L$$

t = Minimum "on" time of LT1070/LT1071 in current limit, $\approx 1\mu\text{s}$

f = Operating frequency (40kHz)

V_F = Forward voltage of external catch diode at I_{LIMIT}

I_{LIMIT} = Current limit of LT1070 ($\approx 8\text{A}$), LT1071 ($\approx 4\text{A}$)

R_L = Internal series resistance of inductor

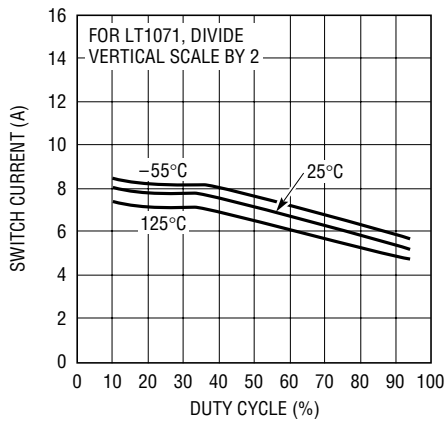
Note 3: $V_{MAX} = 55\text{V}$ for LT1070HV and LT1071HV to avoid switch breakdown.

Note 4: Measured with V_C in hi clamp, $V_{FB} = 0.8\text{V}$. $I_{SW} = 4\text{A}$ for LT1070 and 2A for LT1071.

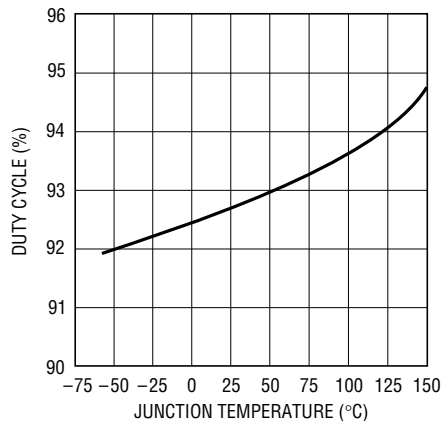
Note 5: For duty cycles (DC) between 50% and 80%, minimum guaranteed switch current is given by $I_{LIM} = 3.33 (2 - \text{DC})$ for the LT1070 and $I_{LIM} = 1.67 (2 - \text{DC})$ for the LT1071.

TYPICAL PERFORMANCE CHARACTERISTICS

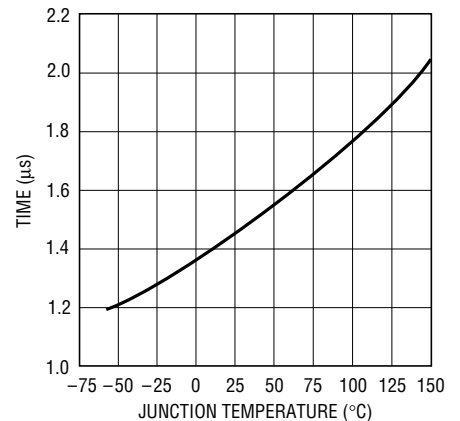
Switch Current Limit vs Duty Cycle



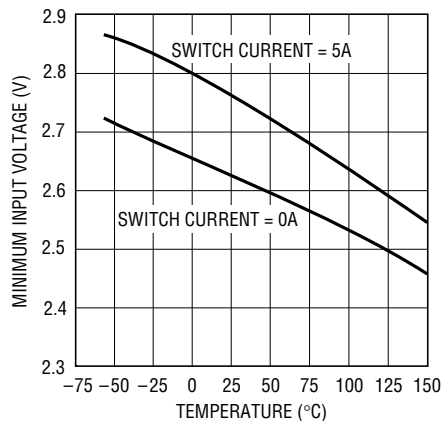
Maximum Duty Cycle



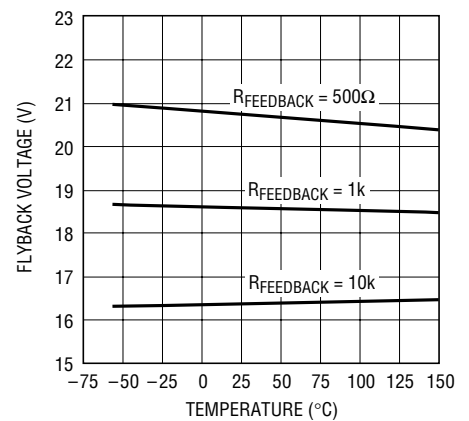
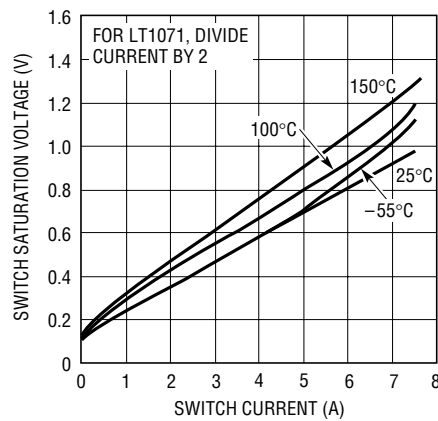
Flyback Blanking Time



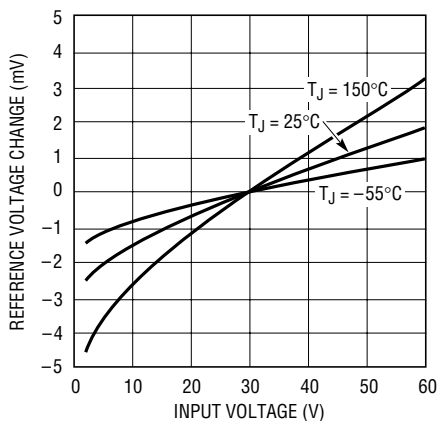
Minimum Input Voltage



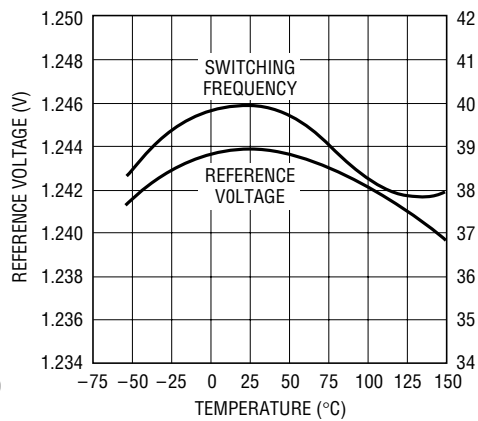
Switch Saturation Voltage



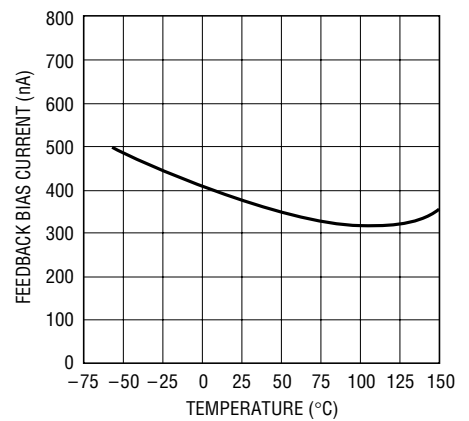
Line Regulation



Reference Voltage vs Temperature

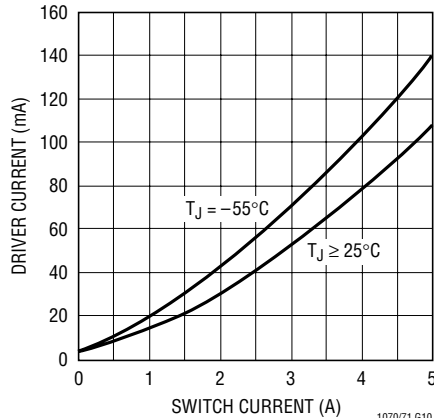


Feedback Bias Current vs Temperature



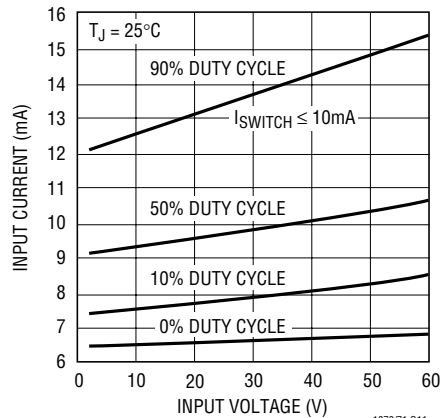
TYPICAL PERFORMANCE CHARACTERISTICS

Driver Current* vs Switch Current



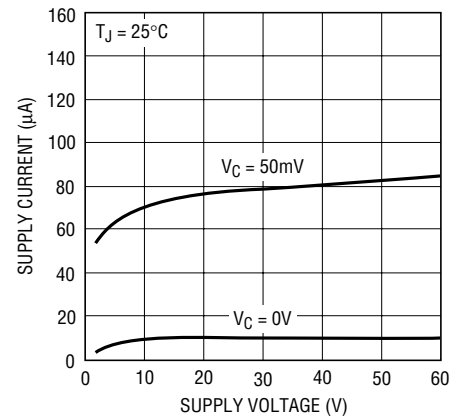
* AVERAGE LT1070 POWER SUPPLY CURRENT IS FOUND BY MULTIPLYING DRIVER CURRENT BY DUTY CYCLE, THEN ADDING QUIESCENT CURRENT

Supply Current vs Input Voltage*

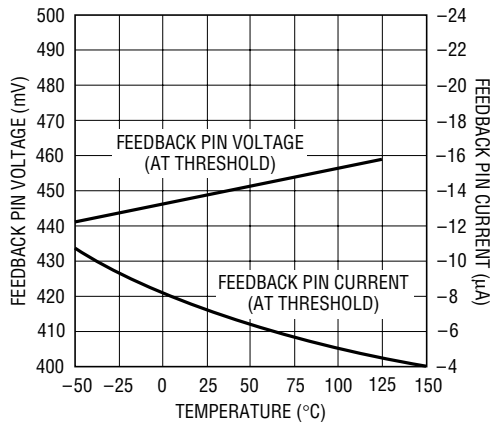


* UNDER VERY LOW OUTPUT CURRENT CONDITIONS, DUTY CYCLE FOR MOST CIRCUITS WILL APPROACH 10% OR LESS

Supply Current vs Supply Voltage (Shutdown Mode)

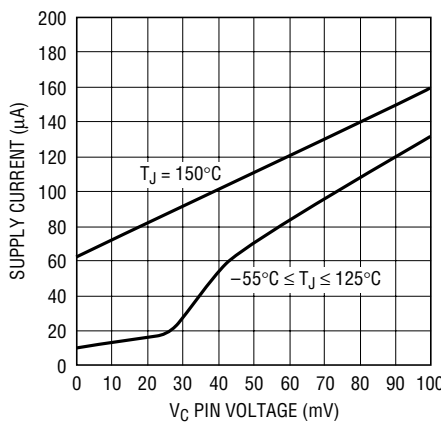


Normal/Flyback Mode Threshold on Feedback Pin



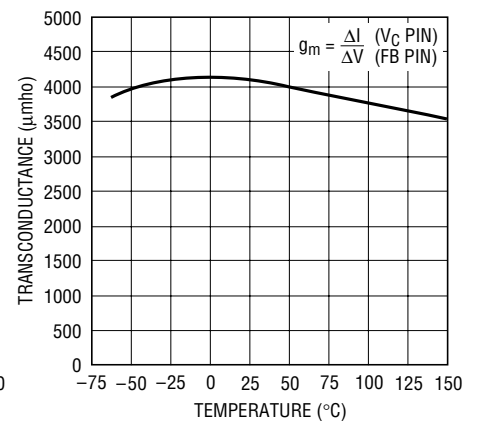
1070/71 G13

Shutdown Mode Supply Current



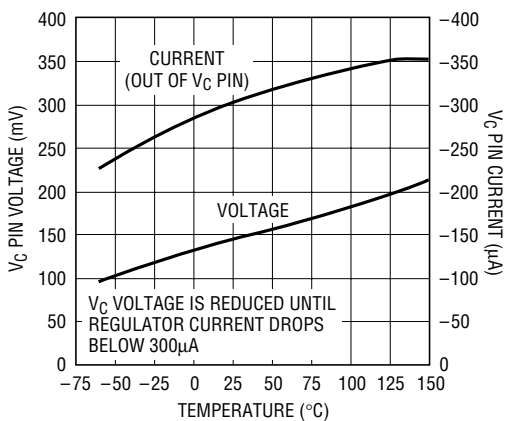
1070/71 G14

Error Amplifier Transconductance



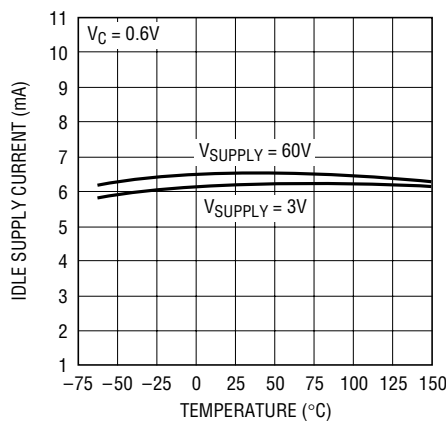
1070/71 G14

Shutdown Thresholds



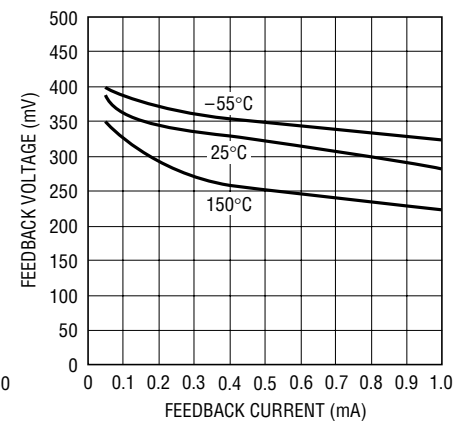
1070/71 G16

Idle Supply Current vs Temperature

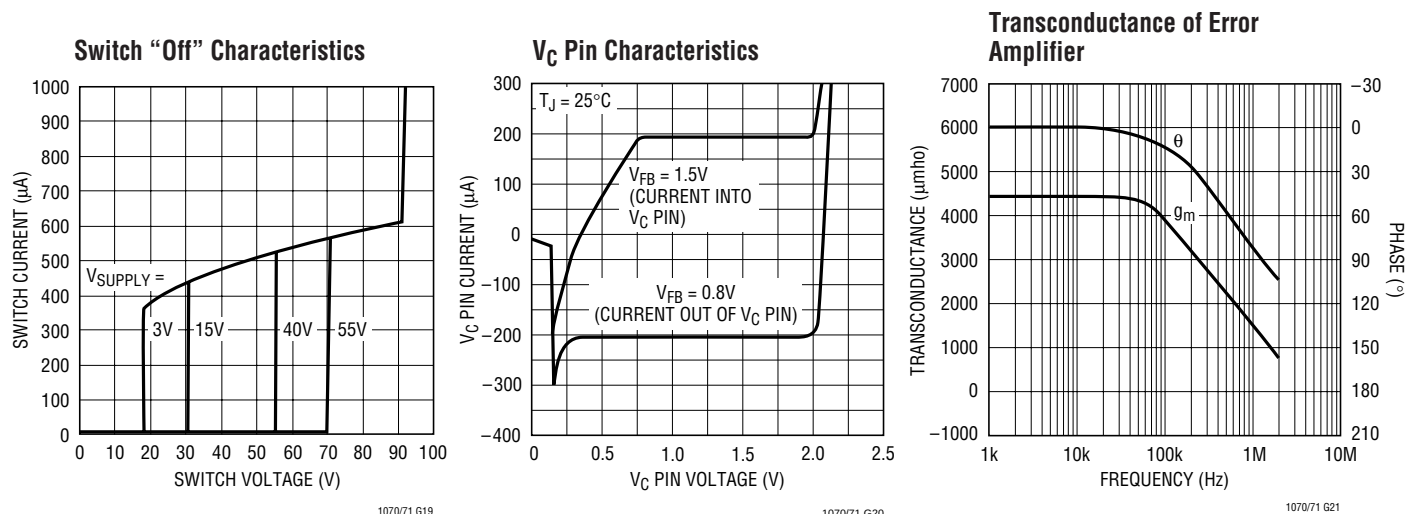


1070/71 G14

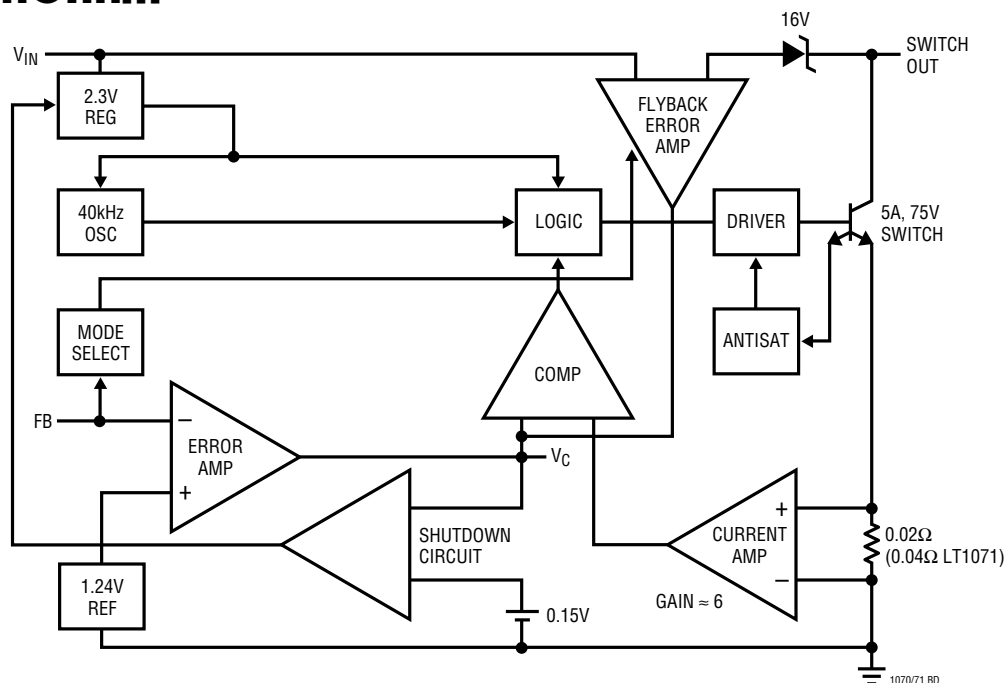
Feedback Pin Clamp Voltage


1070/71 G18
10701fe

TYPICAL PERFORMANCE CHARACTERISTICS



BLOCK DIAGRAM



OPERATION

The LT1070/LT1071 is a current mode switcher. This means that switch duty cycle is directly controlled by switch current rather than by output voltage. Referring to the Block Diagram, the switch is turned "on" at the start of each oscillator cycle. It is turned "off" when switch current reaches a predetermined level. Control of output

voltage is obtained by using the output of a voltage sensing error amplifier to set current trip level. This technique has several advantages. First, it has immediate response to input voltage variations, unlike ordinary switchers which have notoriously poor line transient response. Second, it reduces the 90° phase shift at

OPERATION

midfrequencies in the energy storage inductor. This greatly simplifies closed-loop frequency compensation under widely varying input voltage or output load conditions. Finally, it allows simple pulse-by-pulse current limiting to provide maximum switch protection under output overload or short-circuit conditions. A low drop-out internal regulator provides a 2.3V supply for all internal circuitry of the LT1070/LT1071. This low drop-out design allows input voltage to vary from 3V to 60V with virtually no change in device performance. A 40kHz oscillator is the basic clock for all internal timing. It turns "on" the output switch via the logic and driver circuitry. Special adaptive antisat circuitry detects onset of saturation in the power switch and adjusts driver current instantaneously to limit switch saturation. This minimizes driver dissipation and provides very rapid turn-off of the switch.

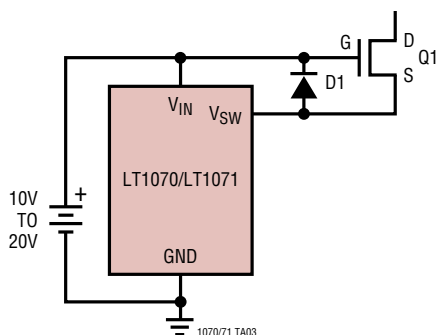
A 1.2V bandgap reference biases the positive input of the error amplifier. The negative input is brought out for output voltage sensing. This feedback pin has a second function; when pulled low with an external resistor, it programs the LT1070/LT1071 to disconnect the main error amplifier output and connects the output of the flyback amplifier to the comparator input. The LT1070/LT1071 will then regulate the value of the flyback pulse with respect to the supply voltage. This flyback pulse is directly proportional to output voltage in the traditional

transformer coupled flyback topology regulator. By regulating the amplitude of the flyback pulse, the output voltage can be regulated with no direct connection between input and output. The output is fully floating up to the breakdown voltage of the transformer windings. Multiple floating outputs are easily obtained with additional windings. A special delay network inside the LT1070/LT1071 ignores the leakage inductance spike at the leading edge of the flyback pulse to improve output regulation.

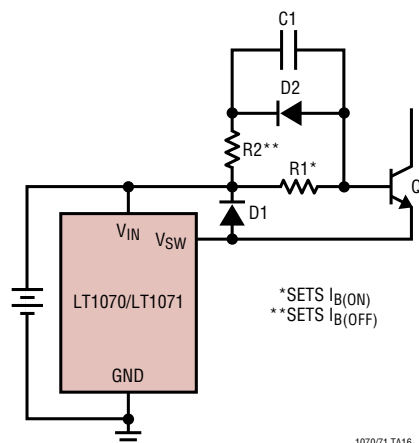
The error signal developed at the comparator input is brought out externally. This pin (V_C) has four different functions. It is used for frequency compensation, current limit adjustment, soft starting and total regulator shutdown. During normal regulator operation this pin sits at a voltage between 0.9V (low output current) and 2.0V (high output current). The error amplifiers are current output (g_m) types, so this voltage can be externally clamped for adjusting current limit. Likewise, a capacitor coupled external clamp will provide soft start. Switch duty cycle goes to zero if the V_C pin is pulled to ground through a diode, placing the LT1070/LT1071 in an idle mode. Pulling the V_C pin below 0.15V causes total regulator shutdown, with only 50 μ A supply current for shutdown circuitry biasing. See AN19 for full application details.

TYPICAL APPLICATIONS (Note that maximum output currents are divided by 2 for the LT1071)

Driving High Voltage FET (for Off-Line Applications, See AN25)



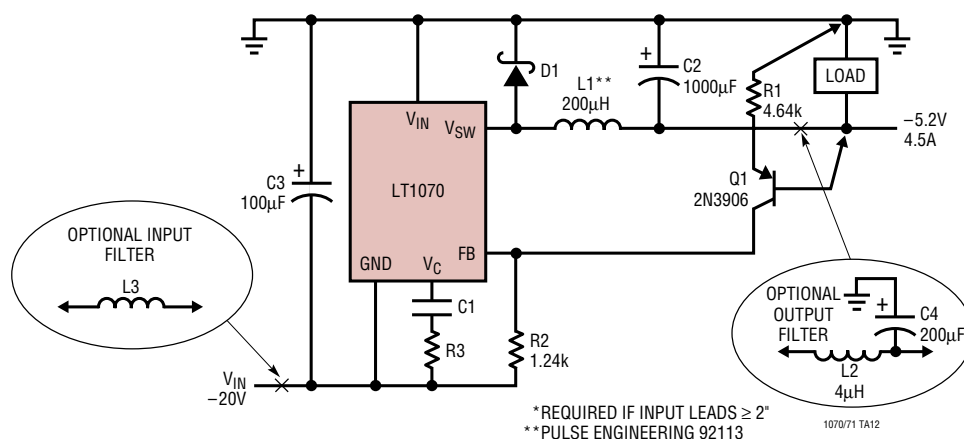
Driving High Voltage NPN



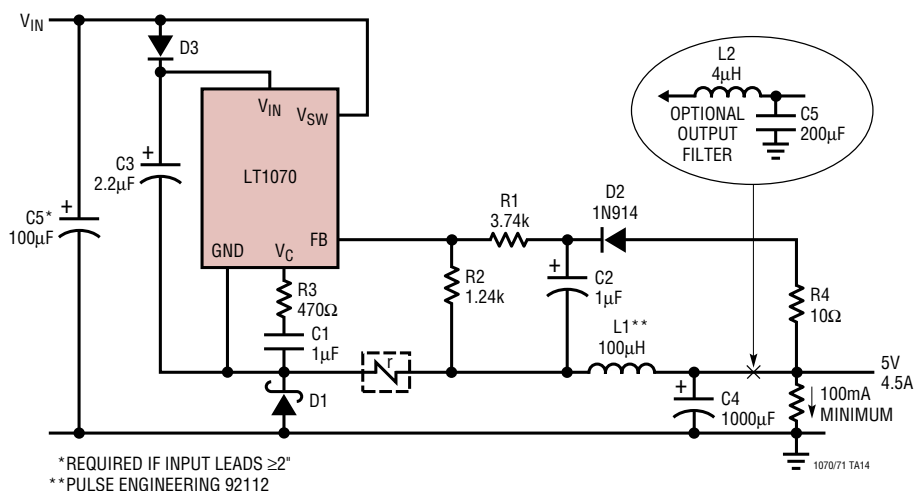
TYPICAL APPLICATIONS

(Note that maximum output currents are divided by 2 for the LT1071)

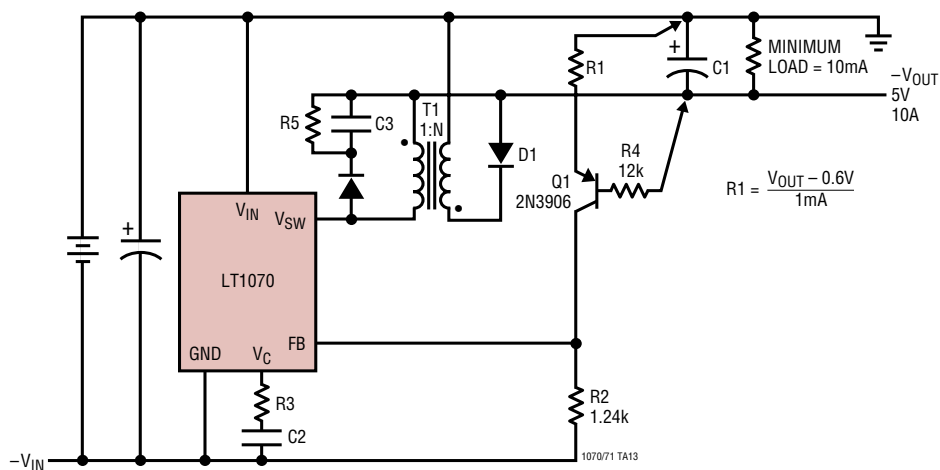
Negative Buck Converter



Positive Buck Converter



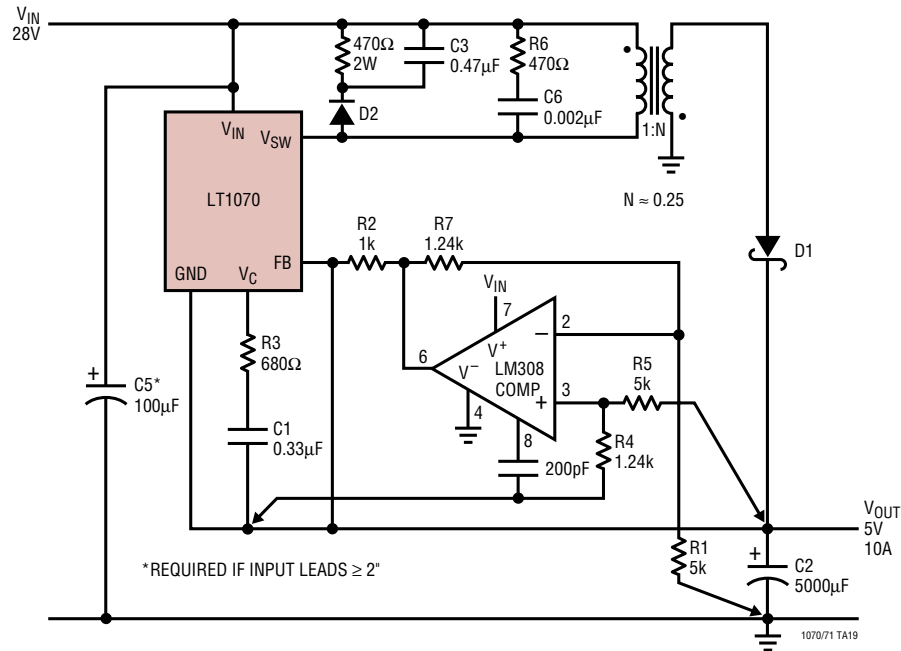
Negative Current Boosted Buck Converter



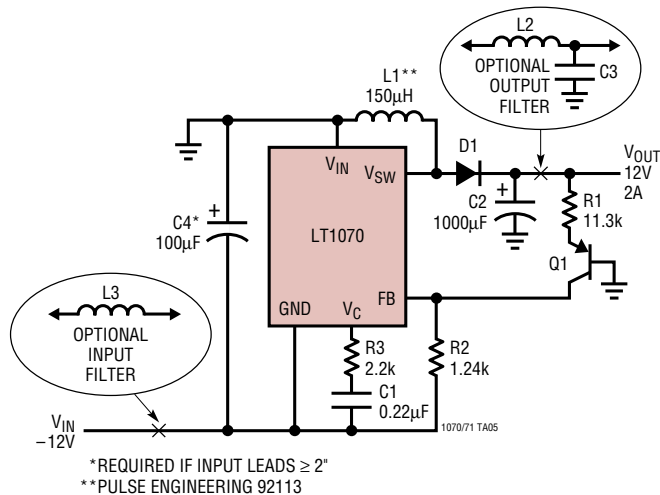
TYPICAL APPLICATIONS

(Note that maximum output currents are divided by 2 for the LT1071)

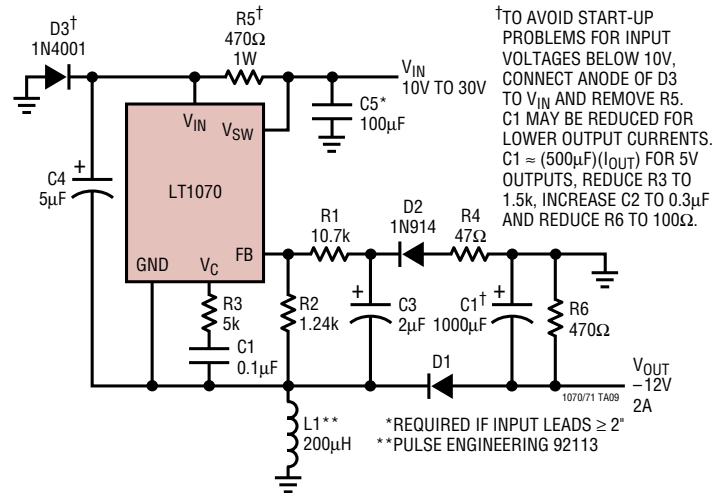
Positive Current Boosted Buck Converter



Negative to Positive Buck/Boost Converter



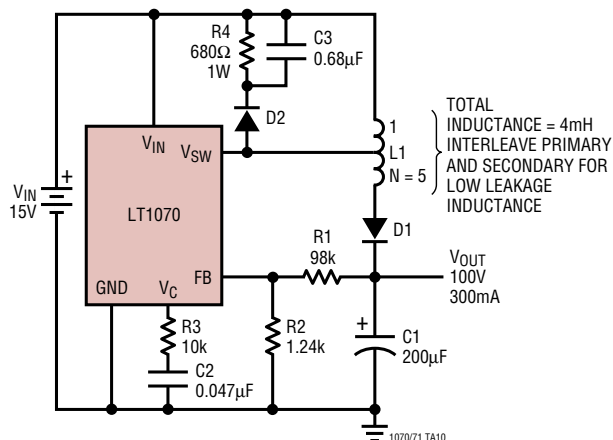
Positive to Negative Buck/Boost Converter



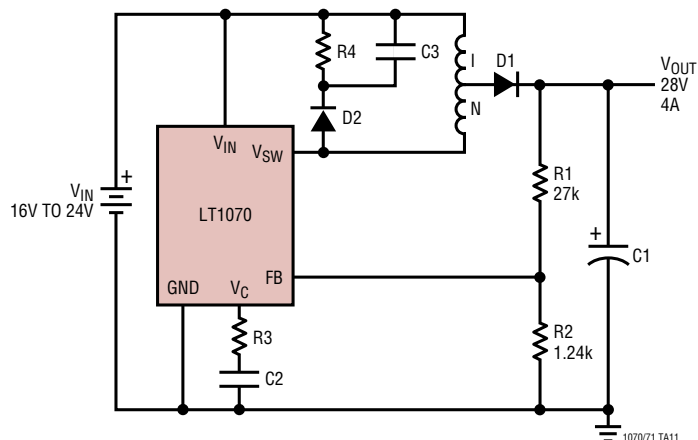
†TO AVOID START-UP PROBLEMS FOR INPUT VOLTAGES BELOW 10V, CONNECT ANODE OF D3 TO V_{IN} AND REMOVE R5. C1 MAY BE REDUCED FOR LOWER OUTPUT CURRENTS. $C1 \approx (500\mu F)(I_{OUT})$ FOR 5V OUTPUTS, REDUCE R3 TO 1.5k, INCREASE C2 TO 0.3μF AND REDUCE R6 TO 100Ω.

TYPICAL APPLICATIONS (Note that maximum output currents are divided by 2 for the LT1071)

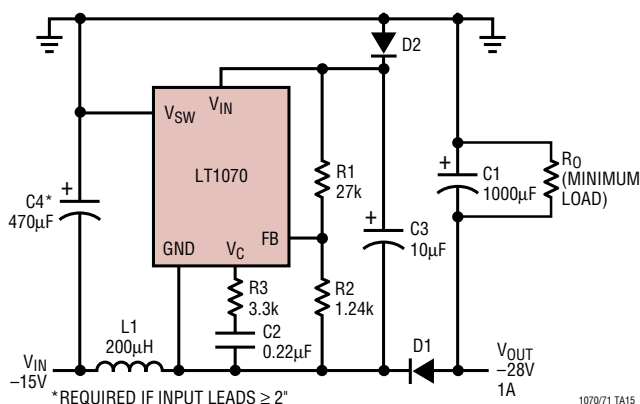
Voltage Boosted Boost Converter



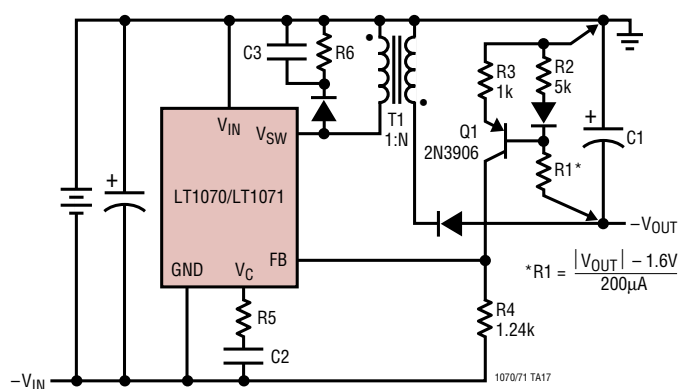
Current Boosted Boost Converter



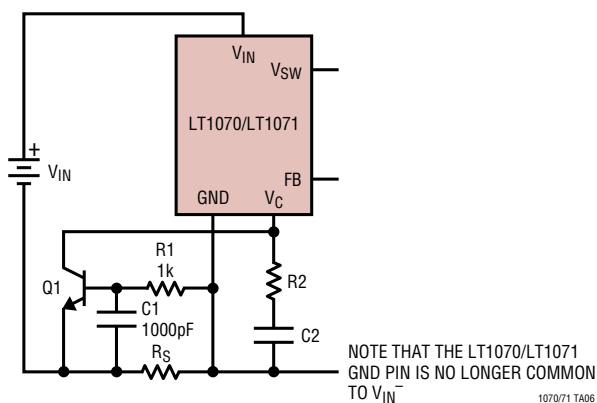
Negative Boost Regulator



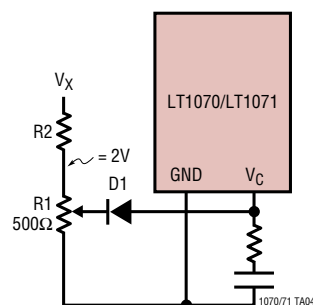
Negative Input/Negative Output Flyback Converter



External Current Limit

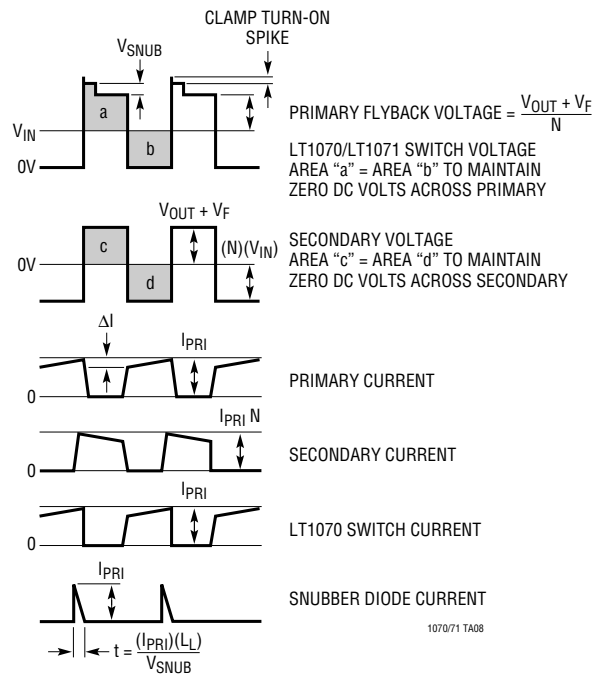
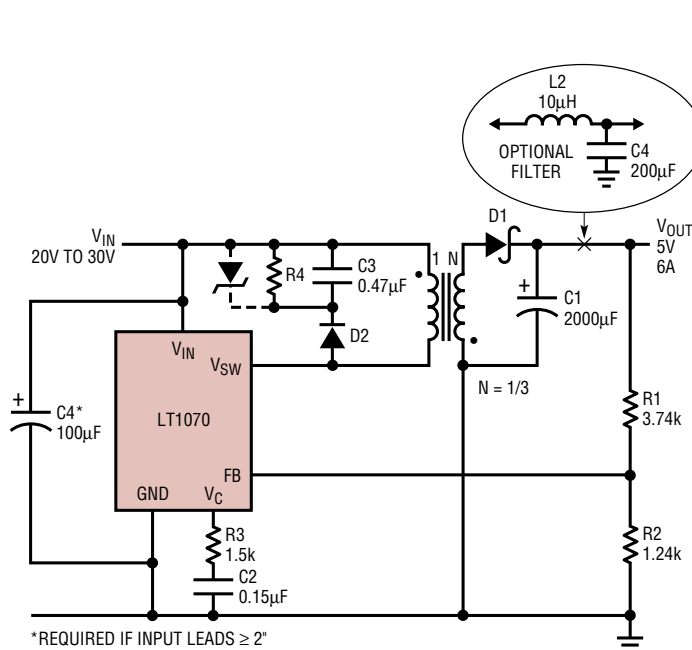


External Current Limit



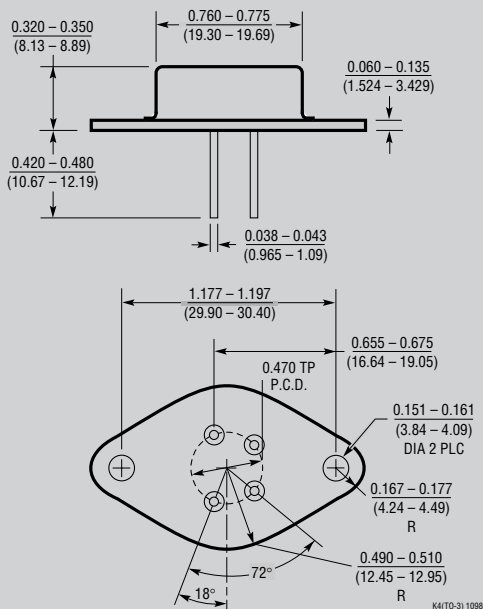
TYPICAL APPLICATIONS (Note that maximum output currents are divided by 2 for the LT1071)

Flyback Converter



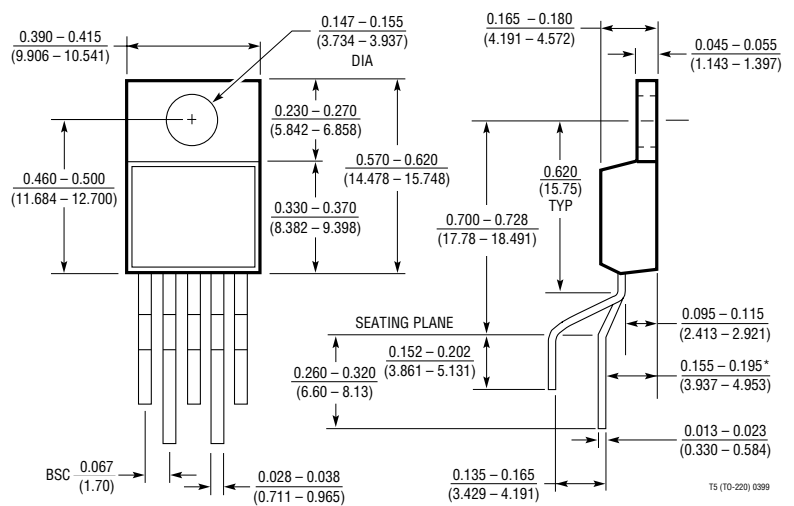
PACKAGE DESCRIPTION

K Package 4-Lead TO-3 Metal Can (Reference LTC DWG # 05-08-1311)



OBSOLETE PACKAGE

T Package 5-Lead Plastic TO-220 (Standard) (Reference LTC DWG # 05-08-1421)



* MEASURED AT THE SEATING PLANE

TYPICAL APPLICATIONS

(Note that maximum output currents are divided by 2 for the LT1071)

The diagram illustrates a 5V to 15V isolated DC-DC converter. The primary side consists of a 5V input source, a 100µF capacitor (C5*), and an LT1070/1071 switching regulator. The regulator's output is connected to a transformer with a turns ratio of 1:N, where N = 0.875 for a 15V output. The secondary side features a diode bridge rectifier (D1) and an optional output filter. The filter includes inductors L1 and L2, and capacitors C1, C3, C4, C5, and C6. The output voltage is 15V. Waveforms for the switch voltage and secondary voltage are shown, indicating a peak-to-peak voltage of approximately 16V for the switch and a peak-to-peak voltage of approximately 15V for the secondary.

COMPONENTS:

- LT1070/1071
- 5V
- 100µF
- 1.5k
- 0.47µF
- 1:N
- N = 0.875 = 7:8 FOR $V_{OUT} = 15V$
- D1
- C1 500µF
- C3 500µF
- C4 500µF
- C5 200µF
- C6 200µF
- L1 10µF
- L2 10µF
- 15V
- COM
- 15V
- OPTIONAL OUTPUT FILTER
- SWITCH VOLTAGE
- SECONDARY VOLTAGE
- V_{IN}
- V_{SW}
- V_{OUT}
- V_F (DIODE FORWARD VOLTAGE)
- t_{OFF}
- t_{ON}
- $(N)(V_{IN})$
- R2
- 500Ω
- 5k
- C2 0.01µF
- FB
- GND
- V_C

***REQUIRED IF INPUT LEADS $\geq 2^\circ$**

1070/71 TA07

The schematic diagram illustrates a 5V/6A buck converter. The input voltage V_{IN} (20V TO 30V) is connected to the V_{IN} pin of the LT1070. The LT1070's V_{SW} pin is connected to the gate of MOSFET Q1. The MOSFET's source is connected to ground, and its drain is connected to the primary of transformer T1. The transformer's secondary is connected to a diode D4, which is in series with a diode D1. The output of the transformer is connected to an inductor L1 (70μH) and a capacitor C1 (2000μF). The output voltage V_{OUT} is 5V/6A. The feedback network consists of resistors R1 (3.74k) and R2 (1.24k) connected to the FB pin of the LT1070. The LT1070's V_C pin is connected to a capacitor C3. The LT1070's GND pin is connected to ground. The LT1070's V_{IN} pin is also connected to a capacitor C2. The LT1070's V_{SW} pin is connected to a diode D3. The LT1070's V_C pin is connected to a capacitor C4. The LT1070's V_{IN} pin is connected to a resistor R4. The LT1070's V_{SW} pin is connected to a resistor R5 (1Ω). The LT1070's V_C pin is connected to a resistor R6 (330Ω). The LT1070's V_{IN} pin is connected to a resistor R3. The LT1070's V_{SW} pin is connected to a resistor R2. The LT1070's V_C pin is connected to a resistor R1. The LT1070's V_{IN} pin is connected to a resistor R4. The LT1070's V_{SW} pin is connected to a resistor R5. The LT1070's V_C pin is connected to a resistor R6. The LT1070's V_{IN} pin is connected to a resistor R3. The LT1070's V_{SW} pin is connected to a resistor R2. The LT1070's V_C pin is connected to a resistor R1.

PART NUMBER	DESCRIPTION	COMMENTS
LT1074/LT1076	High Voltage Switching Regulators	40V Input (60V for HV Versions), 100kHz, 5A and 2A
LT1170/LT1171/ LT1172	100kHz High Efficiency Switching Regulators	40V Input (65V for HV Versions), 5A/2.5A/1.25A Internal Switch
LT1370/LT1371	500kHz High Efficiency Switching Regulators	35V, 6A/3A Internal Switch
LT1374/LT1376	100kHz High Efficiency Switching Regulators	25V Input, 4.5A/1.5A Internal Switch
LT1765	1.25MHz, 3A, Step-Down Regulator	25V Input, TSSOP-16E, S08 Package