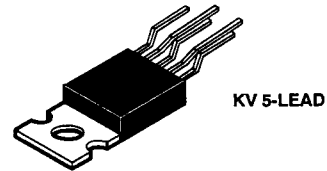
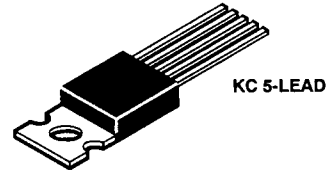
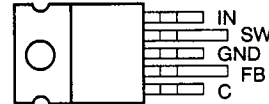


LT1070, LT1070HV 5-A HIGH-EFFICIENCY SWITCHING REGULATORS

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 _J	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[†]. 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 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 without the need for optocouplers or extra transformer windings.

[†] 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.

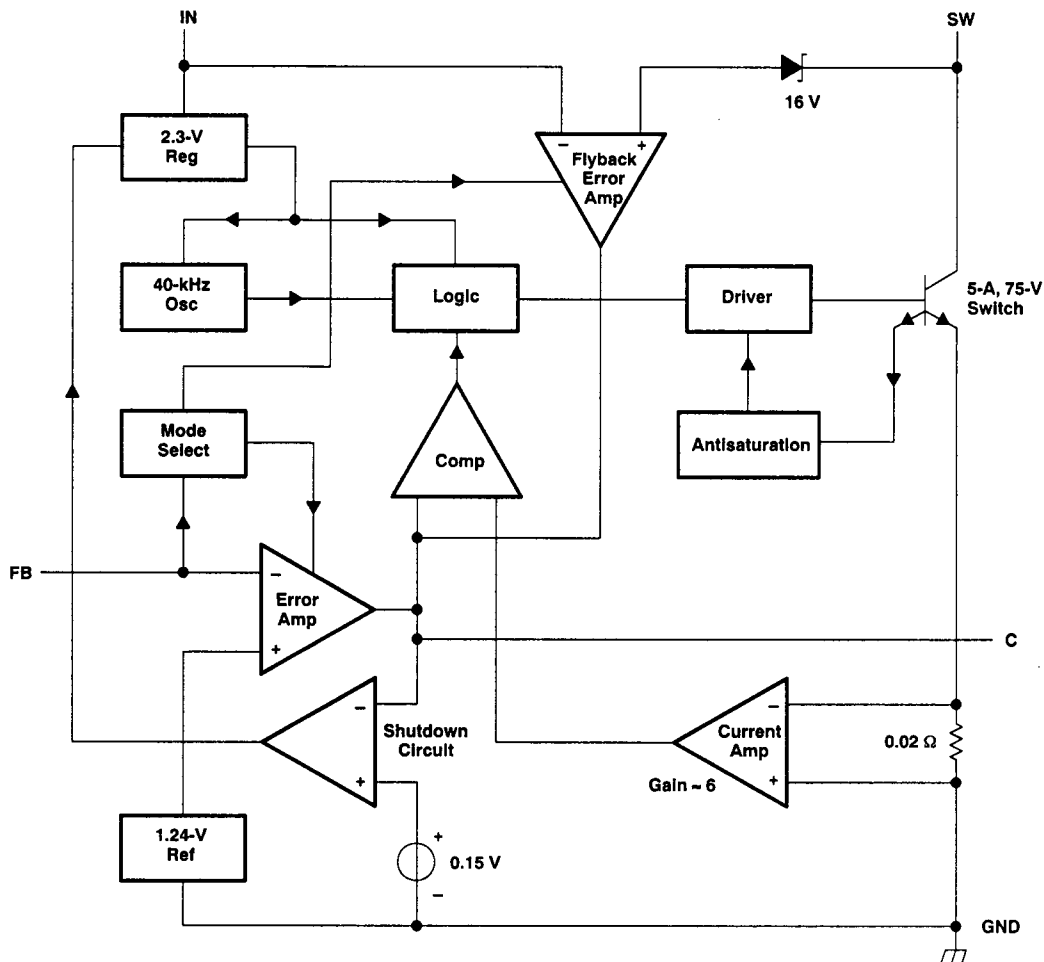
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LT1070, LT1070HV 5-A HIGH-EFFICIENCY SWITCHING REGULATORS

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)	± 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 ~ 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 _A = 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 100°C POWER RATING	T _A = 125°C POWER RATING
KC and KV	2000 mW	16 mW/°C	800 mW	400 mW

**DISSIPATION RATING TABLE 2
CASE TEMPERATURE**

PACKAGE	T _C ≤ 70°C POWER RATING	OPERATING FACTOR ABOVE T _C = 70°C	T _C = 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 _J	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	μmho
			Full range	2400		7000	
	Source current	$V_C = 1.5\text{ V}$, $V_{FB} = 0.8\text{ V}$	25°C	150	200	350	μA
			Full range	120		400	
	Sink current	$V_C = 1.5\text{ V}$, $V_{FB} = 1.5\text{ V}$	25°C	150	200	350	μA
			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	
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	
ΔV_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	μmho
			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	Full range		70	μA
			Sink	Full range		25	

† 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	Ω	
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		μs	

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	μA
$V_{T(off)}$	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- μ A supply current for shutdown-circuitry biasing.

TYPICAL CHARACTERISTICS

table of graphs

		vs		FIGURE
P_{OM}	Maximum output power	vs	Input voltage	1
V_{ref}	Reference voltage	vs	Junction temperature	2
ΔV_{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

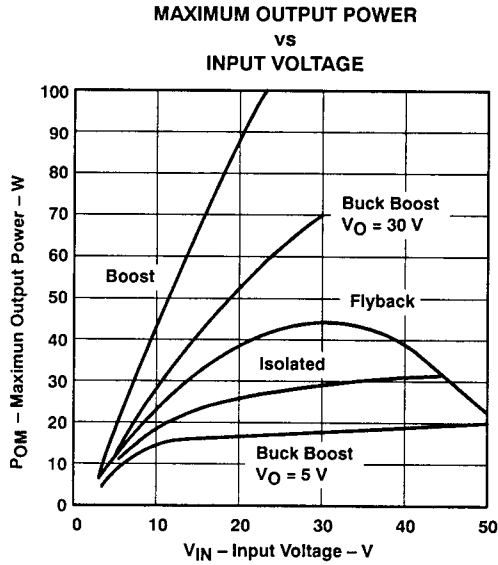


Figure 1

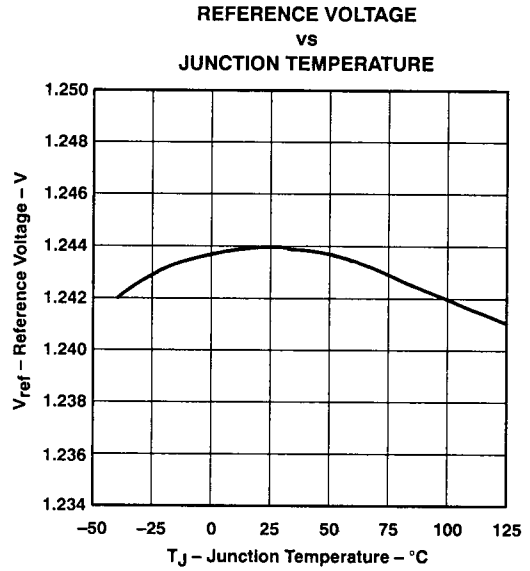


Figure 2

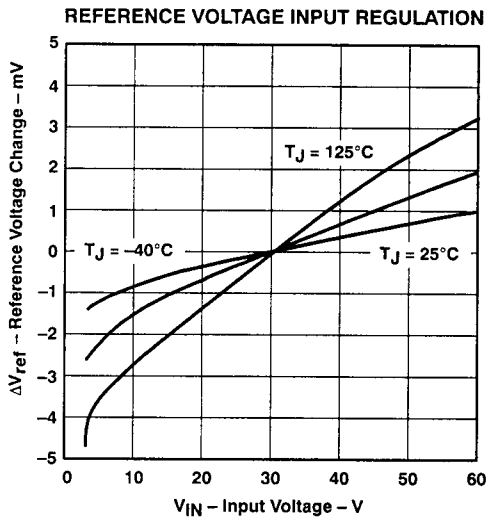


Figure 3

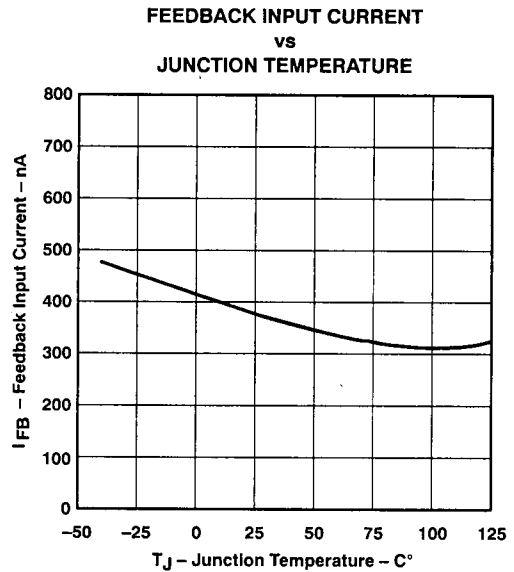


Figure 4

TYPICAL CHARACTERISTICS

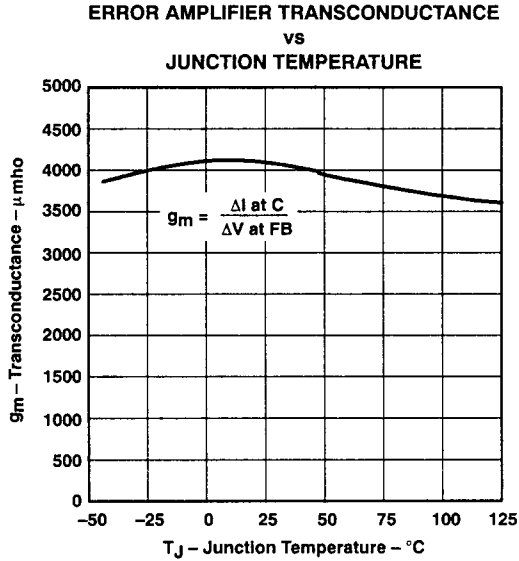


Figure 5

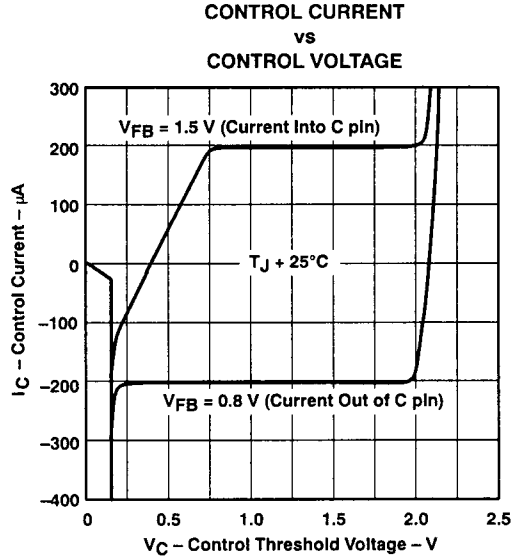


Figure 6

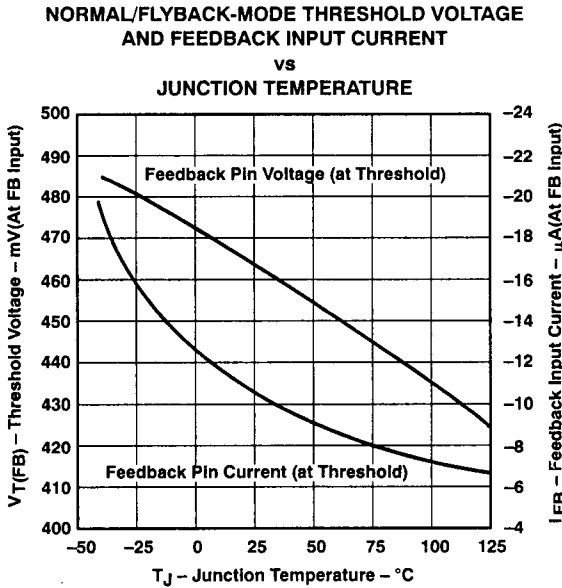


Figure 7

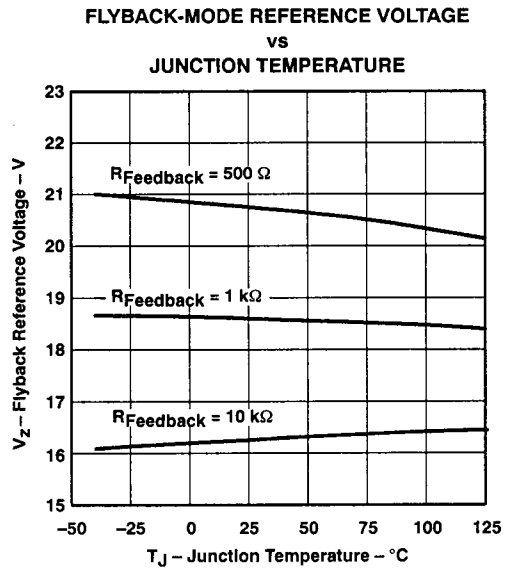


Figure 8

TYPICAL CHARACTERISTICS

FLYBACK SENSE DELAY TIME
vs
JUNCTION TEMPERATURE

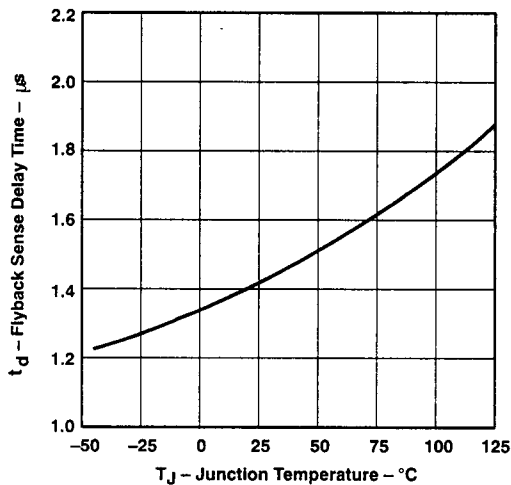


Figure 9

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

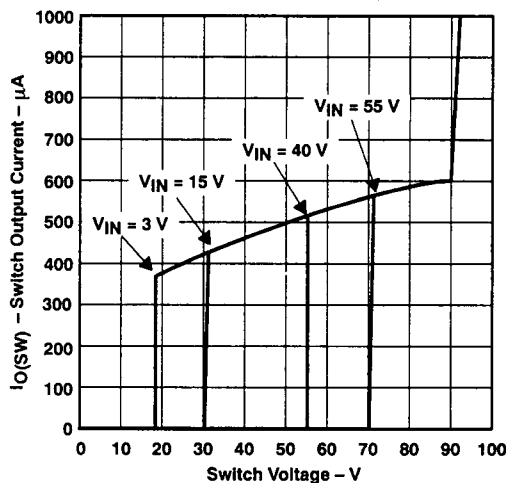


Figure 10

DRIVER BASE CURRENT†
vs
SWITCH OUTPUT CURRENT

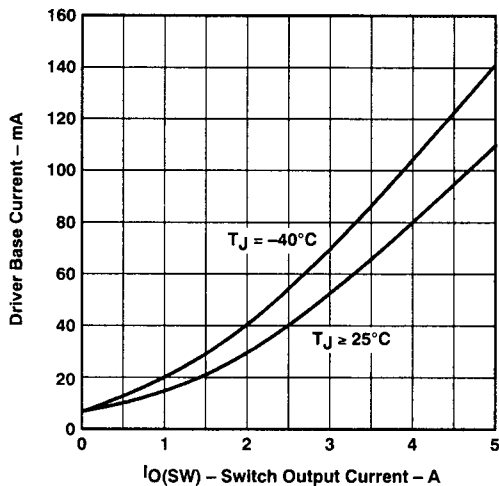


Figure 11

SWITCH SATURATION VOLTAGE
vs
SWITCH CURRENT

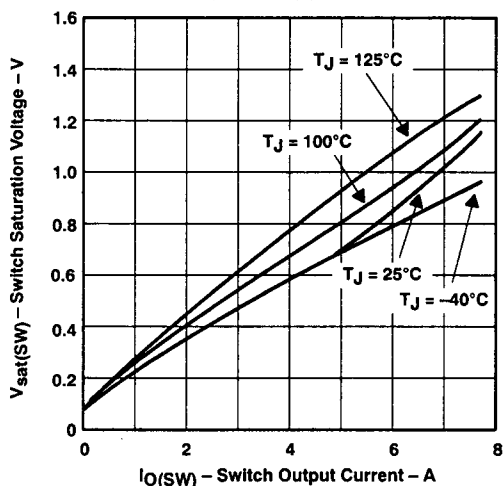


Figure 12

† 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

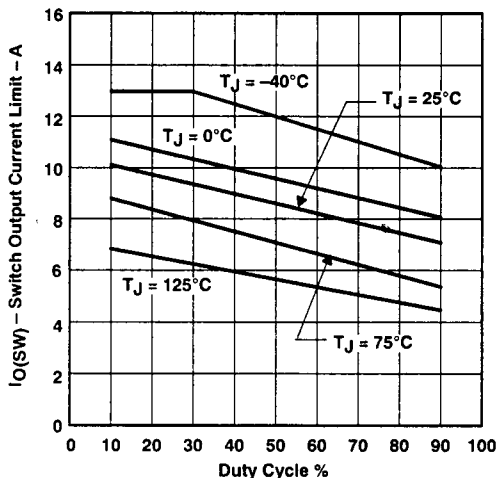


Figure 13

MAXIMUM DUTY CYCLE
vs
JUNCTION TEMPERATURE

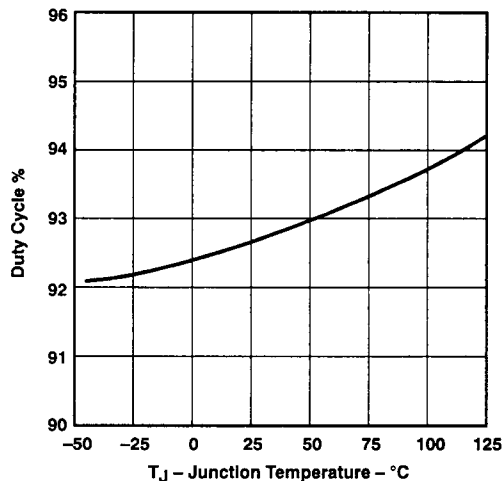


Figure 14

SHUTDOWN-MODE INPUT CURRENT
vs
CONTROL VOLTAGE

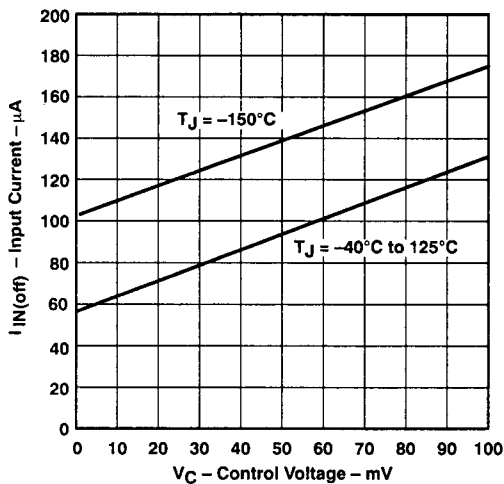


Figure 15

SHUTDOWN-MODE INPUT CURRENT
vs
INPUT CURRENT

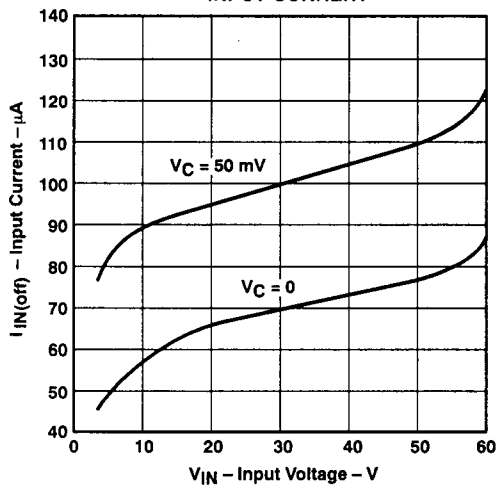


Figure 16

TYPICAL CHARACTERISTICS

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

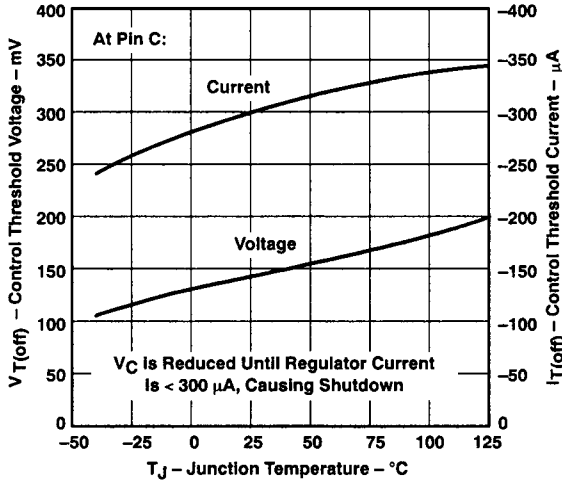


Figure 17

FEEDBACK INPUT VOLTAGE
vs
FEEDBACK INPUT CURRENT

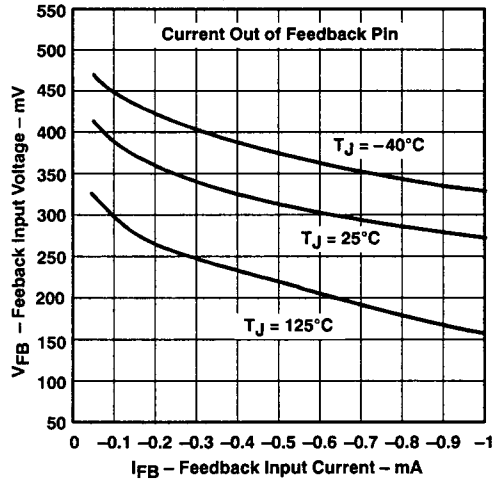


Figure 18

MINIMUM INPUT VOLTAGE
vs
JUNCTION TEMPERATURE

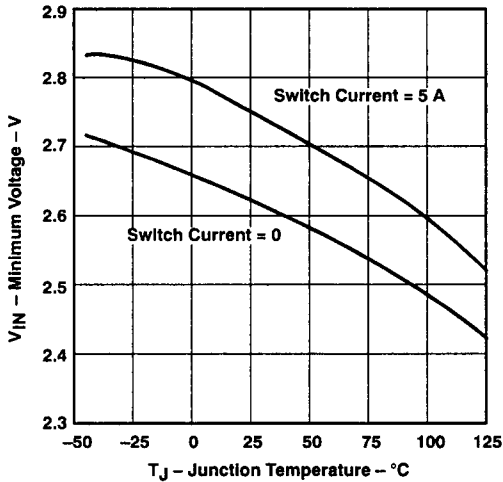


Figure 19

INPUT CURRENT
vs
JUNCTION TEMPERATURE
(SW OUTPUT OPEN)

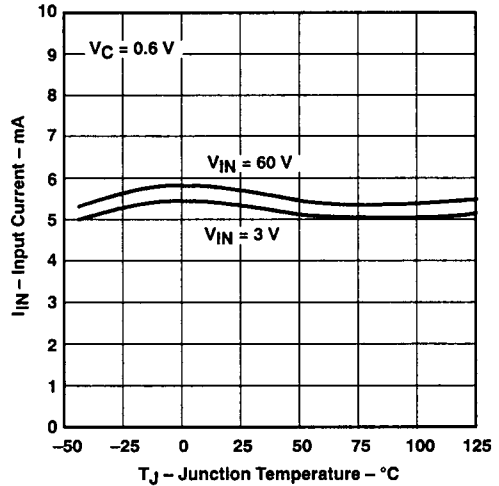
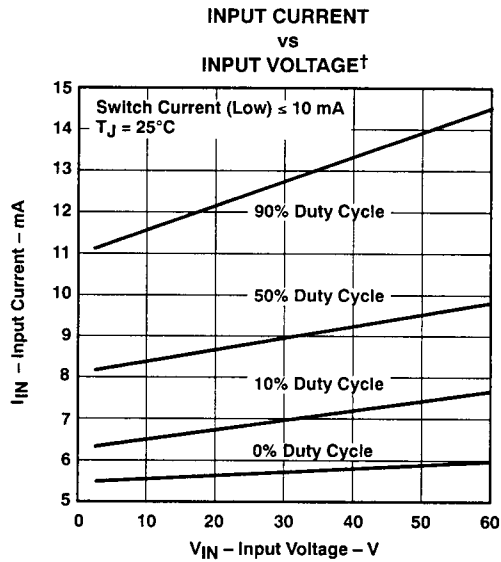


Figure 20

TYPICAL CHARACTERISTICS

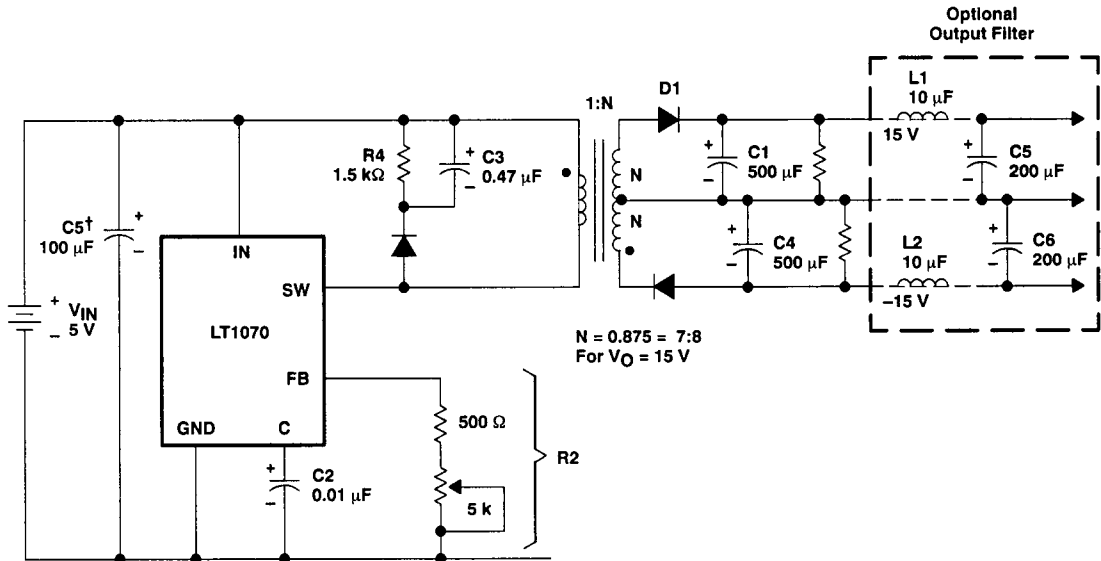


† Under very low output current conditions, duty cycle for most circuits will approach 10% or less.

Figure 21

LT1070, LT1070HV
5-A HIGH-EFFICIENCY SWITCHING REGULATORS

APPLICATION INFORMATION



$N = 0.875 = 7:8$
 For $V_O = 15\text{ V}$

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

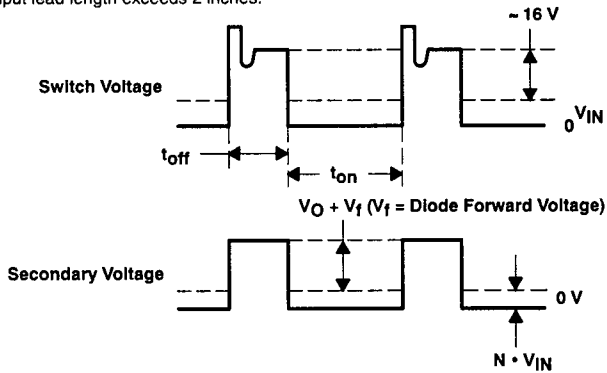
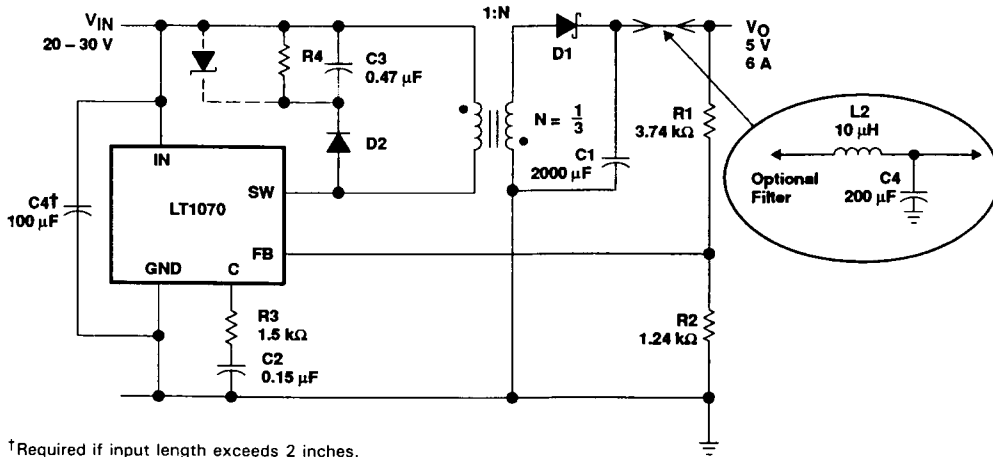


Figure 22. Totally Isolated Converter



APPLICATION INFORMATION



† Required if input length exceeds 2 inches.

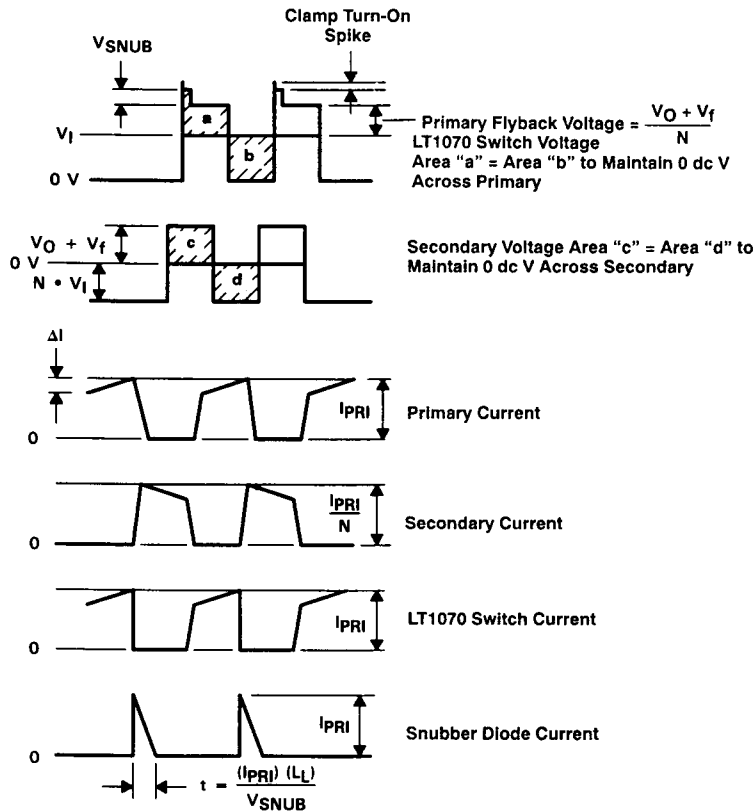


Figure 23. Flyback Converter

APPLICATION INFORMATION

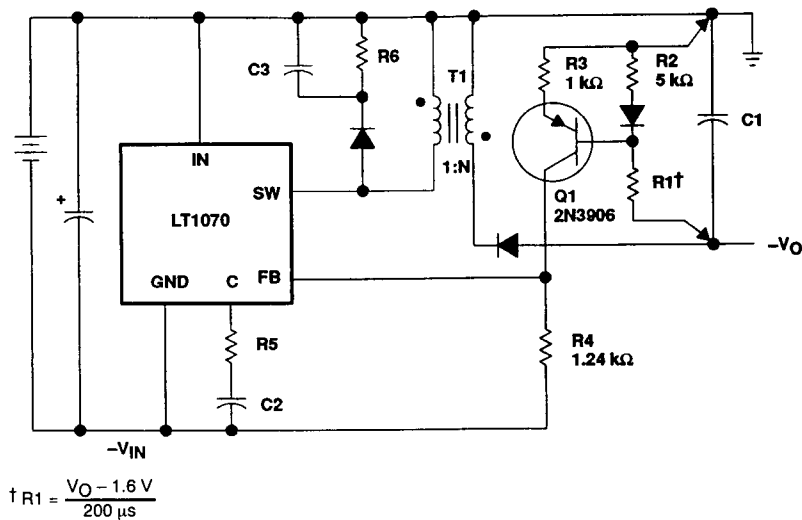


Figure 24. Negative Input - Negative Output Flyback Converter

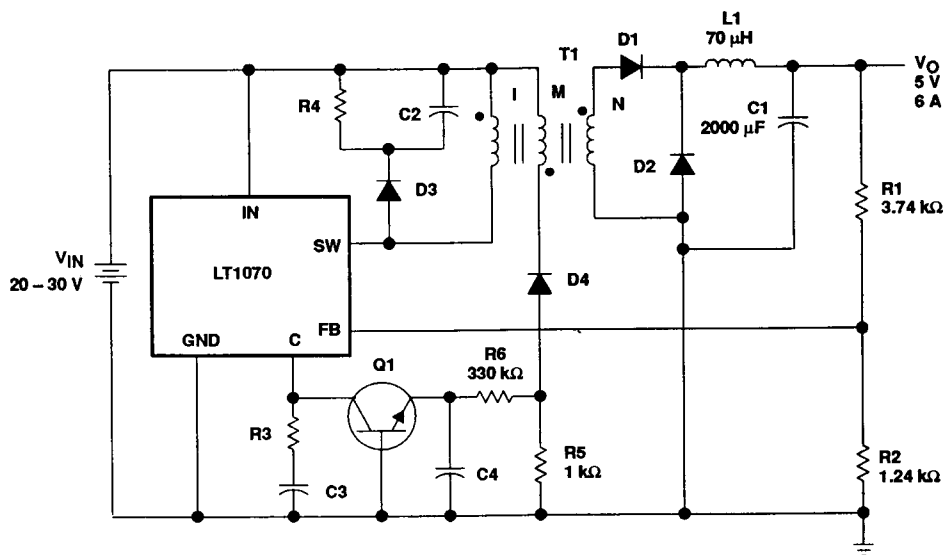


Figure 25. Forward Converter

APPLICATION INFORMATION

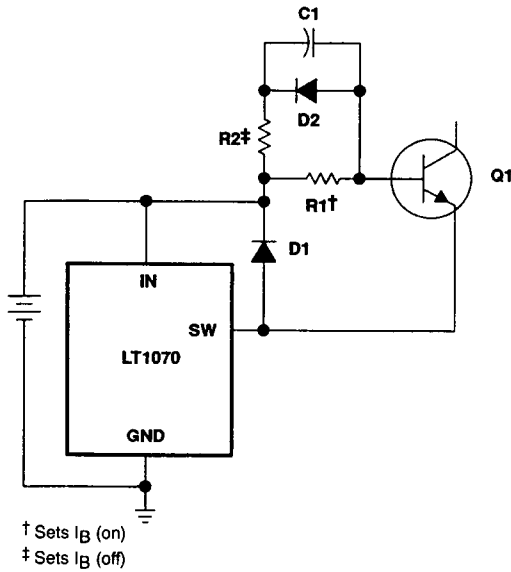


Figure 26. Driving High-Voltage NPN Transistor

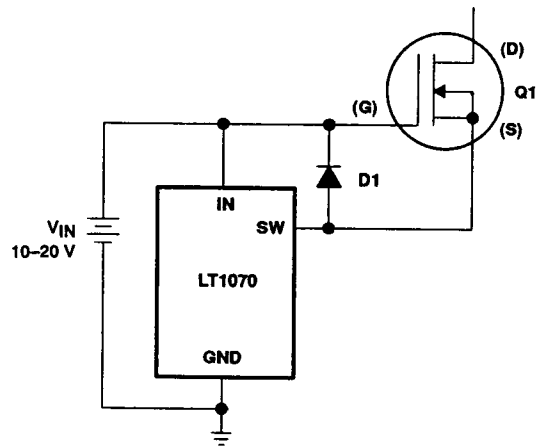


Figure 27. Driving High-Voltage FET

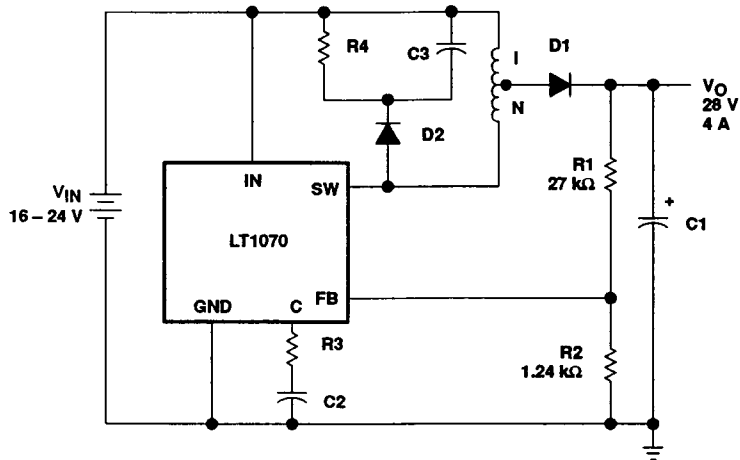


Figure 28. Current-Boosted Boost Converter

LT1070, LT1070HV
5-A HIGH-EFFICIENCY SWITCHING REGULATORS

APPLICATION INFORMATION

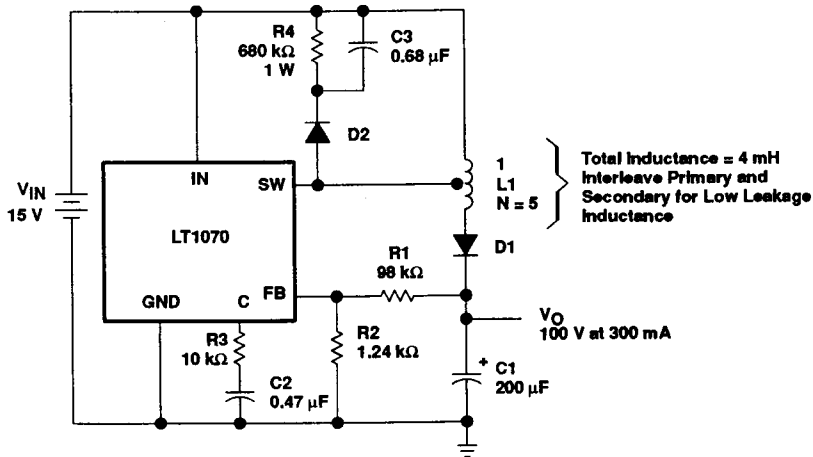
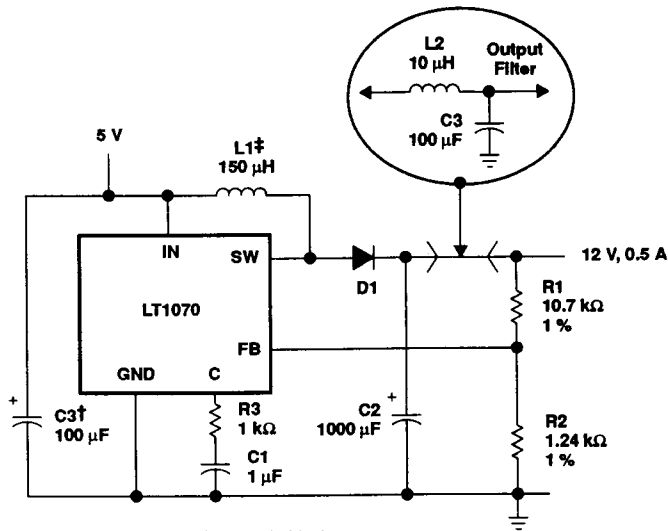


Figure 29. Voltage-Boosted Boost Converter



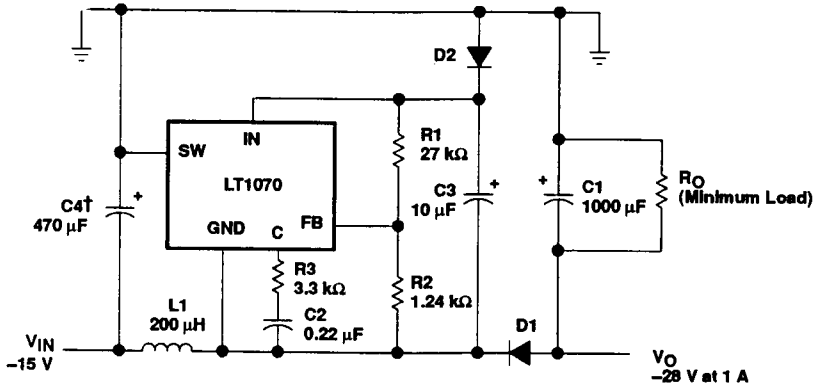
† Capacitors are required if input lead length exceeds 2 inches.

‡ Pulse Engineering 92113.

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

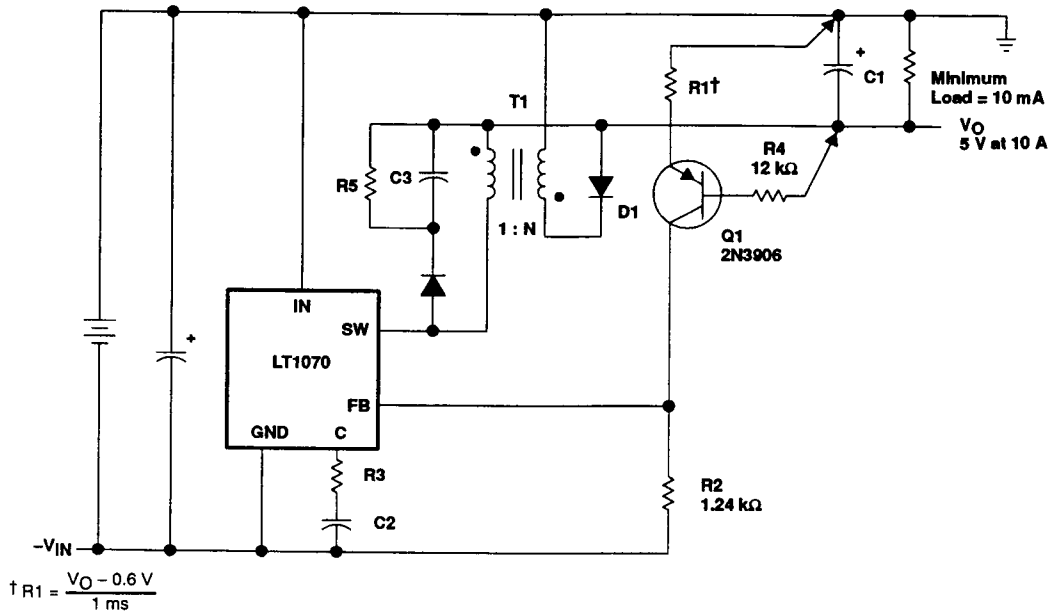


APPLICATION INFORMATION



† Required if input lead length exceeds 2 inches.

Figure 31. Negative Boost Regulator

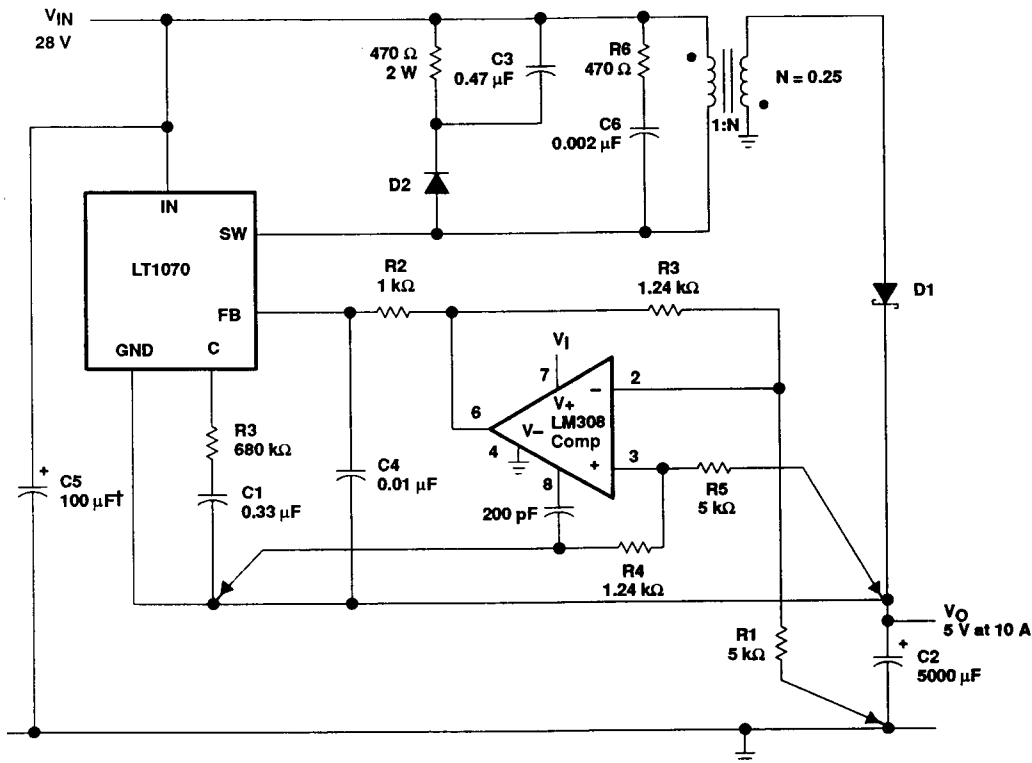


$$\dagger R1 = \frac{V_O - 0.6 \text{ V}}{1 \text{ ms}}$$

Figure 32. Negative Current-Boosted Buck Converter

LT1070, LT1070HV
5-A HIGH-EFFICIENCY SWITCHING REGULATORS

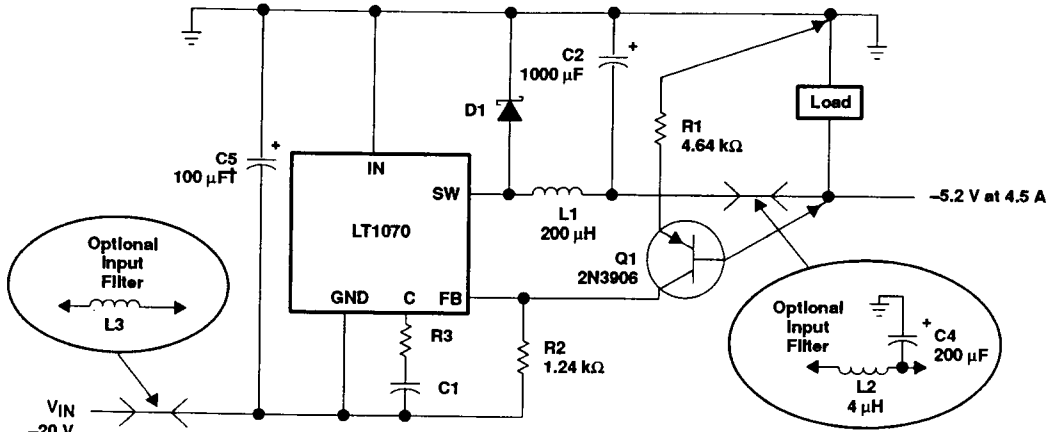
APPLICATION INFORMATION



† Required if input lead length exceeds 2 inches.

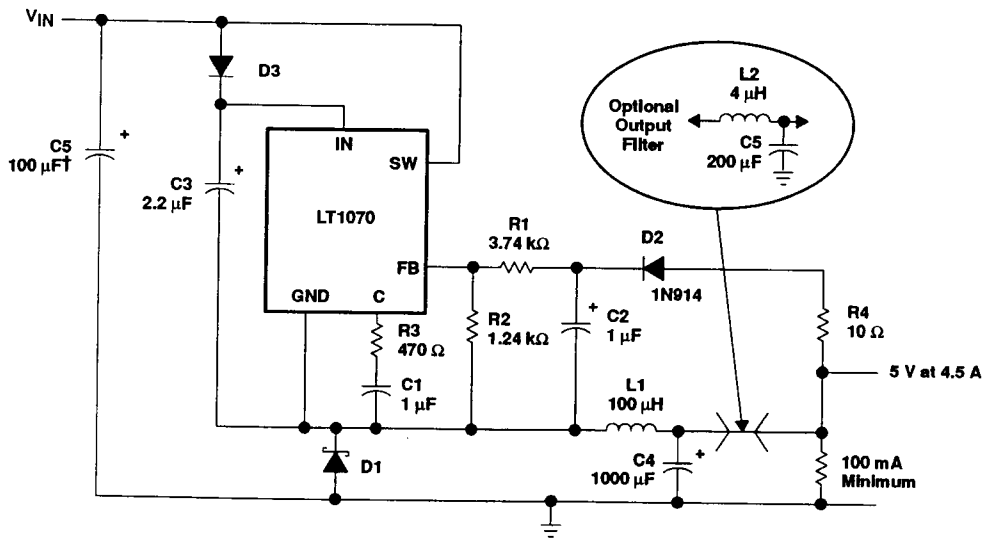
Figure 33. Positive Current-Boosted Buck Converter

APPLICATION INFORMATION



† Required if input lead length exceeds 2 inches.

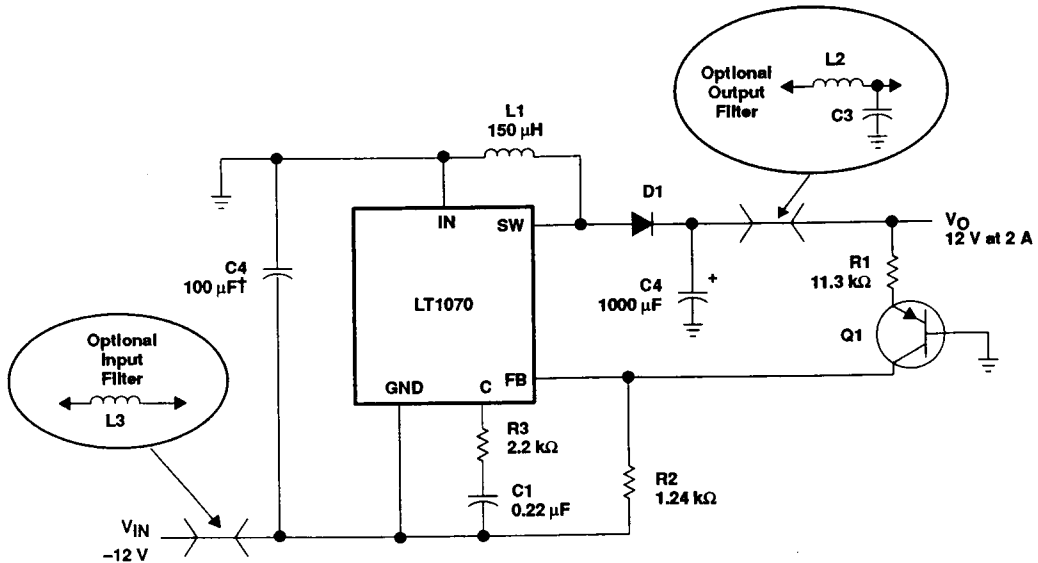
Figure 34. Negative Buck Converter



† Required if input lead length exceeds 2 inches.

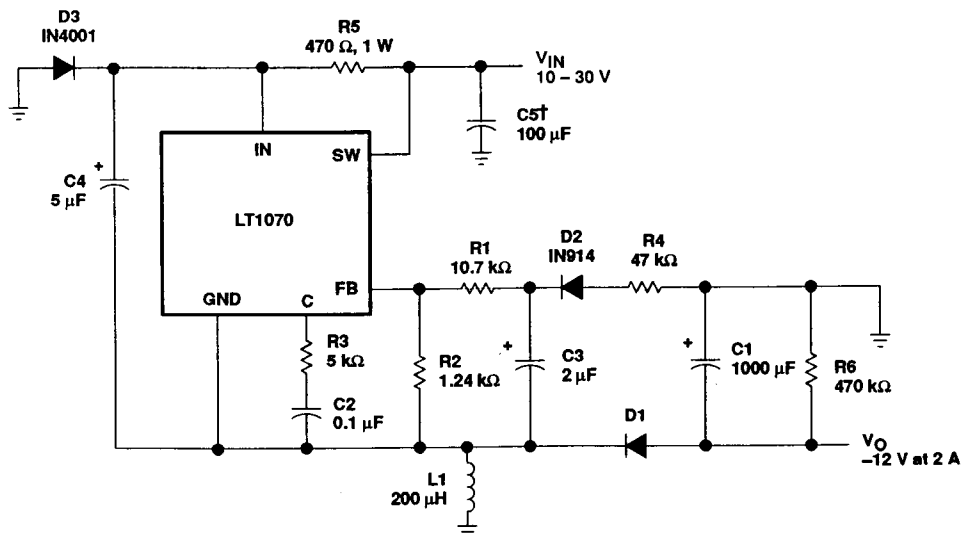
Figure 35. Positive Buck Converter

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

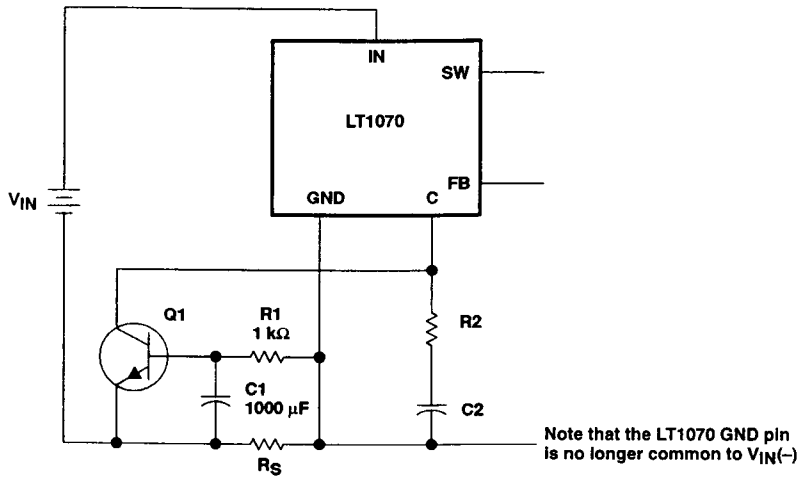


Figure 38. External Current Limit

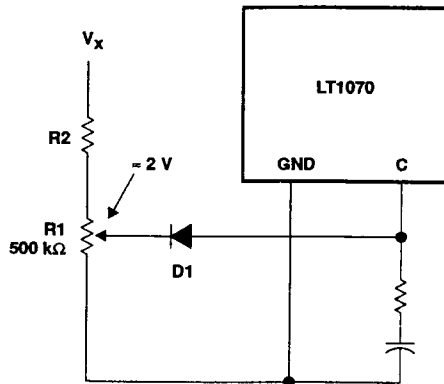


Figure 39. External Current Limit (Adjustable)