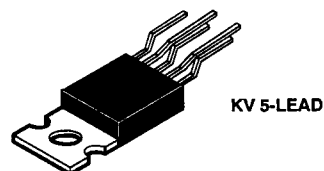
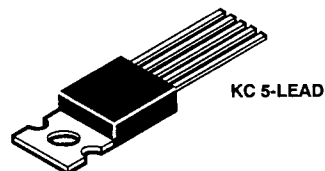
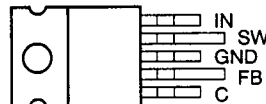


# LT1070, LT1070HV 5-A HIGH-EFFICIENCY SWITCHING REGULATORS

D3222, OCTOBER 1988—REVISED OCTOBER 1991

- **Wide Supply Voltage Range:**  
LT1070HV . . . 3 V to 60 V  
LT1070 . . . 3 V to 40 V
- **Low Quiescent Current . . . 6 mA Typ**
- **Self-Protected Against Overloads**
- **Operates in Most Switching Configurations**
- **Low Shutdown-Mode Supply Current**
- **Floating Outputs in Flyback-Regulated Mode**
- **Available in Standard KC and KV Packages**
- **Can Be Externally Synchronized**

**KC AND KV PACKAGE**  
(KV Package Used for Illustration)  
(TOP VIEW)



AVAILABLE OPTIONS

T <sub>J</sub>	MAX INPUT VOLTAGE	KC PACKAGE	KV PACKAGE
0°C to 100°C	60 V	LT1070HVCKC	LT1070HVCKV
	40 V	LT1070CKC	LT1070CVKV
-40°C to 125°C	60 V	LT1070HVIKC	LT1070HVIKV
	40 V	LT1070IKC	LT1070IKV

## description

The LT1070 is a monolithic, high-efficiency switching regulator. It can be operated in all standard switching configurations including: step-down (buck), step-up (boost), flyback, forward, inverting, and Cuk<sup>†</sup>. A high-current, high-efficiency switch is included in the package along with all oscillator, control, and protection circuitry. Integration of all functions allows the LT1070 to be built in a standard 5-pin KC or KV package. This makes it extremely easy to use and provides reliable operation similar to that obtained with 3-pin linear regulators.

The LT1070 operates with supply voltages from 3 V to 40 V. The LT1070HV, a high-voltage version of the LT1070, operates with supply voltages from 3 V to 60 V. These devices draw only 6 mA of quiescent current, deliver load power up to 100 W with no external power devices, and by utilizing current-mode switching techniques, they provide excellent ac and dc input and output regulation.

The LT1070 is much easier to use than the low-power control chips that are presently available and has many unique features that are not found on these chips. It uses an adaptive saturation-preventing 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  $\mu$ A typical for standby operation. Totally isolated and regulated outputs can be generated by using the optional flyback-regulation mode built into the LT1070 without the need for optocouplers or extra transformer windings.

<sup>†</sup> A boost-buck-derived regulator circuit patented by Slobodan Cuk.

PRODUCTION DATA Information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

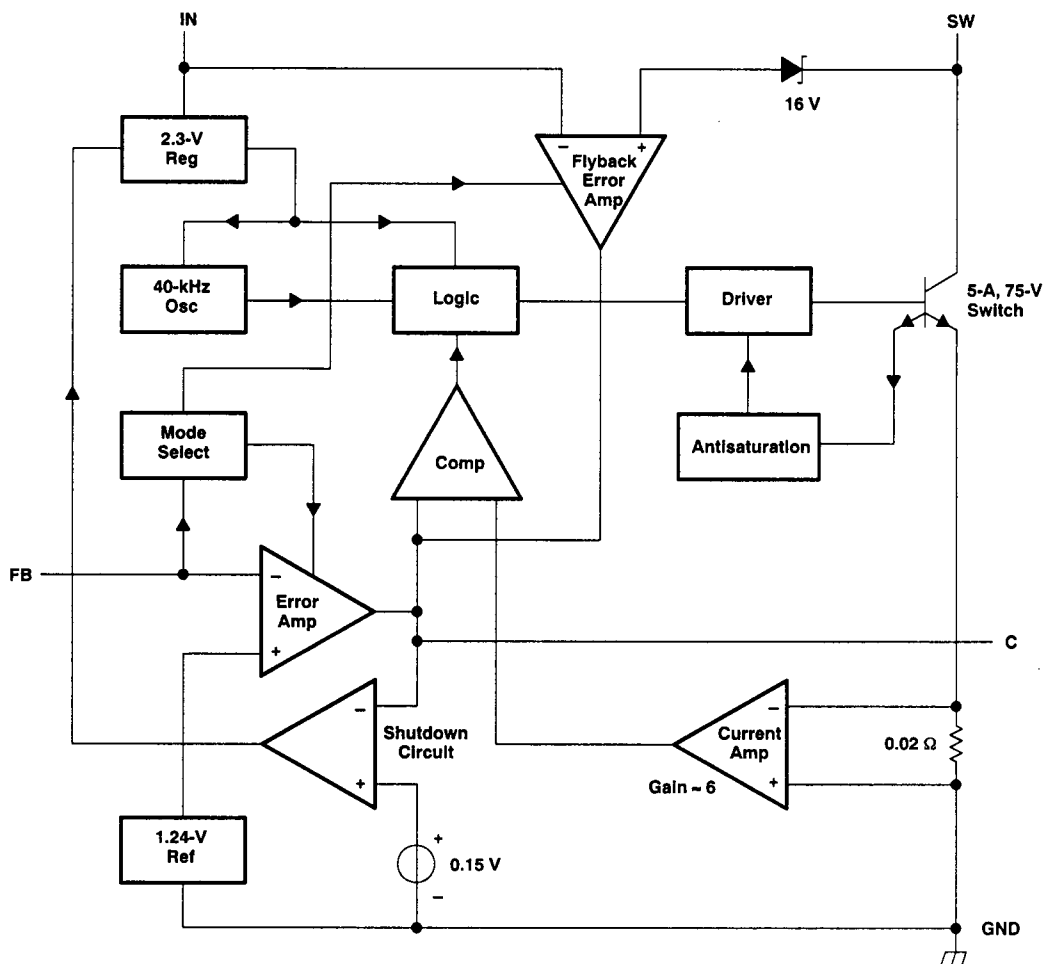
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INSTRUMENTS**

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# LT1070, LT1070HV 5-A HIGH-EFFICIENCY SWITCHING REGULATORS

functional block diagram



Resistor value shown is nominal.

# LT1070, LT1070HV 5-A HIGH-EFFICIENCY SWITCHING REGULATORS

**absolute maximum ratings over operating virtual junction temperature range (unless otherwise noted)**

Supply voltage, $V_{IN}$ (see Note 1): LT1070 .....	40 V
LT1070HV .....	60 V
Switch output voltage: LT1070 .....	65 V
LT1070HV .....	75 V
Feedback input voltage, $V_{FB}$ (transient, 1 ms) .....	$\pm 15$ V
Continuous total dissipation .....	See Dissipation Rating Tables 1 and 2
Operating virtual-junction temperature range:	
LT1070C, LT1070HVC (normal operation) .....	0°C to 100°C
LT1070C, LT1070HVC (short-circuit operation) .....	0°C to 125°C
LT1070I, LT1070HVI .....	-40°C to 125°C
Storage temperature range .....	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds .....	300°C

NOTE 1: Minimum switch-on time for the LT1070 in current limit is  $\sim 1 \mu\text{s}$ . This limits the maximum input voltage during short-circuit conditions, in the step-down and inverting modes only, to  $\sim 35$  V. Normal (unshorted) conditions are not affected. If the LT1070 is being operated in the step-down or inverting mode at high input voltages and short-circuit conditions are expected, a resistor must be placed in series with the inductor.

**DISSIPATION RATING TABLE 1  
FREE-AIR TEMPERATURE**

PACKAGE	T <sub>A</sub> = 25°C POWER RATING	DERATING FACTOR ABOVE T <sub>A</sub> = 25°C	T <sub>A</sub> = 100°C POWER RATING	T <sub>A</sub> = 125°C POWER RATING
KC and KV	2000 mW	16 mW/°C	800 mW	400 mW

**DISSIPATION RATING TABLE 2  
CASE TEMPERATURE**

PACKAGE	T <sub>C</sub> ≤ 70°C POWER RATING	OPERATING FACTOR ABOVE T <sub>C</sub> = 70°C	T <sub>C</sub> = 125°C POWER RATING
KC and KV	20 mW	250 mW/°C	6.25 mW

**recommended operating conditions**

		MIN	MAX	UNIT
Input voltage, $V_{IN}$	LT1070C, LT1070I	3	40	V
	LT1070HVC, LT1070HVI	3	60	
Virtual-junction temperature, T <sub>J</sub>	LT1070C, LT1070HVC	0	100	°C
	LT1070I, LT1070HVI	-40	125	



# LT1070, LT1070HV 5-A HIGH-EFFICIENCY SWITCHING REGULATORS

electrical characteristics at specified virtual-junction temperature,  $V_{IN} = 15\text{ V}$ ,  $V_{FB} = V_{ref}$ , with SW output open (unless otherwise noted)

## reference section

PARAMETER		TEST CONDITIONS†	$T_J$ ‡	MIN	TYP§	MAX	UNIT
$V_{ref}$	Reference voltage	Measured at FB input, $V_C = 0.6\text{ V}$	25°C	1.224	1.244	1.264	V
			Full range	1.214		1.274	
Reference voltage input regulation		$V_{IN} = 3\text{ V to MAX}$ , $V_C = 0.6\text{ V}$	Full range			0.03	%/V

## error amplifier section

PARAMETER		TEST CONDITIONS†	$T_J$ ‡	MIN	TYP§	MAX	UNIT
$I_{FB}$	Feedback input current	$V_{FB} = V_{ref}$	25°C		380	750	nA
			Full range			1100	
$g_m$	Transconductance	$\Delta I_C = \pm 25\ \mu\text{A}$	25°C	3000	4200	6000	$\mu\text{mho}$
			Full range	2400		7000	
	Source current	$V_C = 1.5\text{ V}$ , $V_{FB} = 0.8\text{ V}$	25°C	150	200	350	$\mu\text{A}$
			Full range	120		400	
	Sink current	$V_C = 1.5\text{ V}$ , $V_{FB} = 1.5\text{ V}$	25°C	150	200	350	$\mu\text{A}$
			Full range	120		400	
$V_{O(C)}$	Output voltage	High state, $V_{FB} = 1\text{ V}$	25°C	1.8		2.3	V
		Low state, $V_{FB} = 1.5\text{ V}$		0.25	0.38	0.52	
$A_V$	Voltage amplification	$V_C = 0.7\text{ V to }1.4\text{ V}$	Full range	500	800	2000	V/V
$V_{T(C)}$	Control threshold voltage	Duty cycle = 0	25°C	0.8	0.9	1.08	V
			Full range	0.6		1.25	

## flyback amplifier section

PARAMETER		TEST CONDITIONS†	$T_J$ ‡	MIN	TYP§	MAX	UNIT
$V_{T(FB)}$	Normal-/flyback-mode threshold voltage	$I_{FB} = 50\ \mu\text{A}$	25°C	0.4	0.45	0.54	V
$V_Z$	Flyback reference voltage	$V_C = 0.6\text{ V}$ , $I_{FB} = 50\ \mu\text{A}$	25°C	15	16.3	17.6	V
			Full range	14		18	
$\Delta V_Z$	Change in flyback reference	$V_C = 0.6\text{ V}$ , $I_{FB} = 0.05\text{ to }1\text{ mA}$	25°C	4.5	6.8	8.5	V
	Flyback reference voltage input regulation	$V_C = 0.6\text{ V}$ , $I_{FB} = 50\ \mu\text{A}$ , $V_{IN} = 3\text{ V to MAX}$	25°C		0.01	0.03	%/V
$g_m$	Transconductance	$\Delta I_C \leq \pm 10\ \mu\text{A}$ , $I_{FB} = 50\ \mu\text{A}$	25°C	150	300	500	$\mu\text{mho}$
			Full range	15	32	50	
	Source or sink current	$V_C = 1.5\text{ V}$ , $I_{FB} = 50\ \mu\text{A}$ , $V_{(SW)} = V_Z + V_{IN} \pm 1\text{ V}$	Source	15	32	50	$\mu\text{A}$
			Sink	25	40	70	

† For conditions shown as MIN or MAX, use the appropriate value specified under the recommended operating conditions.

‡ Full range virtual junction temperature is 0°C to 100°C for LT1070C and LT1070HVC and -40°C to 125°C for LT1070I and LT1070HVI

§ All typical values are  $T_A = 25^\circ\text{C}$ .



# LT1070, LT1070HV 5-A HIGH-EFFICIENCY SWITCHING REGULATORS

electrical characteristics at specified virtual junction temperature,  $V_{IN} = 15\text{ V}$ ,  $V_{FB} = V_{ref}$  with SW output open (unless otherwise noted)

## output section

PARAMETER		TEST CONDITIONS†	$T_J$ ‡	MIN	TYP§	MAX	UNIT		
$V_{(BR)SW}$	Switch breakdown voltage	$V_{FB} = 1.5\text{ V}$ , $V_{IN} = 3\text{ V to MAX}$ , $I_{SW} = 5\text{ mA}$	LT1070	Full range			65	V	
			LT1070HV				75		
$R_{on}$	Switch on-state resistance	$V_{FB} = 0.8\text{ V}$ , $I_{SW} = 5\text{ A}$	Full range			0.15	0.24	$\Omega$	
$g_m$	Control-to-switch transconductance		25°C				8	mho	
$I_{SW(lim)}$	Switch current limit	Duty cycle = 50%, $V_{FB} = 0.8\text{ V}$ Duty cycle = 80%, $V_{FB} = 0.8\text{ V}$	Full range			5	13	A	
$\Delta I_{IN}/\Delta I_{SW}$	Input current increase during switch turn-on	$V_{FB} = 0.8\text{ V}$	25°C				25	35	mA/A
f	Frequency		25°C	35	40	45	kHz		
			Full range					33	47
	Maximum duty cycle	$V_{FB} = 1\text{ V}$	25°C	90%	92%	97%			
$t_d$	Flyback sense delay time		25°C				1.5	$\mu\text{s}$	

## shutdown section

PARAMETER		TEST CONDITIONS†	$T_J$ ‡	MIN	TYP§	MAX	UNIT		
$I_{IN(off)}$	Input current	$V_{IN} = 3\text{ V to MAX}$ , $V_C = 50\text{ mV}$	25°C				100	250	$\mu\text{A}$
$V_{T(off)}$	Control threshold voltage	$V_{IN} = 3\text{ V to MAX}$	25°C	100	150	250	mV		
			Full range					50	300

## total device

PARAMETER		TEST CONDITIONS†	$T_J$ ‡	MIN	TYP§	MAX	UNIT		
$V_{IN(min)}$	Minimum input voltage		Full range			2.6	3	V	
$I_{IN}$	Input current	$V_{IN} = 3\text{ V to MAX}$ , $V_C = 0.6\text{ V}$	25°C				6	9	mA

† For conditions shown as MIN or MAX, use the appropriate value specified under the recommended operating conditions.

‡ Full range virtual junction temperature is 0°C to 100°C for LT1070C and LT1070HVC and -40°C to 125°C for LT1070I and LT1070HVI.

§ All typical values are  $T_A = 25^\circ\text{C}$ .

# LT1070, LT1070HV

## 5-A HIGH-EFFICIENCY SWITCHING REGULATORS

---

### theory of operation

The LT1070 is a current-mode switcher. This means that the switch duty cycle is directly controlled by switch current rather than by output voltage. Referring to the functional block diagram, the switch is turned on at the start of each oscillator cycle. It is turned off when the switch current reaches a predetermined level. Control of output voltage is obtained by using the output of a voltage-sensing error amplifier to set the current trip level. This technique has several advantages. First, it has immediate response to input-voltage variations, which is unlike ordinary switchers that have poor input transient response. Second, it reduces the 90° phase shift at 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 conditions. A low-dropout internal regulator provides a 2.3-V supply for all internal circuitry on the LT1070. This low-dropout design allows input voltage to vary from 3 V to 60 V with virtually no change in device performance. A 40-kHz oscillator is the basic clock for all internal timing. It turns on the output switch via the logic and driver circuitry. Special adaptive antisaturation circuitry detects the 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 1.2-V band-gap 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 to disconnect the main error-amplifier output and connects the output 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 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 (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 0.9 V (low output current) and 2 V (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 C pin is pulled to ground through a diode. This places the LT1070 in an idle mode. Pulling the C pin below 0.15 V causes total regulator shutdown, with only 50- $\mu$ A supply current for shutdown-circuitry biasing.

**TYPICAL CHARACTERISTICS**

**table of graphs**

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$P_{OM}$	Maximum output power	vs	Input voltage	1
$V_{ref}$	Reference voltage	vs	Junction temperature	2
$\Delta V_{ref}$	Reference voltage change	vs	Input voltage	3
$I_{FB}$	Feedback input current	vs	Junction temperature	4
$g_m$	Error amplifier transconductance	vs	Junction temperature	5
$I_C$	Control current	vs	Control voltage	6
$V_{T(FB)}$	Normal-/flyback-mode threshold voltage	vs	Junction temperature	7
$I_{FB}$	Feedback input current	vs	Junction temperature	7
$V_z$	Flyback-mode reference voltage	vs	Junction temperature	8
$t_d$	Flyback sense delay time	vs	Junction temperature	9
$I_{O(SW)}$	Switch output current (with switch off)	vs	Switch voltage	10
	Driver base current	vs	Switch output current	11
$V_{sat(SW)}$	Switch saturation voltage	vs	Switch output current	12
$I_{O(SW)}$	Switch output current limit	vs	Duty cycle	13
	Maximum duty cycle	vs	Junction temperature	14
$I_{IN(off)}$	Shutdown-mode input current	vs	Control voltage	15
$I_{IN(off)}$	Shutdown-mode input current	vs	Input voltage	16
$V_{T(off)}$	Shutdown-mode control threshold voltage	vs	Junction temperature	17
$V_{T(off)}$	Shutdown-mode control threshold current	vs	Junction temperature	17
$V_{FB}$	Feedback input voltage	vs	Feedback input current	18
$V_{IN(min)}$	Minimum input voltage	vs	Junction temperature	19
$I_{IN}$	Input current	vs	Junction temperature	20
$I_{IN}$	Input current	vs	Input voltage	21

**table of application circuits**

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TYPICAL CHARACTERISTICS

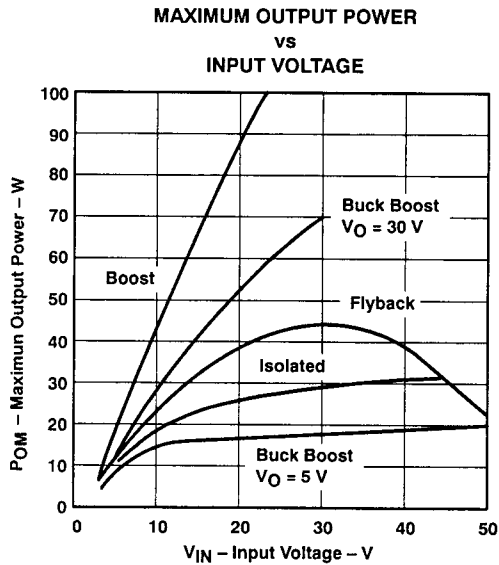


Figure 1

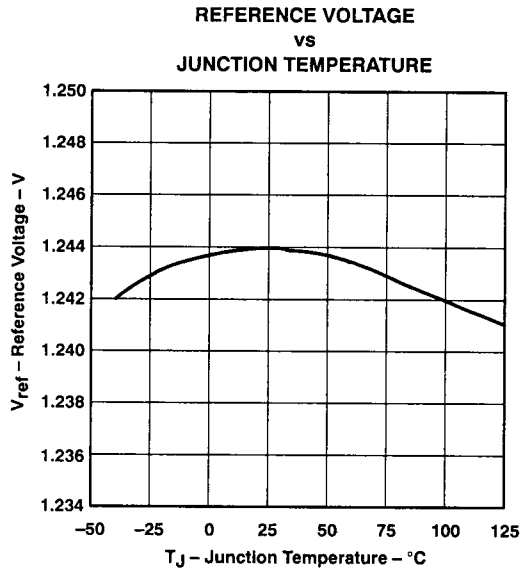


Figure 2

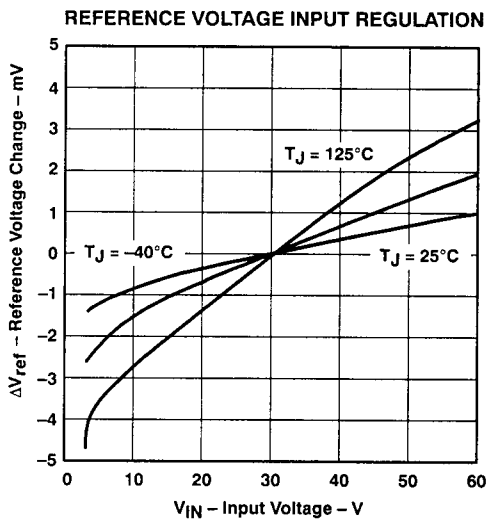


Figure 3

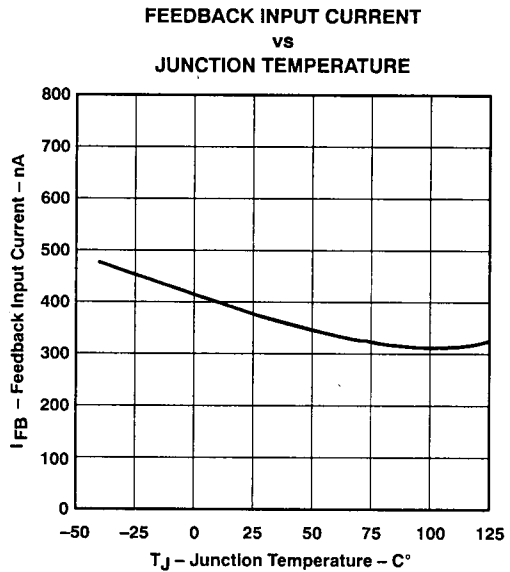


Figure 4



TYPICAL CHARACTERISTICS

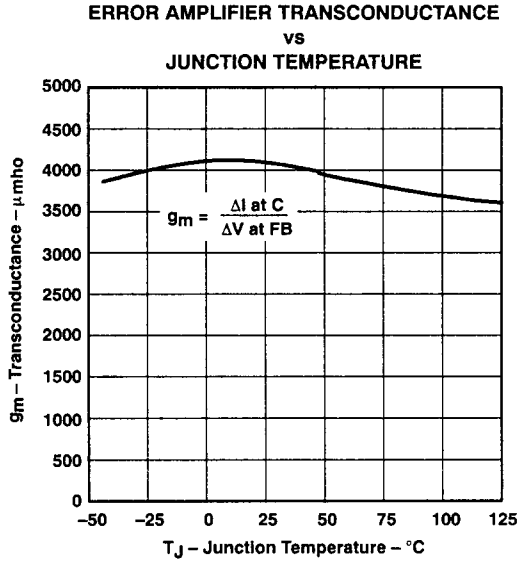


Figure 5

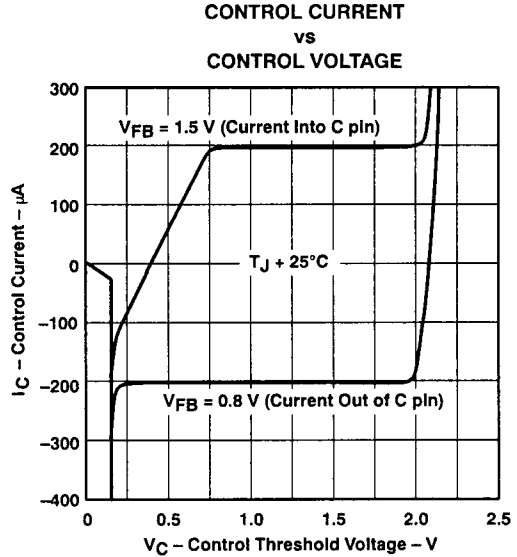


Figure 6

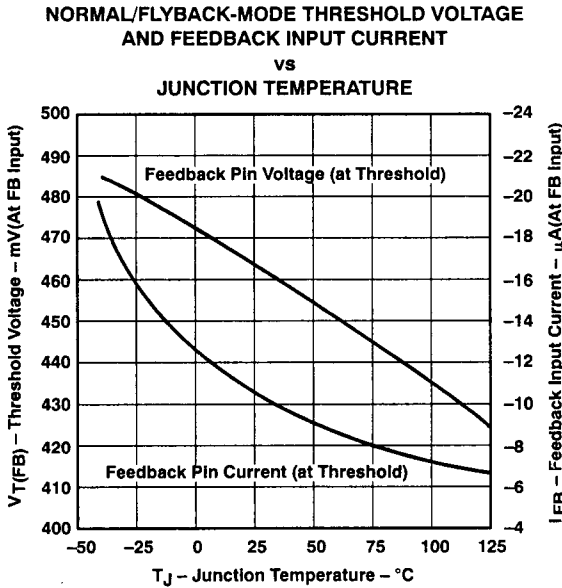


Figure 7

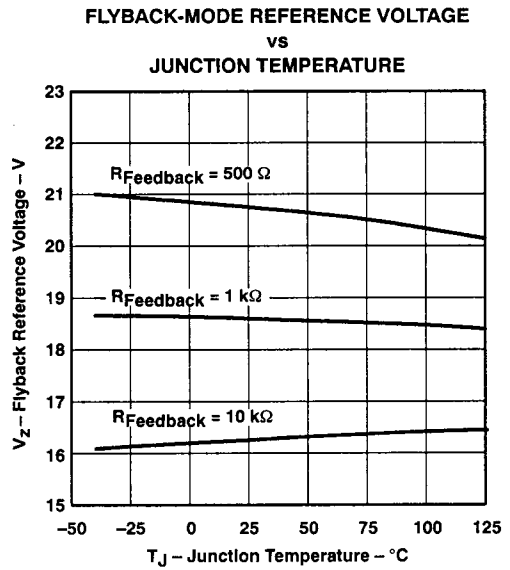


Figure 8

TYPICAL CHARACTERISTICS

FLYBACK SENSE DELAY TIME  
vs  
JUNCTION TEMPERATURE

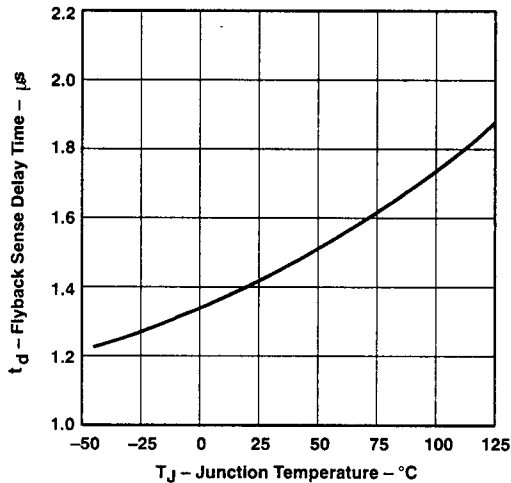


Figure 9

SWITCH OUTPUT CURRENT  
vs  
SWITCH VOLTAGE and INPUT VOLTAGE  
(WITH SWITCH OFF)

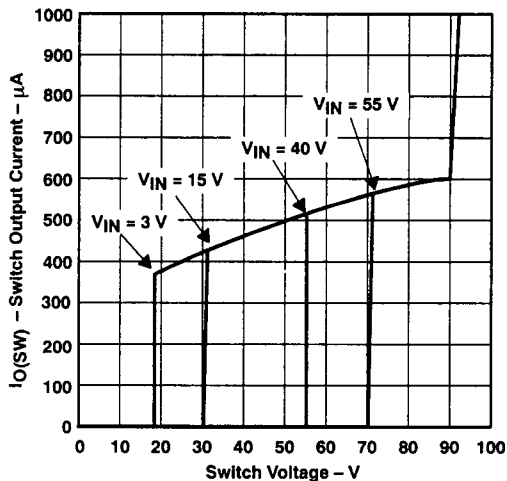


Figure 10

DRIVER BASE CURRENT†  
vs  
SWITCH OUTPUT CURRENT

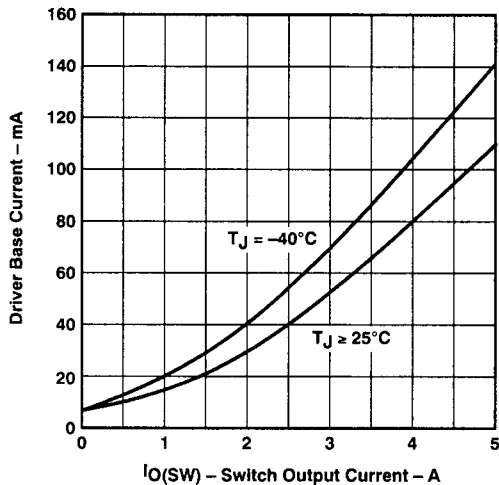


Figure 11

SWITCH SATURATION VOLTAGE  
vs  
SWITCH CURRENT

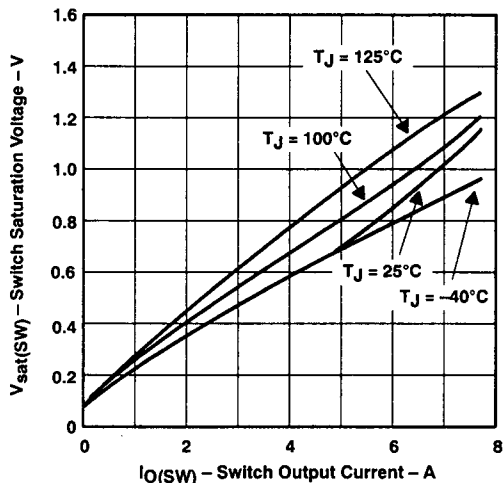


Figure 12

† Average input current is found by multiplying driver base current by duty cycle plus quiescent current.

TYPICAL CHARACTERISTICS

SWITCH OUTPUT CURRENT LIMIT  
vs  
DUTY CYCLE

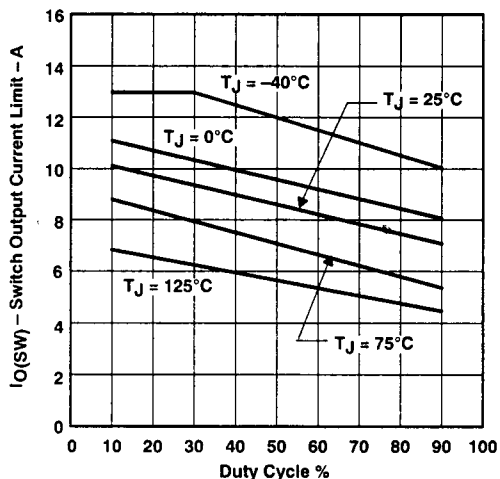


Figure 13

MAXIMUM DUTY CYCLE  
vs  
JUNCTION TEMPERATURE

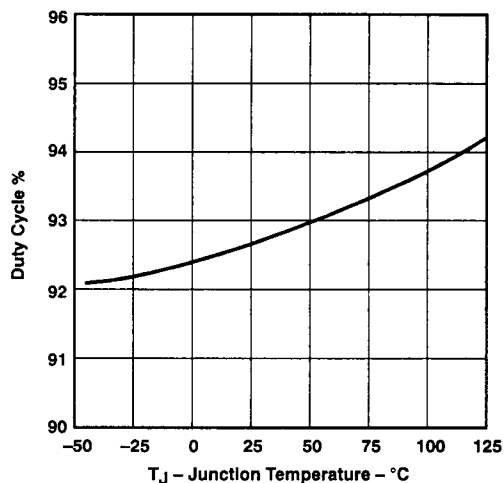


Figure 14

SHUTDOWN-MODE INPUT CURRENT  
vs  
CONTROL VOLTAGE

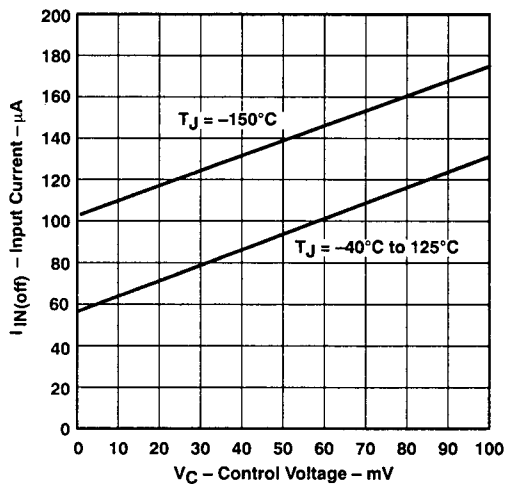


Figure 15

SHUTDOWN-MODE INPUT CURRENT  
vs  
INPUT CURRENT

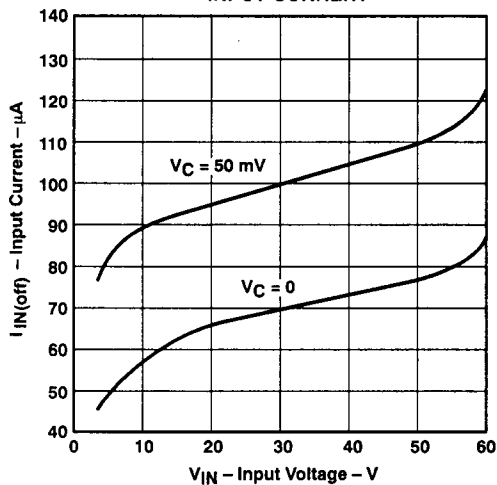


Figure 16

TYPICAL CHARACTERISTICS

CONTROL THRESHOLD VOLTAGE AND CURRENT  
vs  
JUNCTION TEMPERATURE  
(SHUTDOWN MODE)

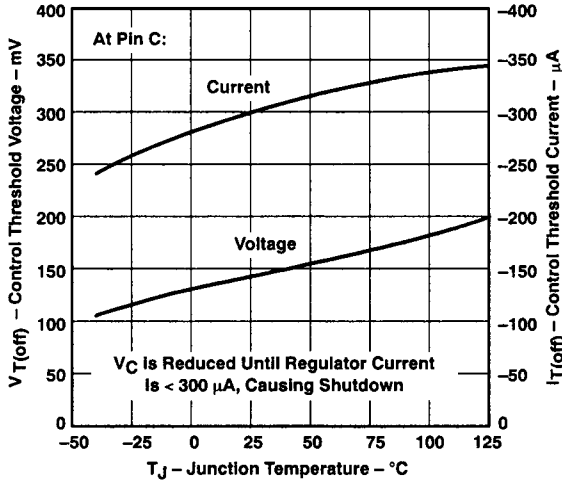


Figure 17

FEEDBACK INPUT VOLTAGE  
vs  
FEEDBACK INPUT CURRENT

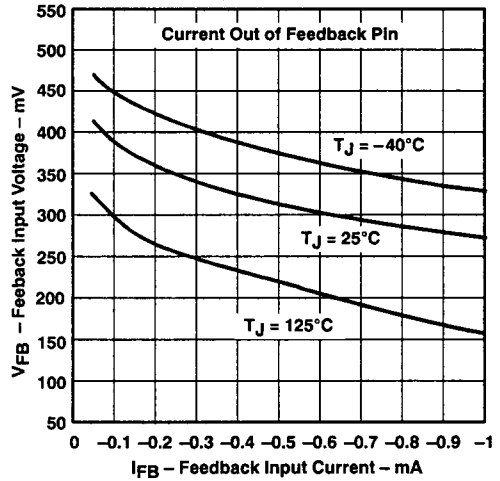


Figure 18

MINIMUM INPUT VOLTAGE  
vs  
JUNCTION TEMPERATURE

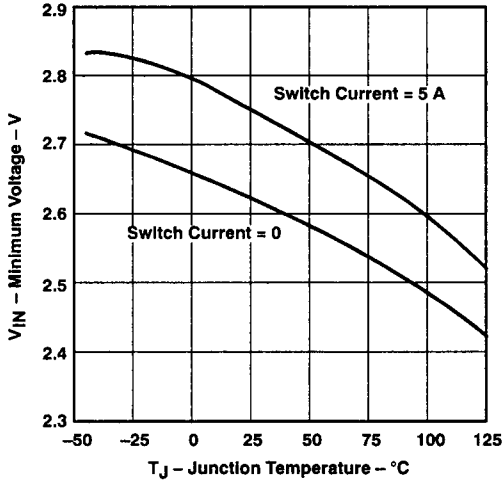


Figure 19

INPUT CURRENT  
vs  
JUNCTION TEMPERATURE  
(SW OUTPUT OPEN)

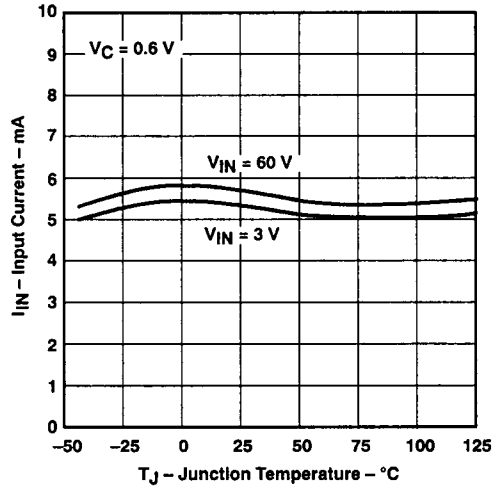
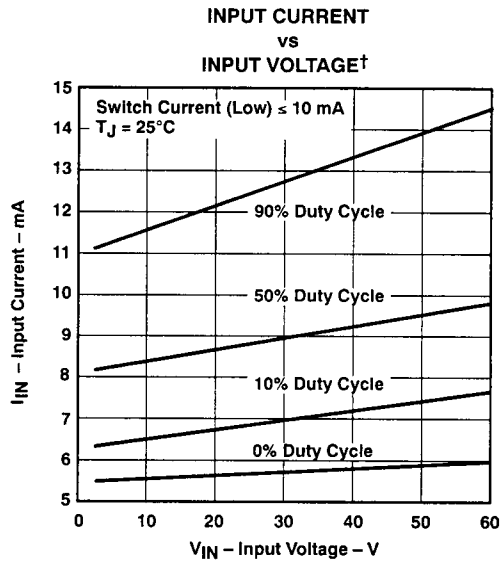


Figure 20

TYPICAL CHARACTERISTICS

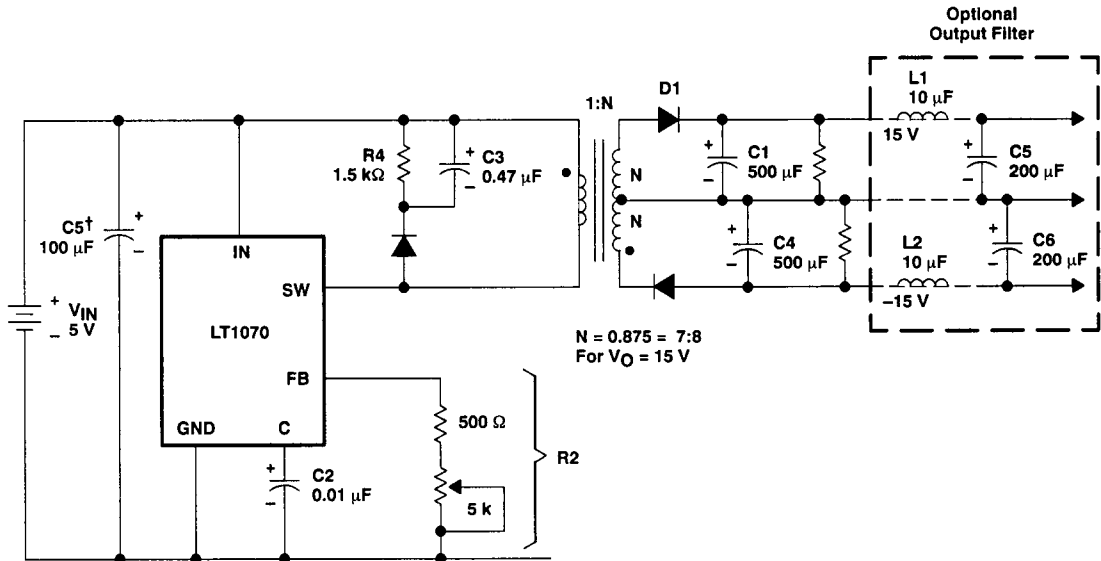


† Under very low output current conditions, duty cycle for most circuits will approach 10% or less.

Figure 21

# LT1070, LT1070HV 5-A HIGH-EFFICIENCY SWITCHING REGULATORS

## APPLICATION INFORMATION



†Capacitors are required if input lead length exceeds 2 inches.

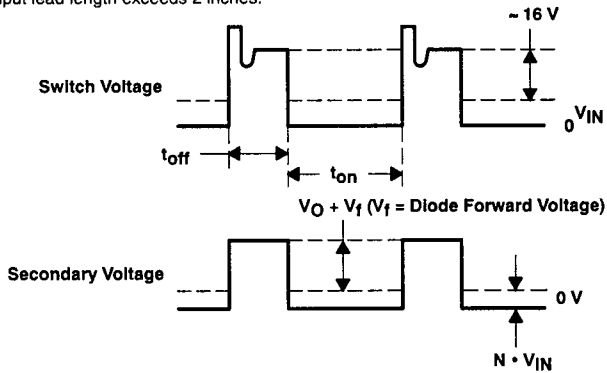
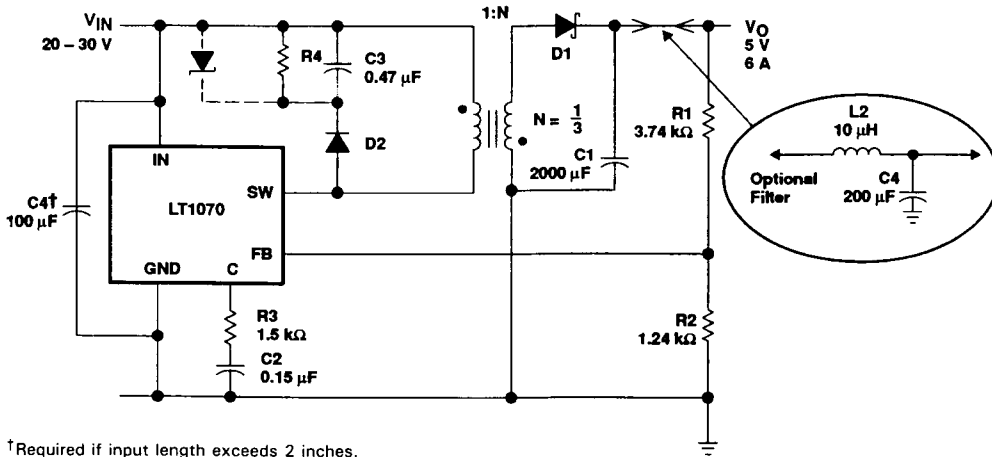


Figure 22. Totally Isolated Converter

APPLICATION INFORMATION



† Required if input length exceeds 2 inches.

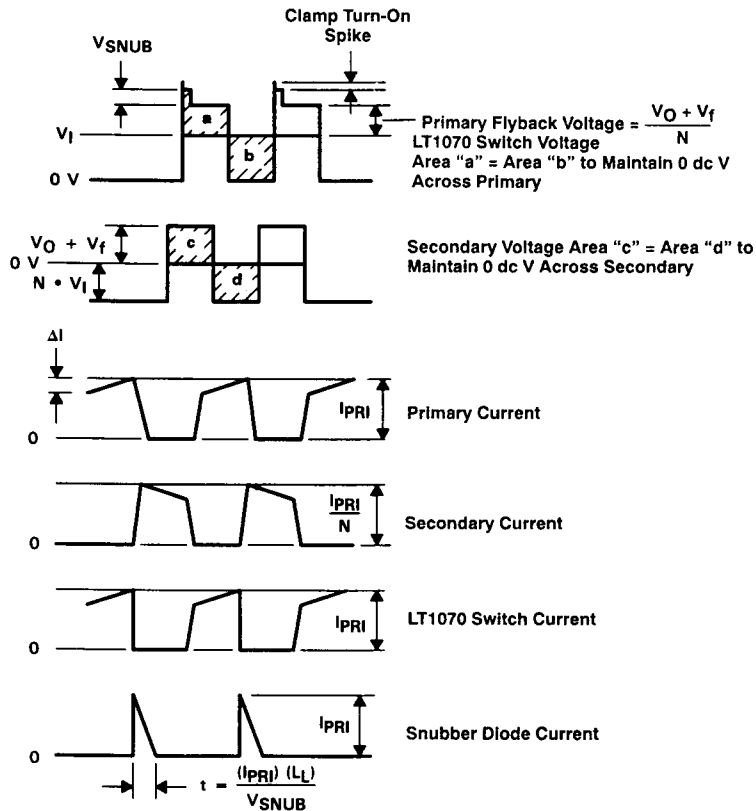


Figure 23. Flyback Converter

APPLICATION INFORMATION

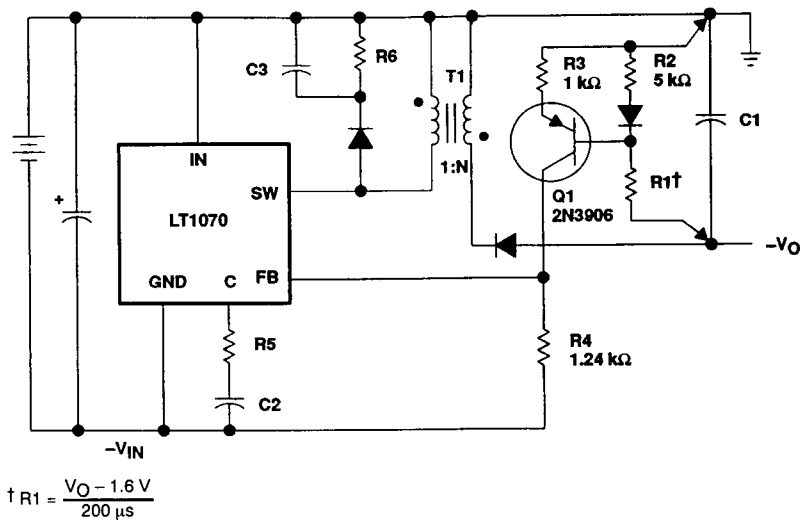


Figure 24. Negative Input - Negative Output Flyback Converter

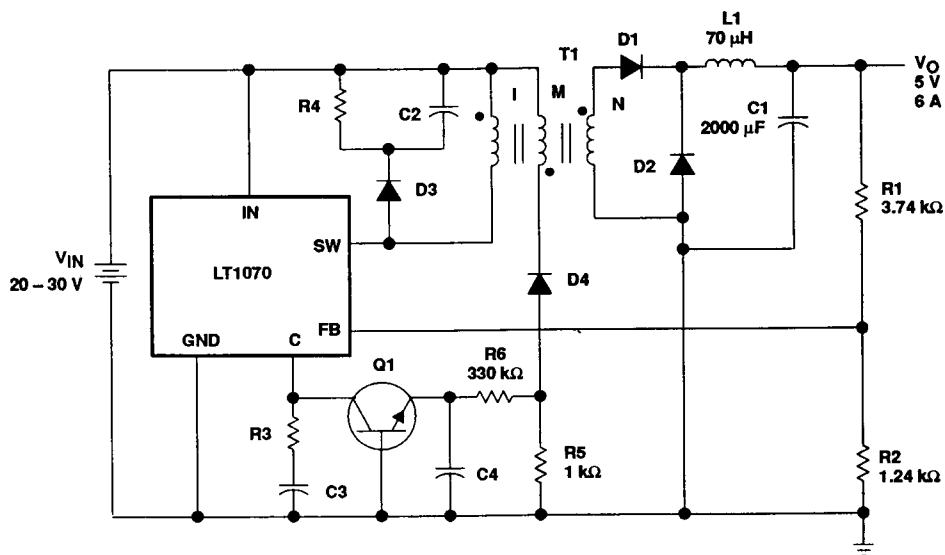


Figure 25. Forward Converter



APPLICATION INFORMATION

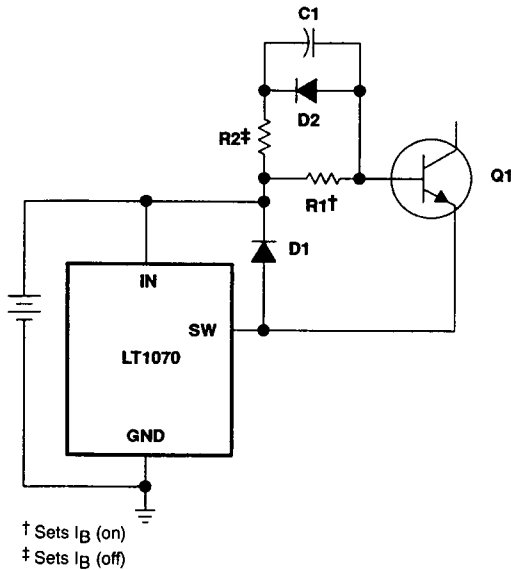


Figure 26. Driving High-Voltage NPN Transistor

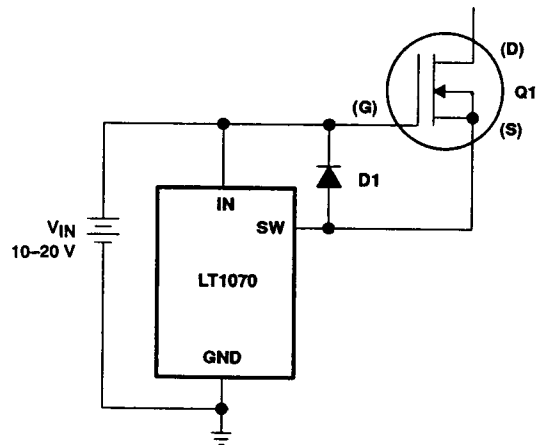


Figure 27. Driving High-Voltage FET

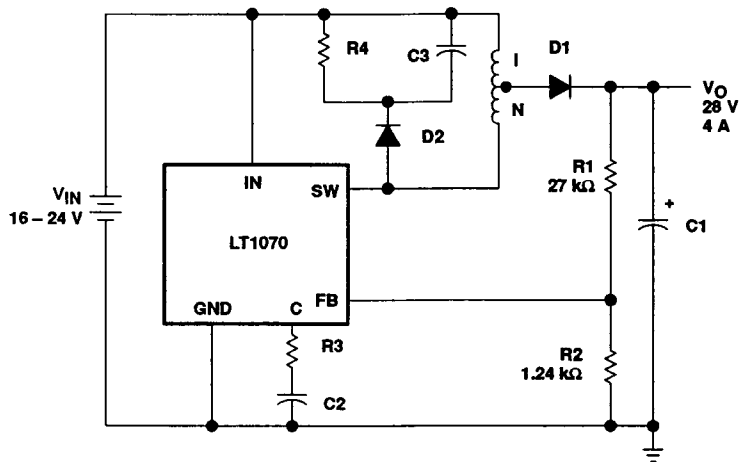
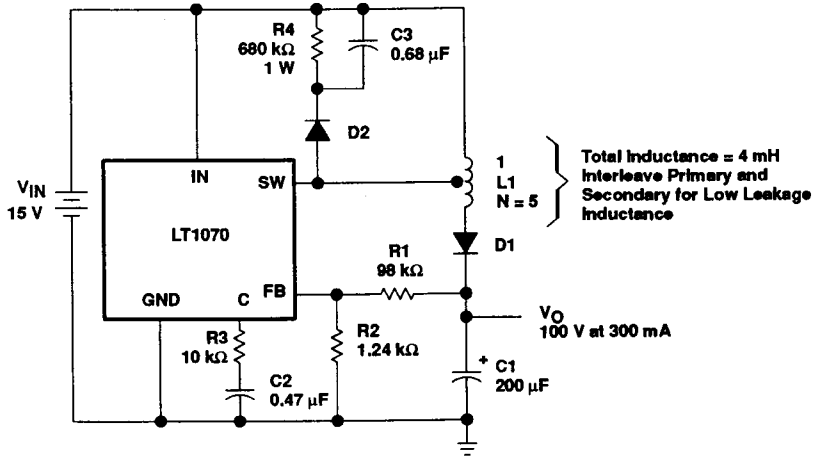


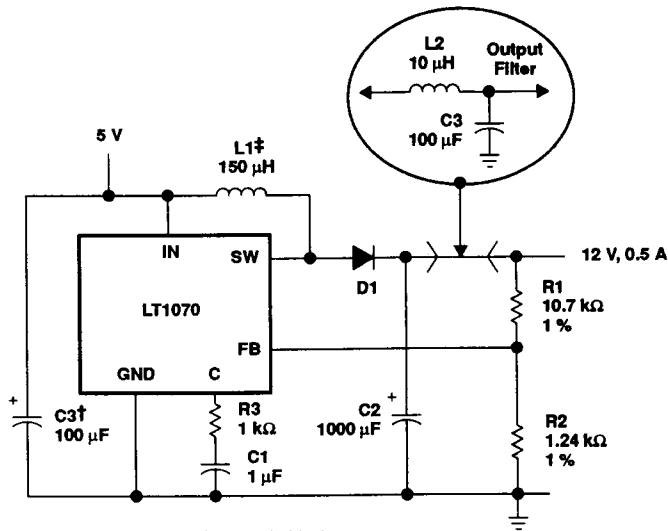
Figure 28. Current-Boosted Boost Converter

**LT1070, LT1070HV**  
**5-A HIGH-EFFICIENCY SWITCHING REGULATORS**

**APPLICATION INFORMATION**



**Figure 29. Voltage-Boosted Boost Converter**

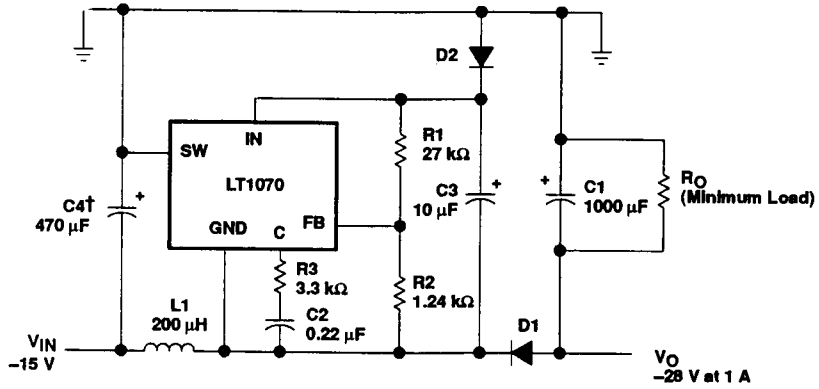


† Capacitors are required if input lead length exceeds 2 inches.

‡ Pulse Engineering 92113.

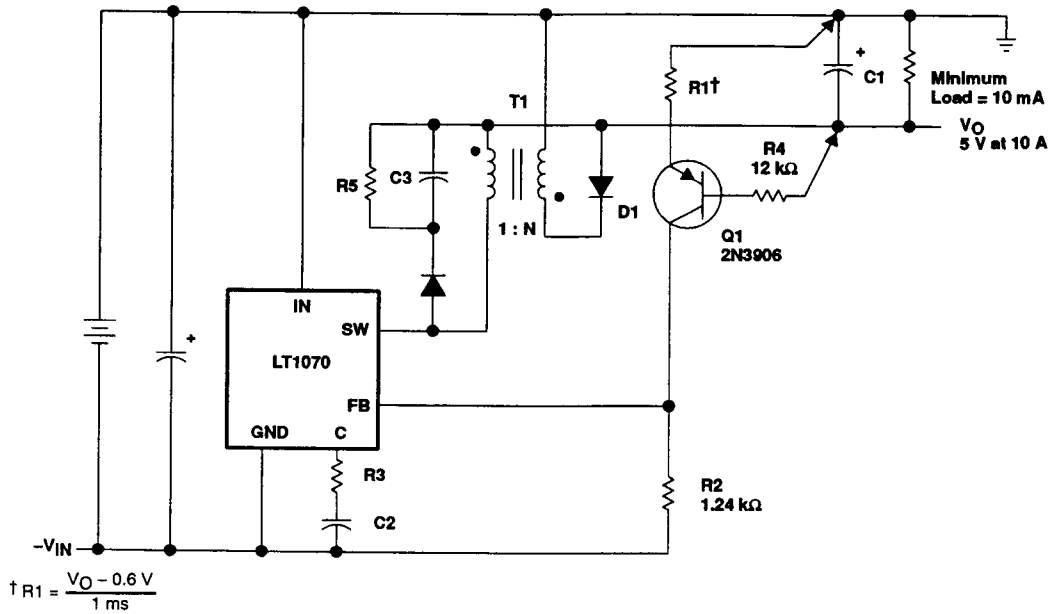
**Figure 30. Boost Converter (5 V to 12 V)**

APPLICATION INFORMATION



† Required if input lead length exceeds 2 inches.

Figure 31. Negative Boost Regulator

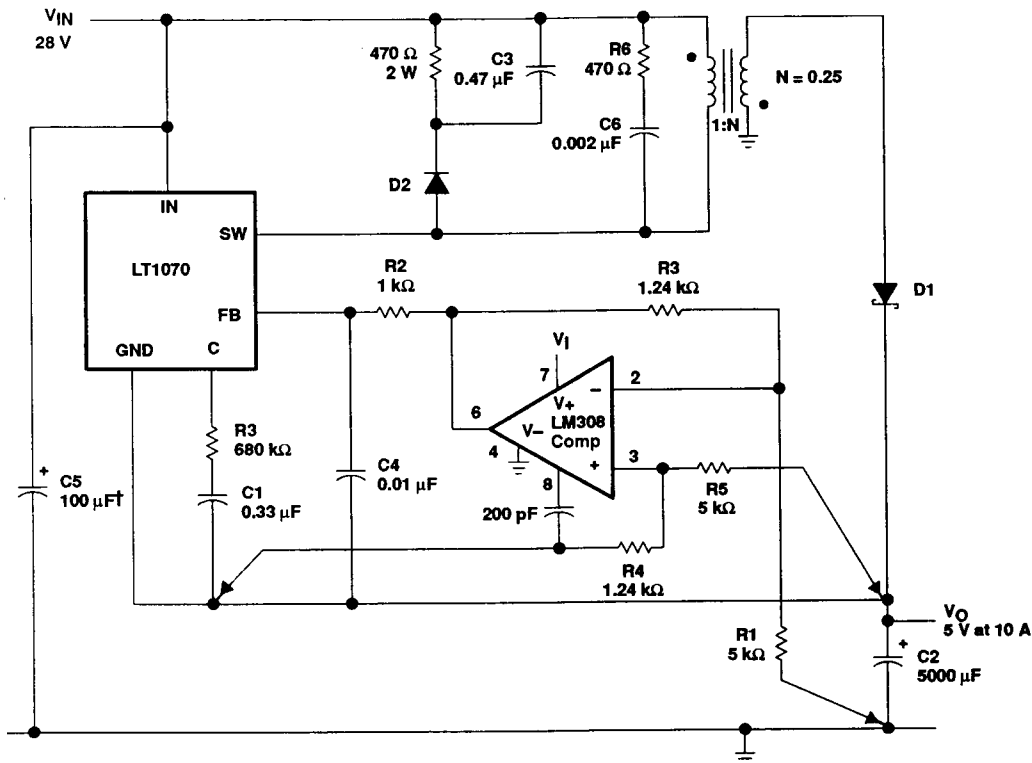


$$\dagger R1 = \frac{V_O - 0.6 \text{ V}}{1 \text{ ms}}$$

Figure 32. Negative Current-Boosted Buck Converter

**LT1070, LT1070HV**  
**5-A HIGH-EFFICIENCY SWITCHING REGULATORS**

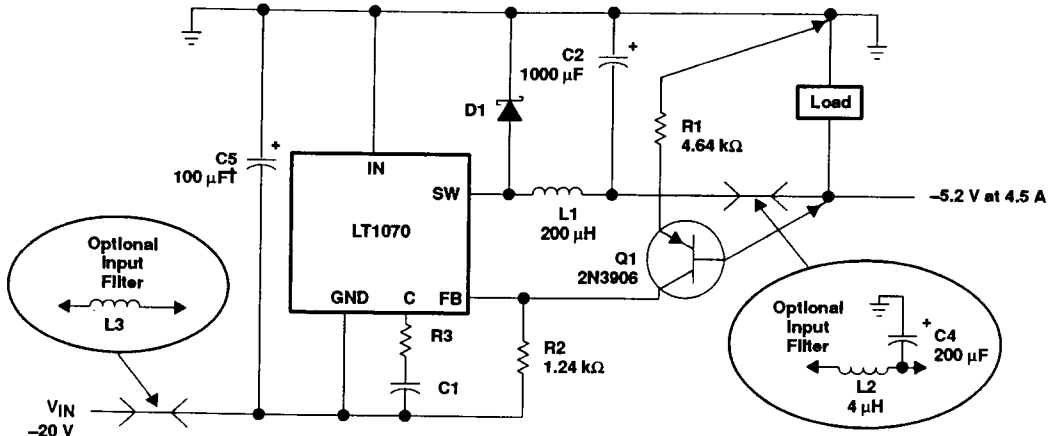
**APPLICATION INFORMATION**



† Required if input lead length exceeds 2 inches.

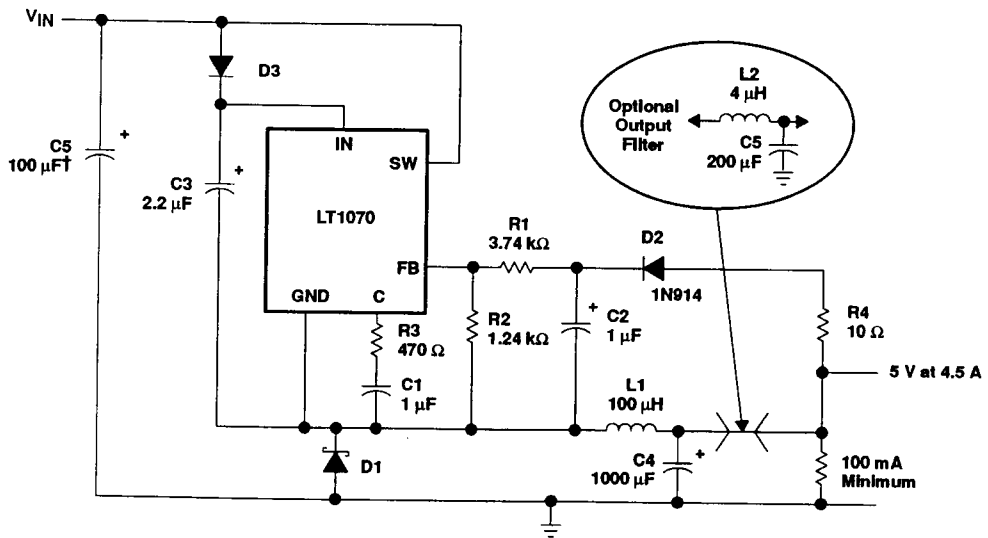
**Figure 33. Positive Current-Boosted Buck Converter**

APPLICATION INFORMATION



† Required if input lead length exceeds 2 inches.

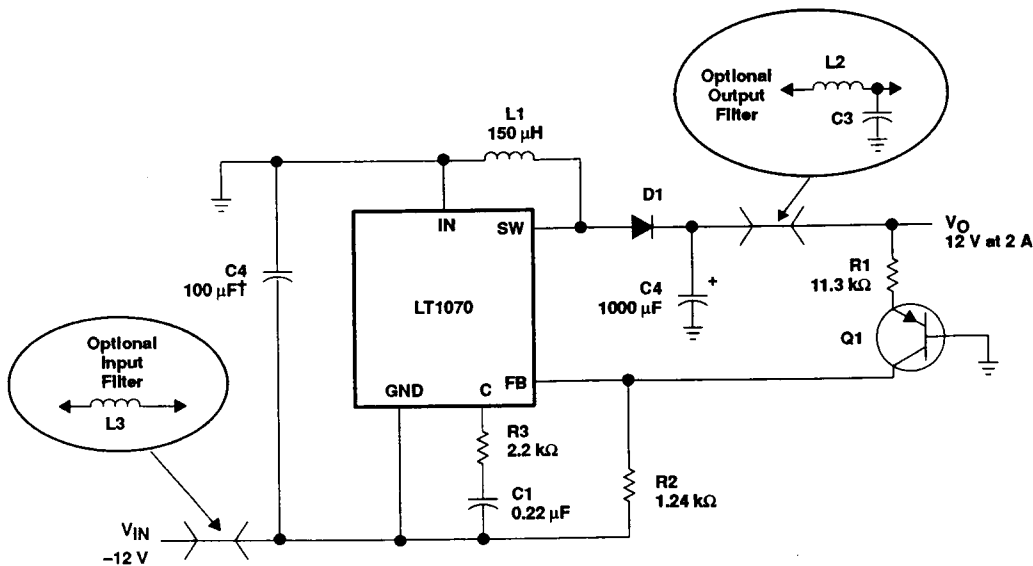
Figure 34. Negative Buck Converter



† Required if input lead length exceeds 2 inches.

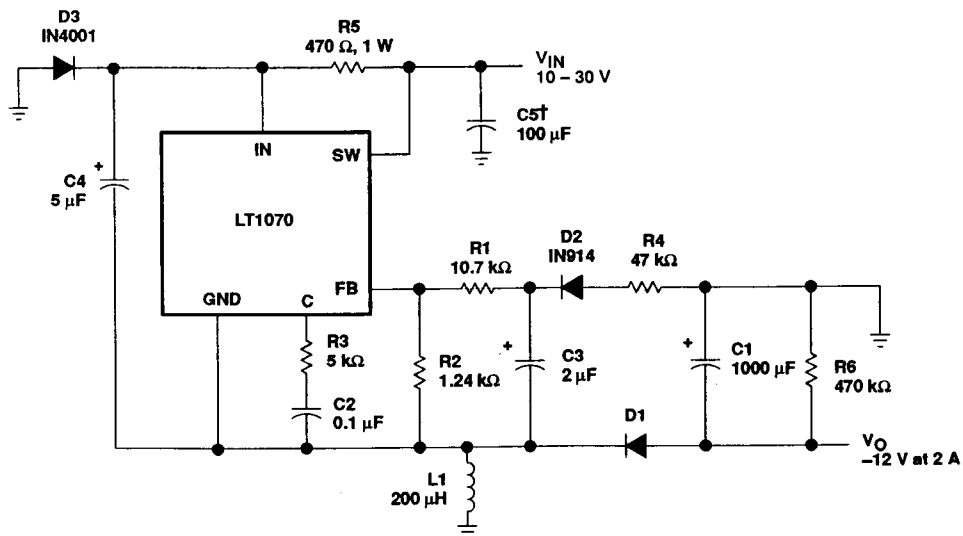
Figure 35. Positive Buck Converter

APPLICATION INFORMATION



† Required if input lead length exceeds 2 inches.

Figure 36. Negative-to-Positive Buck-Boost Converter



† Required if input lead length exceeds 2 inches.

Figure 37. Positive-to-Negative Buck-Boost Converter

APPLICATION INFORMATION

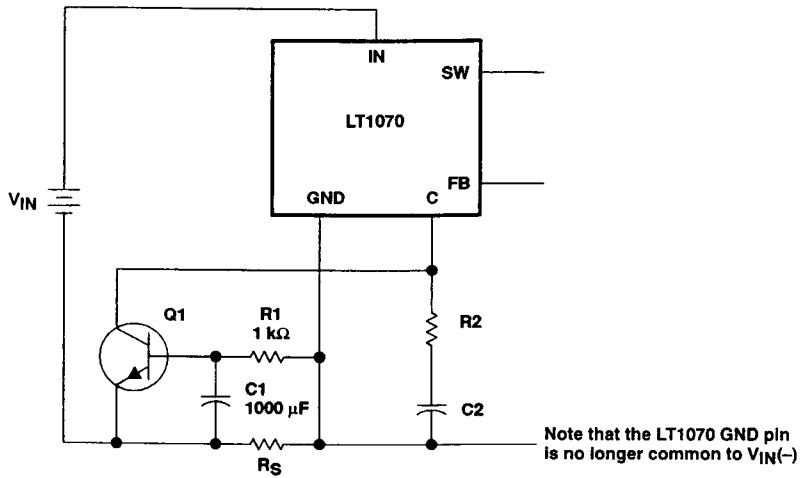


Figure 38. External Current Limit

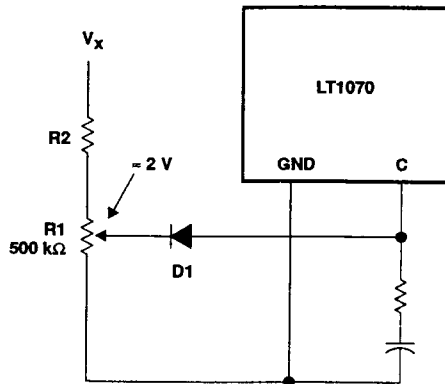


Figure 39. External Current Limit (Adjustable)