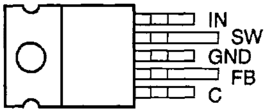
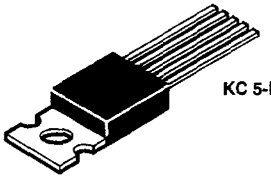
D3344, JULY 1989–REVISED AUGUST 1991

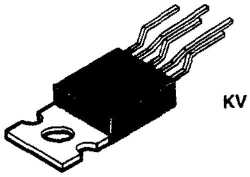
- **Wide Supply-Voltage Range:**
  LT1071HV . . . 3 V to 60 V
  LT1071 . . . 3 V to 40 V
- **Low Quiescent Current . . . 6 mA Typ**
- **Internal 2.5-A Switch**
- **Few External Parts Required**
- **Self-Protected Against Overloads**
- **Operates in Most Switching Configurations**
- **Low Shutdown-Mode 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)





KC 5-Lead



KV 5-Lead

AVAILABLE OPTIONS

T_J	MAX INPUT VOLTAGE	KC PACKAGE	KV PACKAGE
0°C to	60 V	LT1071HVCKC	LT1071HVCKV
100°C	40 V	LT1071CKC	LT1071CKV
–40°C to	60 V	LT1071HVIKC	LT1071HVIKV
125°C	40 V	LT1071IKC	LT1071IKV

description

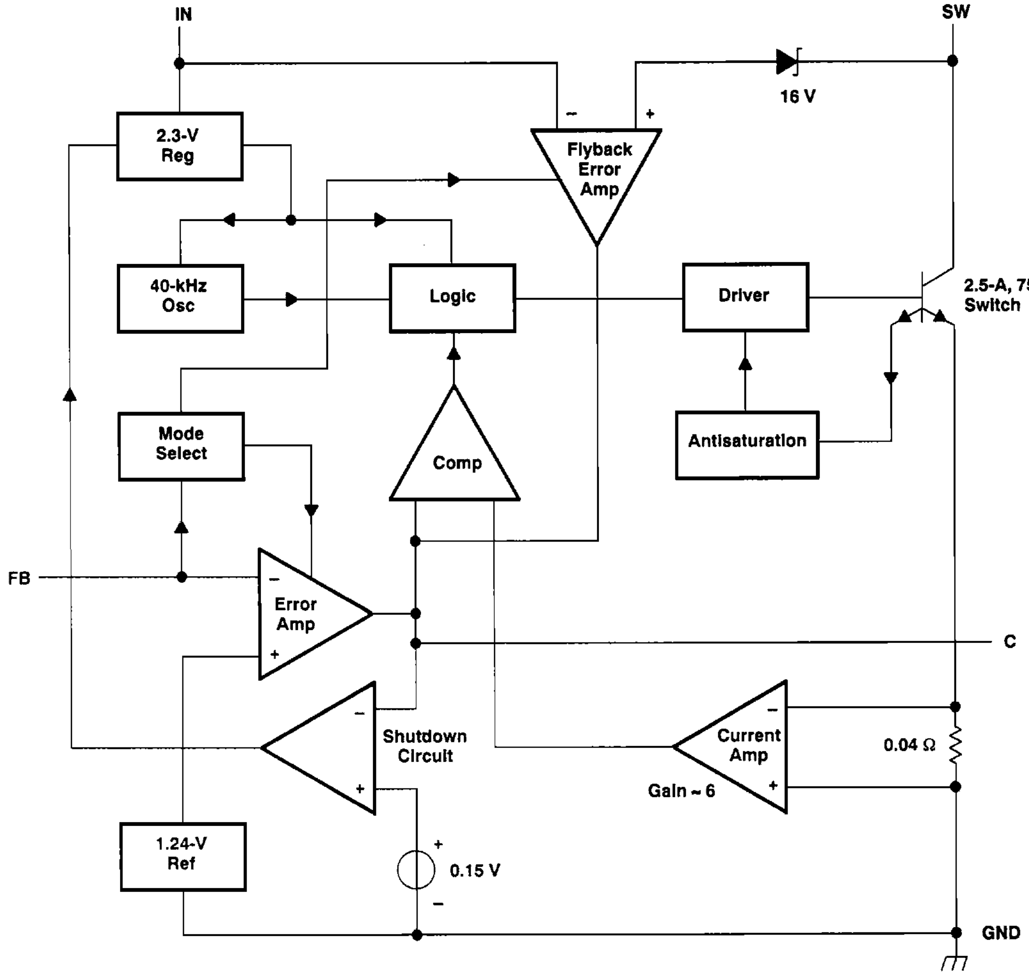
The LT1071 is a monolithic, high-efficiency switching regulator. It can be operated in all standard switching configurations including: step-down (buck), step-up (boost), flyback, forward, inverting, and Cuk†. A high-current, high-efficiency switch is included in the package along with all oscillator, control, and protection circuitry. Integration of all functions allows the LT1071 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 LT1071 operates with supply voltages from 3 V to 40 V. The LT1071HV, a high-voltage version of the LT1071, 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, provide excellent ac and dc input and output regulation.

The LT1071 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 μA typical for standby operation. Totally isolated and regulated outputs can be generated by using the optional flyback-regulation mode built into the LT1071 without using optocouplers or extra transformer windings.

†A boost-buck-derived regulator circuit patented by Slobodan Ćuk.

functional block diagram



Resistor value shown is nominal.

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

Supply voltage, V_{IN} (see Note 1): LT1071 .... 40 V
LT1071HV .... 60 V
Switch output voltage: LT1071 .... 65 V
LT1071HV .... 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: LT1071C, LT1071HVC .... 0°C to 125°C
LT1071I, LT1071HVI .... −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 LT1071 in current limit is ≈ 1 µs. 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 LT1071 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	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 125°C$ POWER RATING
KC	2000 mW	16 mW/°C	400 mW
KV	2000 mW	16 mW/°C	400 mW

DISSIPATION RATING TABLE 2 – CASE TEMPERATURE

PACKAGE	$T_C \le 70°C$ POWER RATING	DERATING FACTOR ABOVE $T_C = 70°C$	$T_C = 125°C$ POWER RATING
KC	20 W	250 mW/°C	6.25 W
KV	20 W	250 mW/°C	6.25 W

recommended operating conditions

		MIN	MAX	UNIT
Input voltage, V_{IN}	LT1071C, LT1071I	3	40	V
	LT1071HVC, LT1071HVI	3	60	
Virtual-junction temperature, T_J	LT1071C, LT1071HVC	0	100	°C
	LT1071I, LT1071HVI	−40	125	

electrical characteristics at specified virtual junction temperature, V_{IN} = 15 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}	Output voltage	Measured at FB input, V_C = 0.6 V	25°C	1.224	1.244	1.264	V
			Full range	1.214		1.274	
	Input regulation	V_{IN} = 3 V to MAX, V_C = 0.6 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		350	750	nA
				Full range			1100	
g_m	Transconductance	ΔI_C = ±25 μA		25°C	3000	4400	6000	μmho
				Full range	2400		7000	
	Source current	V_C = 1.5 V,	V_{FB} = 0.8 V	25°C	150	200	350	μA
				Full range	120		400	
	Sink current	V_C = 1.5 V,	V_{FB} = 1.5 V	25°C	150	200	350	μA
				Full range	120		400	
$V_{O(C)}$	Output voltage	High state,	V_{FB} = 1 V	25°C	1.8		2.3	V
		Low state,	V_{FB} = 1.5 V		0.25	0.38	0.52	
A_V	Voltage amplication	V_C = 0.7 V to 1.4 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
$V_{T(FB)}$	Flyback threshold voltage	I_{FB} = 50 μA			25°C	0.4	0.45	0.54	V
V_Z	Flyback reference	I_{FB} = 50 μA,	I_C = −1 to +1 μA,	V_C = 0.6 V	25°C	15	16.3	17.6	V
					Full range	14		18	
ΔV_Z	Change in flyback reference	I_{FB} = 0.05 to 1 mA,	I_C = −1 to +1 μA,	V_C = 0.6 V	25°C	4.5	6.8	8.5	V
	Flyback reference input regulation	I_{FB} = 50 μA, I_C = −1 to +1 μA,	V_{IN} = 3 V to MAX, V_C = 0.6 V		25°C		0.01	0.03	%/V
g_m	Transconductance	I_{FB} = 50 μA,	$\Delta I_C \le \pm 10$ μA		25°C	150	300	500	μmho
	Sink or source current	V_C = 1.5 V, $V_{(SW)} = V_Z + V_{IN} \pm 1$ V	I_{FB} = 50 μA,	Source	Full range	15	32	50	μA
				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 LT1071C and LT1071HVC and −40°C to 125°C for LT1071I and LT1071HVI.
§ All typical values are T_A = 25°C.

electrical characteristics at specified virtual junction temperature, V_{IN} = 15 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 V, I_{SW} = 5 mA	V_{IN} = 3 V to MAX,	LT1071	Full range	65			V
				LT1071HV		75			
Ron	Switch on-state resistance	V_{FB} = 0.8 V,	I_{SW} = 2 A		Full range		0.3	0.5	Ω
g_m	Control-to-switch transconductance				25°C		4		mho
$I_{SW(lim)}$	Switch current limit	V_{FB} = 0.8 V, See Note 2	Duty cycle ≤ 50%		≥25°C	2.5		5	A
			Duty cycle ≤ 50%		<25°C	2.5		5.5	
			Duty cycle = 80%		Full range	2		5	
$\Delta I_{IN}/\Delta I_{SW}$	Input current increase during switch turn-on	V_{FB} = 0.8 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 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
$I_{IN(off)}$	Shutdown mode input current	V_{IN} = 3 V to MAX,	V_C = 0.05 V	25°C		100	250	µA
$V_{C(off)}$	Control threshold voltage	V_{IN} = 3 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 V to MAX,	V_C = 0.6 V	25°C		6	9	mA

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.
‡ Full range virtual junction temperature is 0°C to 100°C for LT1071C and LT1071HVC and −40°C to 125°C for LT1071I and LT1071HVI.
§ All typical values are T_A = 25°C.
NOTE 2: For duty cycles between 50% and 80%, minimum switch output current is given by $I_{SW(lim)}$ = 1.67 (2-duty cycle).

theory of operation

The LT1071 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 LT1071. 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 LT1071 to disconnect the main error-amplifier output and connects the output of the flyback amplifier to the comparator input. The 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 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 (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 LT1071 in an idle mode. Pulling the C pin below 0.15 V causes total regulator shutdown, with only 50-μA supply current for shutdown-circuitry biasing.

TYPICAL CHARACTERISTICS

table of graphs

				FIGURE
P_{OM}	Maximum output power	vs	Input voltage	1
f	Switching frequency	vs	Junction temperature	2
V_{ref}	Reference voltage	vs	Junction temperature	2
	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
g_m	Error amplifier transconductance	vs	Frequency	6
	Error amplifier phase shift	vs	Frequency	6
I_C	Control current	vs	Control voltage	7
$V_{T(FB)}$	Normal-flyback-mode threshold voltage	vs	Junction temperature	8
I_{FB}	Feedback input current	vs	Junction temperature	8
V_z	Flyback reference voltage	vs	Junction temperature	9
t_d	Flyback sense delay time	vs	Junction temperature	10
$I_{O(SW)}$	Switch (output with switch off) current	vs	Switch voltage	11
	Driver base current	vs	Switch output current	12
$V_{sat(SW)}$	Switch saturation voltage	vs	Switch output current	13
$I_{O(SW)}$	Switch output current limit	vs	Duty cycle	14
	Maximum duty cycle	vs	Junction temperature	15
I_{IN}	Shutdown-mode input current	vs	Control threshold voltage	16
I_{IN}	Shutdown-Mode input current	vs	Input voltage	17
$V_{T(C)}$	Shutdown-mode control threshold voltage	vs	Junction temperature	18
$I_{T(C)}$	Shutdown-mode control threshold current	vs	Junction temperature	18
V_{FB}	Feedback input voltage	vs	Feedback input current	19
	Minimum input voltage	vs	Junction temperature	20
I_{IN}	Input current	vs	Junction temperature	21
I_{IN}	Input current	vs	Input voltage	22

table of application circuits

APPLICATION	FIGURE
Totally isolated converter	23
Boost converter (5 V to 12 V)	24

TYPICAL CHARACTERISTICS

MAXIMUM OUTPUT POWER vs INPUT VOLTAGE

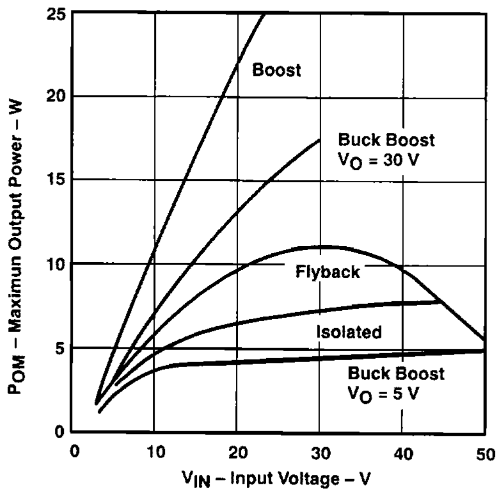

Figure 1

REFERENCE VOLTAGE AND SWITCHING FREQUENCY vs JUNCTION TEMPERATURE

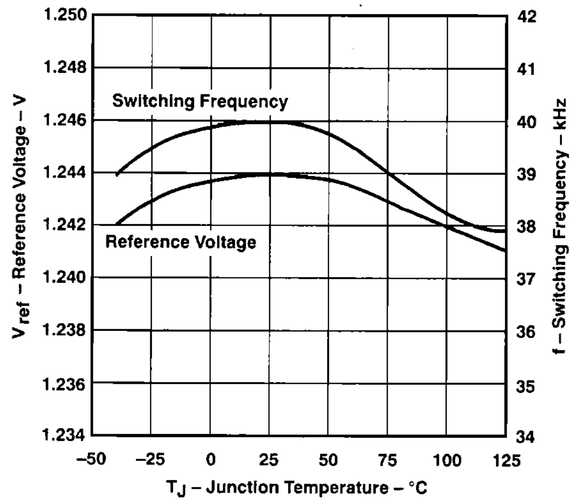

Figure 2

REFERENCE VOLTAGE INPUT REGULATION

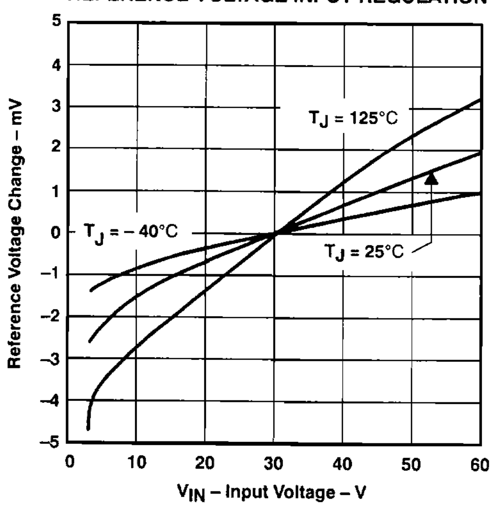

Figure 3

FEEDBACK INPUT CURRENT vs JUNCTION TEMPERATURE

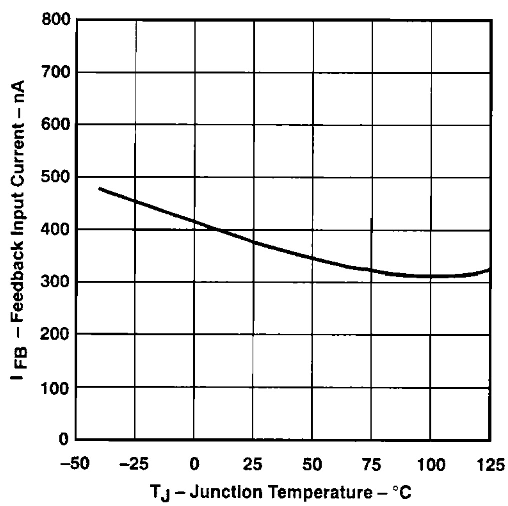

Figure 4

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TYPICAL CHARACTERISTICS

ERROR AMPLIFIER TRANSDUCTANCE vs JUNCTION TEMPERATURE

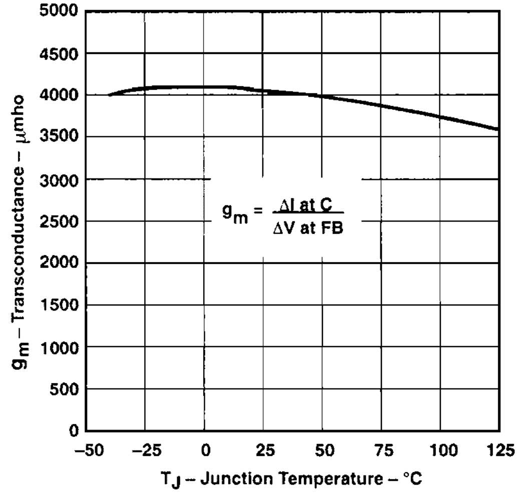

Figure 5

ERROR AMPLIFIER TRANSCONDUCTANCE AND PHASE SHIFT vs FREQUENCY

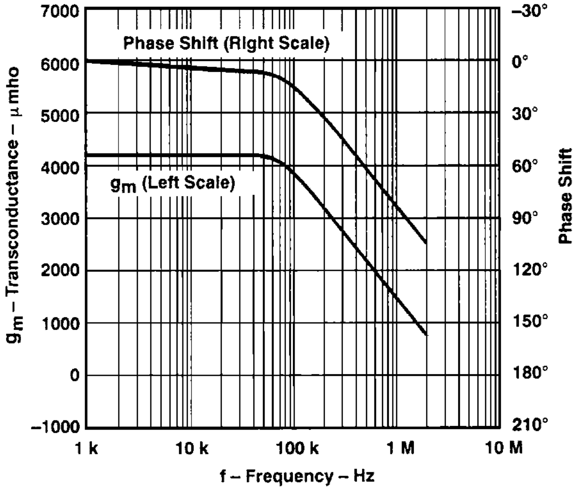

Figure 6

CONTROL CURRENT vs CONTROL VOLTAGE

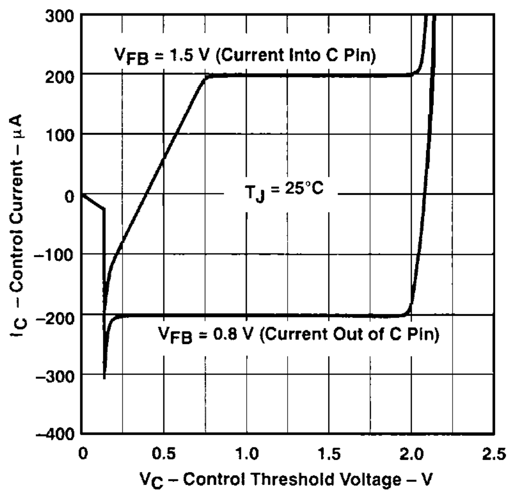

Figure 7

NORMAL-FLYBACK-MODE THRESHOLD VOLTAGE AND FEEDBACK INPUT CURRENT vs JUNCTION TEMPERATURE

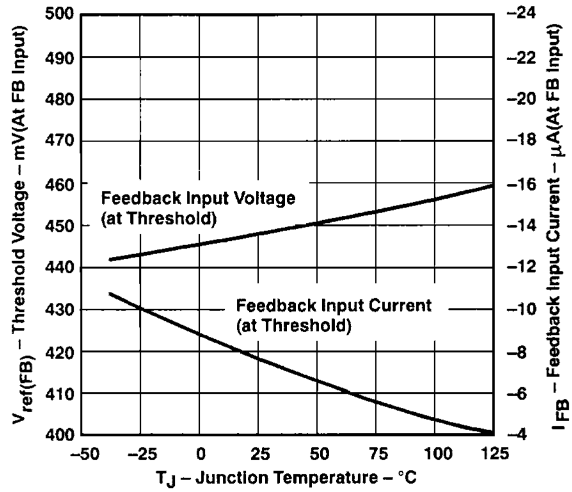

Figure 8

TYPICAL CHARACTERISTICS

FLYBACK MODE REFERENCE VOLTAGE
vs
JUNCTION TEMPERATURE

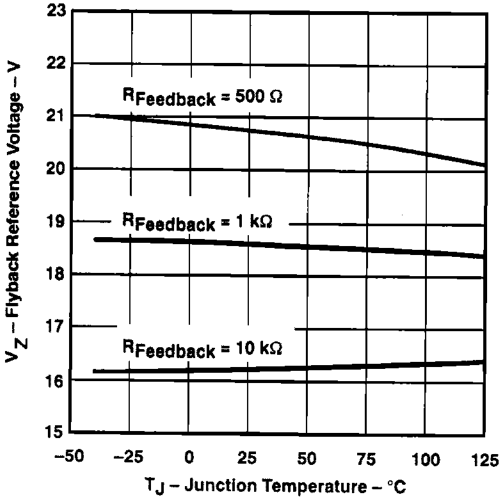

Figure 9

FLYBACK SENSE DELAY TIME
vs
JUNCTION TEMPERATURE

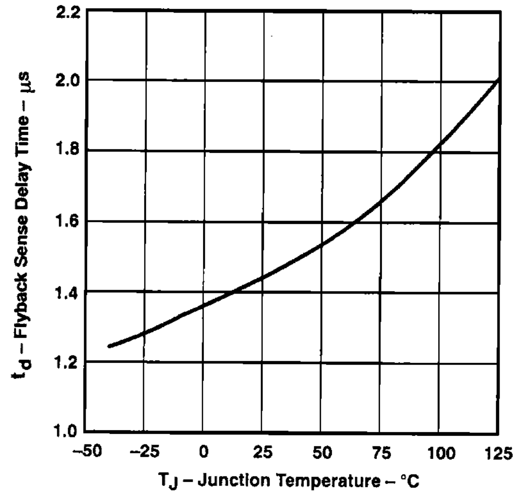

Figure 10

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

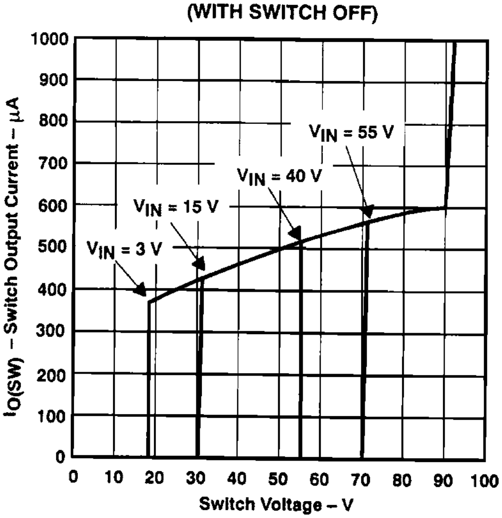

Figure 11

DRIVER BASE CURRENT†
vs
SWITCH OUTPUT CURRENT

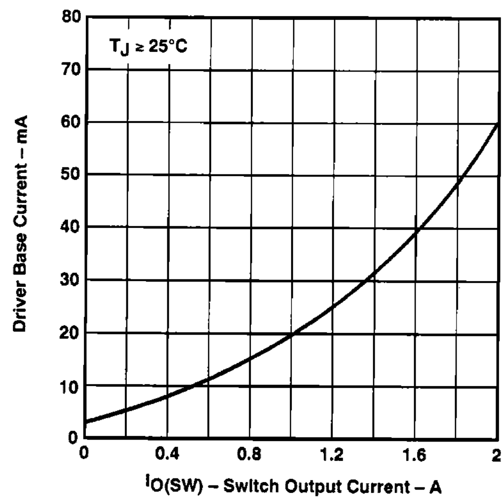

Figure 12

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

TYPICAL CHARACTERISTICS

SWITCH SATURATION VOLTAGE
vs
SWITCH CURRENT

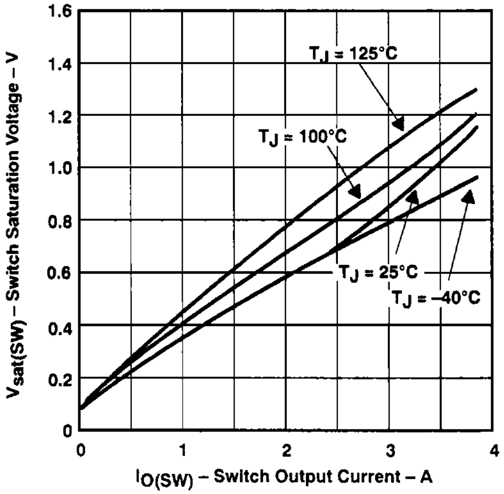

Figure 13

SWITCH OUTPUT CURRENT LIMIT
vs
DUTY CYCLE

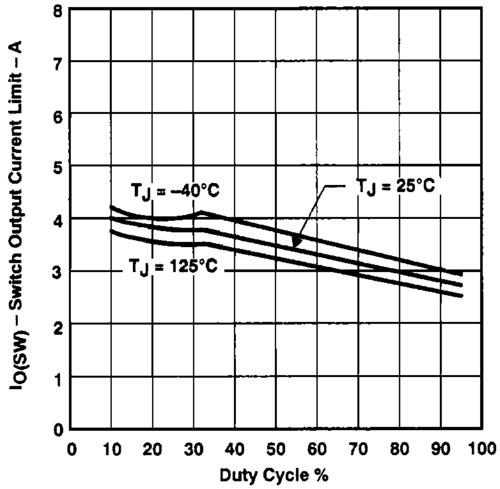

Figure 14

DUTY CYCLE (MAX)
vs
JUNCTION TEMPERATURE

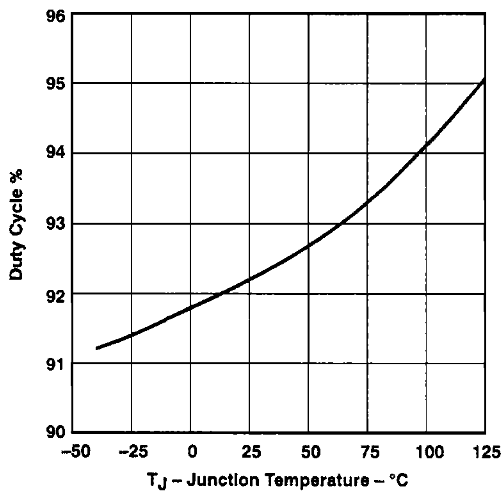

Figure 15

SHUTDOWN MODE
INPUT CURRENT
vs
CONTROL THRESHOLD VOLTAGE

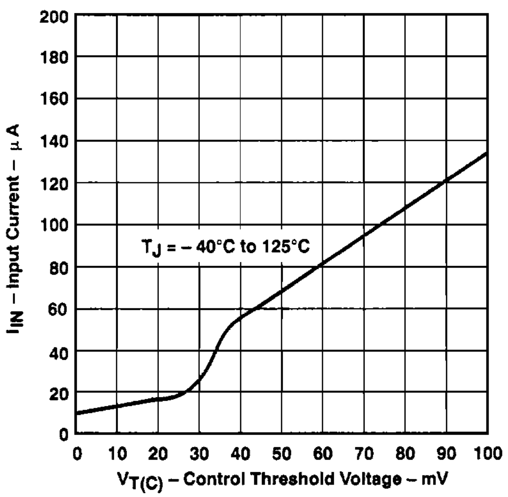

Figure 16

TYPICAL CHARACTERISTICS

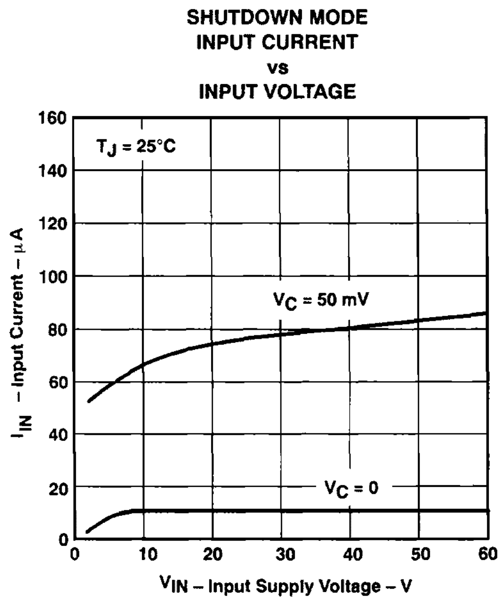

Figure 17

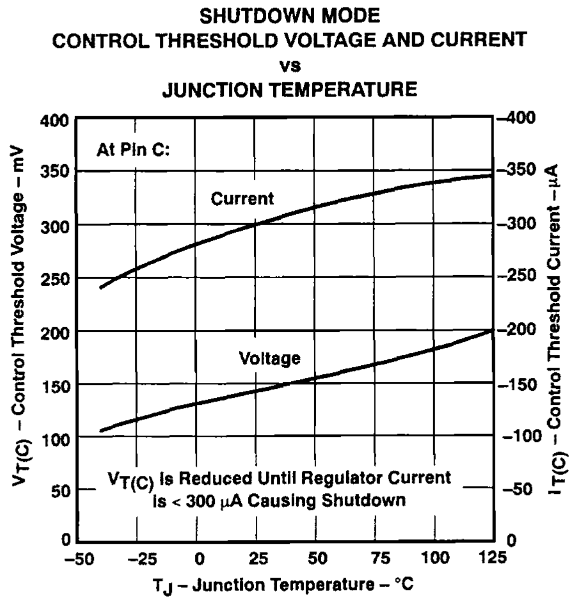

Figure 18

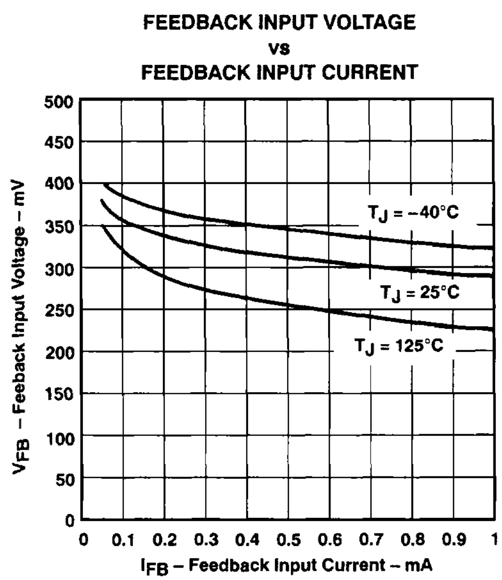

Figure 19

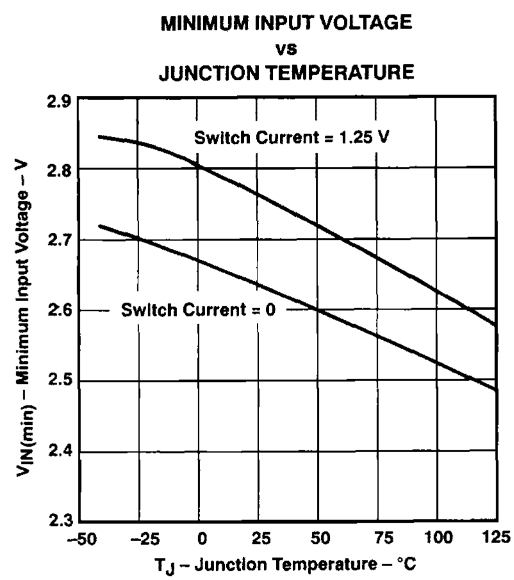

Figure 20

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TYPICAL CHARACTERISTICS

INPUT CURRENT vs JUNCTION TEMPERATURE (SW OUTPUT OPEN)

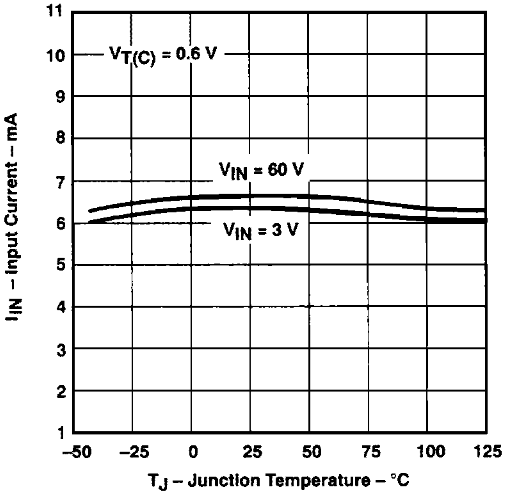
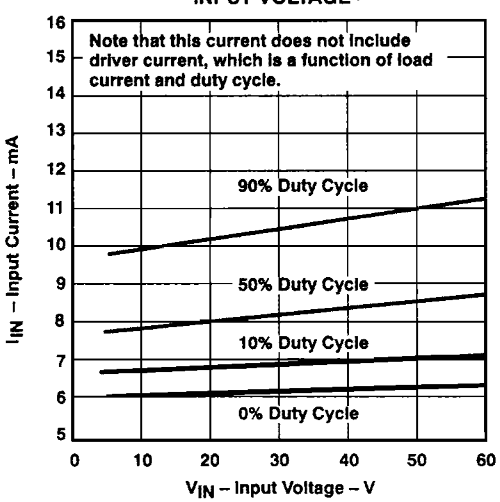


Figure 21

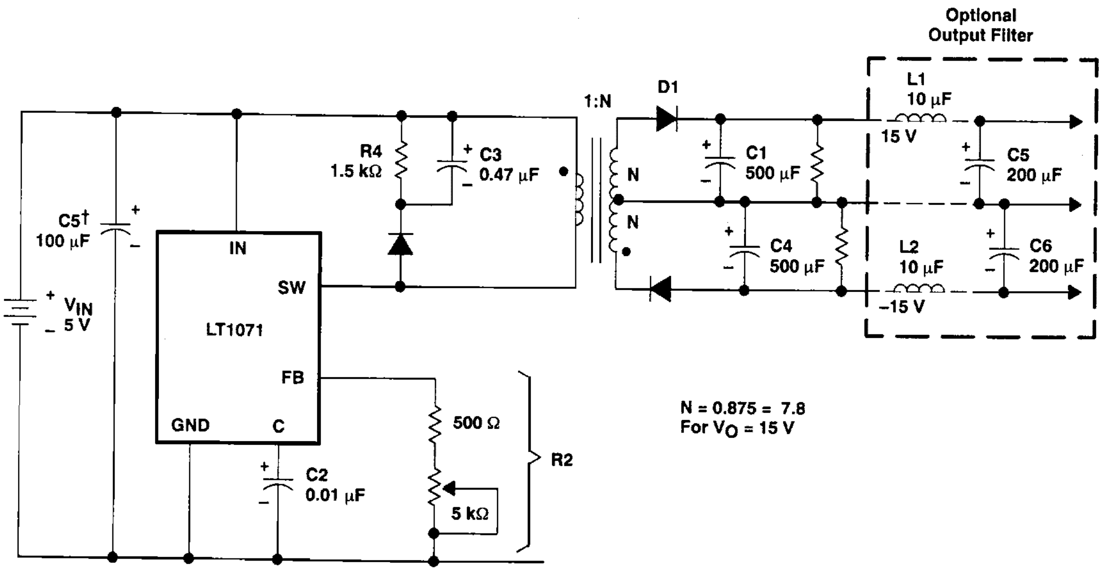
INPUT CURRENT vs INPUT VOLTAGE†

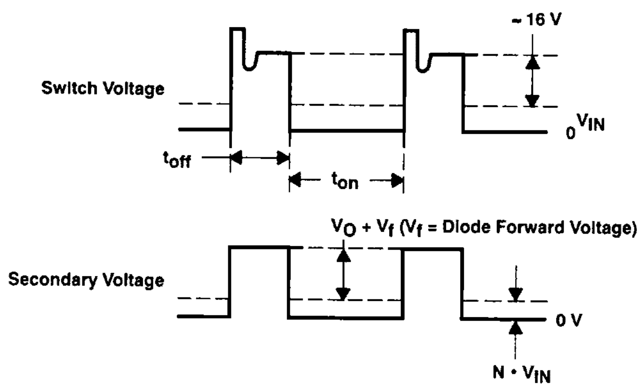


† Under very low output current conditions, duty cycle for most circuits will approach 10% or less.

Figure 22

APPLICATION INFORMATION





† Capacitors are required if input leads ≥ 2 inches.

Figure 23. Totally Isolated Converter

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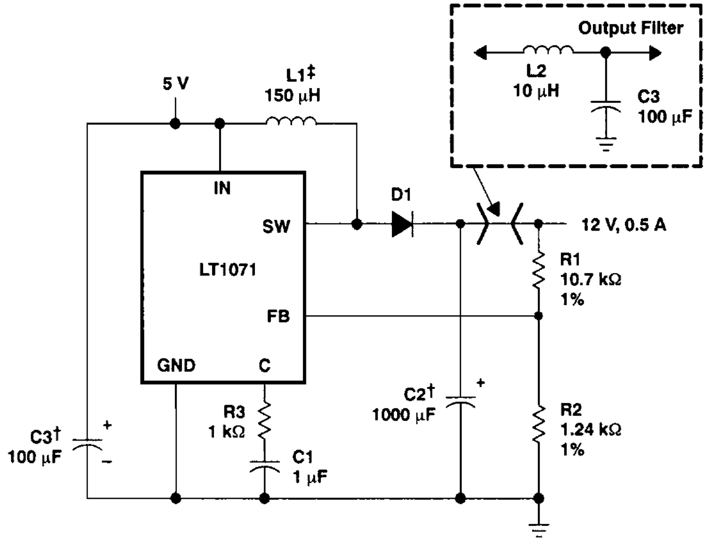
APPLICATION INFORMATION



† Capacitors are required if input leads ≥ 2 inches.
‡ Pulse Engineering 92113

Figure 24. Boost Converter (5 V to 12 V)