

# LT1072, LT1072HV

## 1.25-A HIGH-EFFICIENCY SWITCHING REGULATORS

SLVS071A – NOVEMBER 1989 – REVISED AUGUST 1995

- **Wide Supply-Voltage Range:**  
LT1072HV . . . 3 V to 60 V  
LT1072 . . . 3 V to 40 V
- **Low Quiescent Current . . . 6 mA Typ**
- **Internal 1.25-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**
- **Can Be Externally Synchronized**

AVAILABLE OPTIONS

T <sub>J</sub>	MAX INPUT VOLTAGE	KC PACKAGE	KV PACKAGE	P PACKAGE
0°C to 100°C	60 V	LT1072HVCKC	LT1072HVCKV	LT1072HVC P
	40 V	LT1072CKC	LT1072CKV	LT1072CP
–40°C to 125°C	60 V	LT1072HVIKC	LT1072HVIKV	LT1072HVIP
	40 V	LT1072IKC	LT1072IKV	LT1072IP

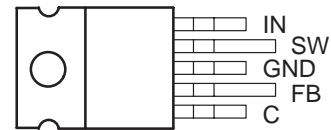
### description

The LT1072 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 LT1072 to be built in standard 5-terminal KC or a KV packages and the 8-terminal P package. This makes it extremely easy to use and provides reliable operation similar to that obtained with 3-terminal linear regulators.

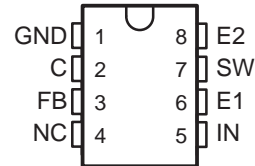
The LT1072 operates with supply voltages from 3 V to 40 V. The LT1072HV, a high-voltage version of the LT1072, operates with supply voltages from 3 V to 60 V. These devices draw only 6 mA of quiescent current, deliver load power up to 20 W with no external power devices, and by utilizing current-mode switching techniques, provide excellent ac and dc input and output regulation.

The LT1072 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 LT1072 without using optocouplers or extra transformer windings.

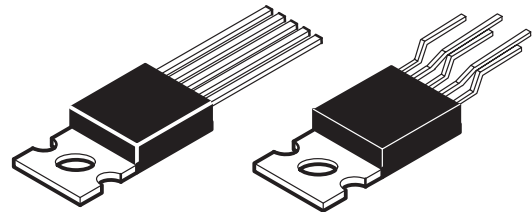
KC AND KV PACKAGE  
(KV Package Used for Illustration)  
(TOP VIEW)



P Package  
(TOP VIEW)



NC = No internal connection



KC 5-Lead

KV 5-Lead

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

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The diagram illustrates the control system for a flyback converter. The input (IN) is connected to a 2.3-V Regulator (Reg) and a Flyback Error Amp. The Flyback Error Amp's non-inverting input (+) is connected to a 16 V source, and its inverting input (-) is connected to the output (SW). The output of the Flyback Error Amp is connected to the Logic block. The Logic block is also connected to a 40-kHz Oscillator (Osc) and a Mode Select block. The Mode Select block is connected to an Error Amp and a Shutdown Circuit. The Error Amp's non-inverting input (+) is connected to a 1.24-V Reference (Ref), and its inverting input (-) is connected to the feedback (FB) signal. The output of the Error Amp is connected to the Logic block. The Shutdown Circuit's non-inverting input (+) is connected to a 0.15 V source, and its inverting input (-) is connected to the output of the Error Amp. The output of the Shutdown Circuit is connected to the Logic block. The Logic block is connected to a Driver block, which is connected to a 1.25-A, 75-V Switch. The switch is connected to the output (SW) and the output capacitor (C). The output capacitor (C) is connected to the output (SW) and the output (E2). The output (E2) is connected to a 0.16 Ω resistor, which is connected to the output (E1). The output (E1) is connected to a Current Amp block, which has a gain of approximately 6. The output of the Current Amp is connected to the Logic block. The Logic block is also connected to an Antisaturation block, which is connected to the Driver block.

† Always connect E1 to ground when using the P package. The emitters (E1 and E2) are tied internally to ground on the KC and KV packages.

# LT1072, LT1072HV

## 1.25-A HIGH-EFFICIENCY SWITCHING REGULATORS

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

Supply voltage, $V_{I(IN)}$ (see Note 1):	LT1072	40 V
	LT1072HV	60 V
Switch output voltage:	LT1072	65 V
	LT1072HV	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, $T_J$ :	LT1072C, LT1072HVC	0°C to 125°C
	LT1072I, LT1072HVI	–40°C to 125°C
Storage temperature range, $T_{stg}$		–65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds		260°C

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTE 1: Minimum switch-on time for the LT1072 in current limit is  $\approx 0.7 \mu s$ . This limits the maximum input voltage during short-circuit conditions, in the step-down and inverting modes only, to  $\approx 40$  V. Normal (unshorted) conditions are not affected. If the LT1072 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	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 125^\circ\text{C}$ POWER RATING
KC	2000 mW	16 mW/°C	400 mW
KV	2000 mW	16 mW/°C	400 mW
P	1000 mW	8 mW/°C	200 mW

**DISSIPATION RATING TABLE 2 – CASE TEMPERATURE**

PACKAGE	$T_C \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_C = 70^\circ\text{C}$	$T_C = 125^\circ\text{C}$ 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, $V_{I(IN)}$	LT1072C, LT1072I	3	40	V
	LT1072HVC, LT1072HVI	3	60	
Virtual-junction temperature, $T_J$	LT1072C, LT1072HVC	0	100	°C
	LT1072I, LT1072HVI	–40	125	



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## 1.25-A HIGH-EFFICIENCY SWITCHING REGULATORS

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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
$V_{ref}$ Output 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	
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		350	750	nA
		Full range			1100	
Transconductance	$\Delta I_{(C)} = \pm 25\text{ }\mu\text{A}$	25°C	3000	4400	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
$V_{(TO)(C)}$ 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	$I_{(FB)} = 50\text{ }\mu\text{A}$	25°C	0.4	0.45	0.54	V
Flyback threshold voltage	$I_{(FB)} = 50\text{ }\mu\text{A}$ , $I_{(C)} = -1\text{ to }+1\text{ }\mu\text{A}$ , $V_{(C)} = 0.6\text{ V}$	25°C	15	16.3	17.6	V
		Full range	14		18	
Change in flyback reference	$I_{(FB)} = 0.05\text{ to }1\text{ mA}$ , $I_{(C)} = -1\text{ to }+1\text{ }\mu\text{A}$ , $V_{(C)} = 0.6\text{ V}$	25°C	4.5	6.8	8.5	V
Flyback reference input regulation	$I_{(FB)} = 50\text{ }\mu\text{A}$ , $I_{(C)} = -1\text{ to }+1\text{ }\mu\text{A}$ , $V_{(IN)} = 3\text{ V to MAX}$ , $V_{(C)} = 0.6\text{ V}$	25°C		0.01	0.03	%/V
Transconductance	$I_{(FB)} = 50\text{ }\mu\text{A}$ , $\Delta I_{(C)} \leq \pm 10\text{ }\mu\text{A}$	25°C	150	300	500	$\mu\text{mho}$
Sink or source current	$V_{(C)} = 1.5\text{ V}$ , $I_{(FB)} = 50\text{ }\mu\text{A}$ , $V_{(SW)} = V_Z + V_{(IN)} \pm 1\text{ V}$	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 LT1072C and LT1072HVC and -40°C to 125°C for LT1072L and LT1072HVL.

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



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# LT1072, LT1072HV

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**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	$V_{(FB)} = 1.5\text{ V}$ , $V_{(IN)} = 3\text{ V to MAX}$ , $I_{(SW)} = 5\text{ mA}$	LT1072 LT1072HV	Full range	65 75		V
$r_{on}$ Switch on-state resistance	$V_{(FB)} = 0.8\text{ V}$ , $I_{(SW)} = 1.25\text{ mA}$	Full range		0.6	1	$\Omega$
Control-to-switch transconductance		25°C		2		mho
$I_{(SW)(lim)}$ Switch current limit	$V_{(FB)} = 0.8\text{ V}$ , See Note 2	Duty cycle $\leq 50\%$ Duty cycle $\leq 50\%$ Duty cycle = 80%	$\geq 25^\circ\text{C}$ <25°C Full range	1.25 1.25 1	3 3.5 2.5	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 Full range	35 33	40 47	45	kHz
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
$I_{off(IN)}$ Shutdown mode input current	$V_{(IN)} = 3\text{ V to MAX}$ , $V_{(C)} = 0.05\text{ V}$	25°C		100	250	$\mu\text{A}$
$V_{(TO)(C)}$ Control threshold voltage	$V_{(IN)} = 3\text{ V to MAX}$	25°C Full range	100 50	150 300	250	mV

### total device

PARAMETER	TEST CONDITIONS†	$T_J$ ‡	MIN	TYP§	MAX	UNIT
$V_{I(min)(IN)}$ Minimum input voltage		Full range		2.6	3	V
$I_{I(IN)}$ 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 LT1072C and LT1072HVC and –40°C to 125°C for LT1072I and LT1072HVI.

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

NOTE 2: For duty cycles between 50% and 80%, minimum switch output current is given by  $I_{(SW)(lim)} = 0.833$  (2-duty cycle).



# LT1072, LT1072HV

## 1.25-A HIGH-EFFICIENCY SWITCHING REGULATORS

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### theory of operation

The LT1072 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  $90^\circ$  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 LT1072. 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 terminal has a second function when pulled low with an external resistor. It programs the LT1072 to disconnect the main error-amplifier output and connects the output of the flyback amplifier to the comparator input. The LT1072 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 LT1072 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 terminal (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 terminal 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 terminal is pulled to ground through a diode. This places the LT1072 in an idle mode. Pulling the C terminal below 0.15 V causes total regulator shutdown, with only 50- $\mu$ A supply current for shutdown-circuitry biasing.

In the P package, the emitters of the power transistors are brought out separately from the ground terminal. This eliminates errors due to ground-terminal voltage drops and allows the user to reduce the switch-current limit (2:1) by leaving the second emitter (E2) disconnected. The first emitter (E1) should always be connected to the ground terminal. Note that switch on-state resistance doubles when E2 is left open, so efficiency will suffer somewhat when switch currents exceed 100 mA. Also, note that chip dissipation will actually *increase* with E2 open during normal load operations, even though dissipation in current-limit mode will *decrease*.

## TYPICAL CHARACTERISTICS

**Table of Graphs**

			FIGURE
P <sub>OM</sub>	Maximum output power	vs Input voltage	1
V <sub>ref</sub>	Reference voltage	vs Junction temperature	2
f	Switching frequency	vs Junction temperature	2
	Reference voltage change	vs Input voltage	3
I <sub>FB</sub>	Feedback input current	vs Junction temperature	4
g <sub>m</sub>	Error amplifier transconductance	vs Junction temperature	5
g <sub>m</sub>	Error amplifier transconductance	vs Frequency	6
	Error amplifier phase shift	vs Frequency	6
I <sub>C</sub>	Control current	vs Control voltage	7
V <sub>T(FB)</sub>	Normal/flyback mode threshold voltage	vs Junction temperature	8
I <sub>FB</sub>	Feedback input current	vs Junction temperature	8
V <sub>Z</sub>	Flyback reference voltage	vs Junction temperature	9
t <sub>d</sub>	Flyback sense delay time	vs Junction temperature	10
I <sub>O(SW)</sub>	Switch output current (with switch off)	vs Switch voltage	11
	Driver base current	vs Switch output current	12
V <sub>sat(SW)</sub>	Switch saturation voltage	vs Switch output current	13
I <sub>O(SW)</sub>	Switch output current limit	vs Duty cycle	14
	Maximum duty cycle	vs Junction temperature	15
I <sub>IN</sub>	Shutdown-mode input current	vs Control voltage	16
I <sub>IN</sub>	Shutdown-mode input current	vs Input voltage	17
V <sub>T(C)</sub>	Shutdown-mode control threshold voltage	vs Junction temperature	18
I <sub>T(C)</sub>	Shutdown-mode control threshold current	vs Junction temperature	18
V <sub>FB</sub>	Feedback input voltage at normal/flyback mode threshold	vs Feedback input current	19
	Minimum input voltage	vs Junction temperature	20
I <sub>IN</sub>	Input current (SW output open)	vs Junction temperature	21
I <sub>IN</sub>	Input current	vs Input voltage	22

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## TYPICAL CHARACTERISTICS

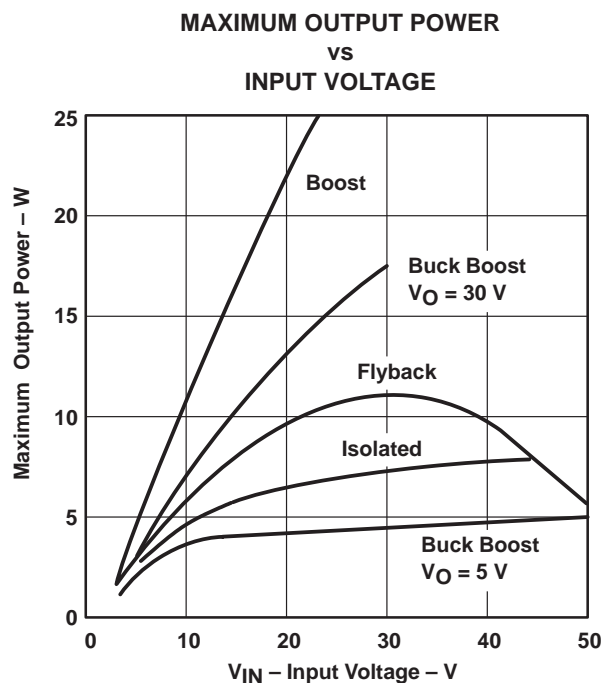


Figure 1

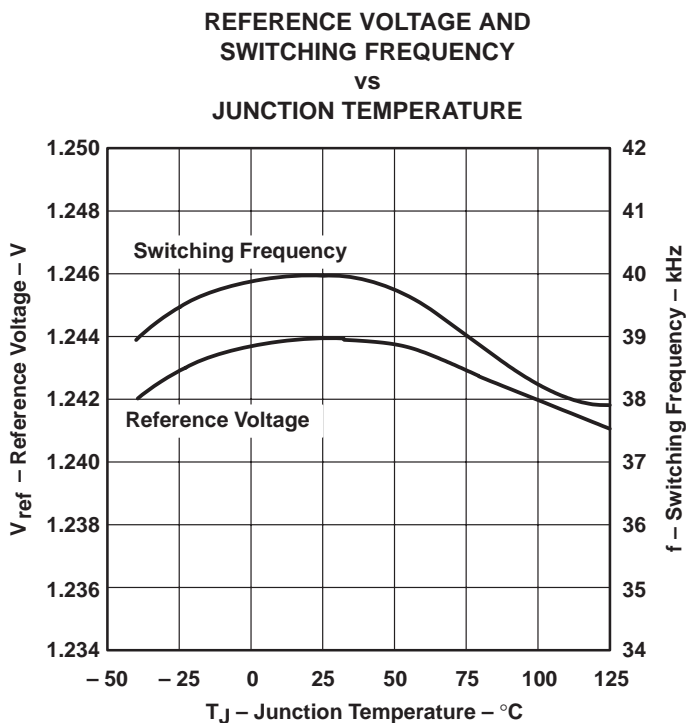


Figure 2

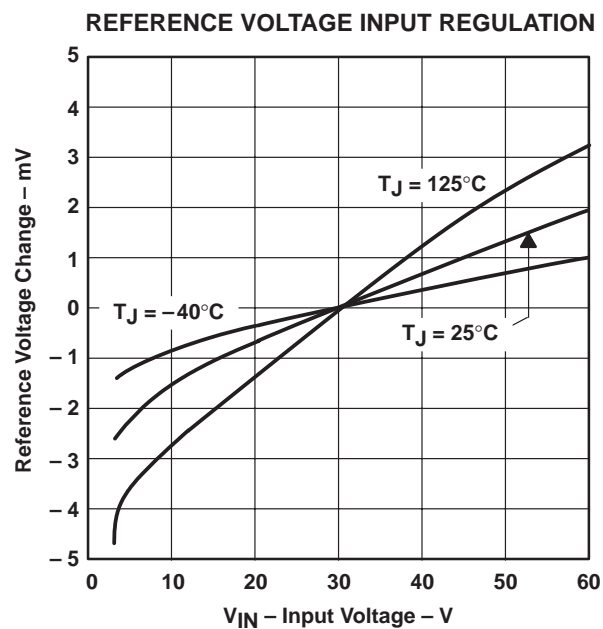


Figure 3

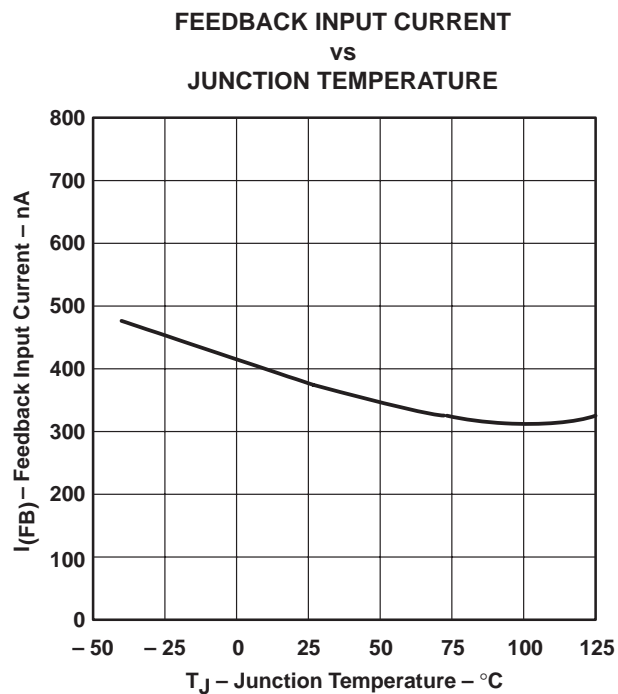


Figure 4



## TYPICAL CHARACTERISTICS

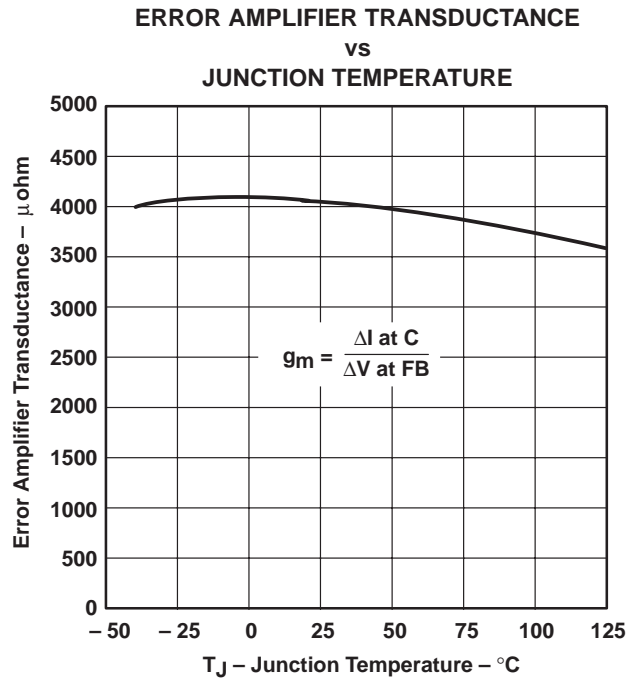


Figure 5

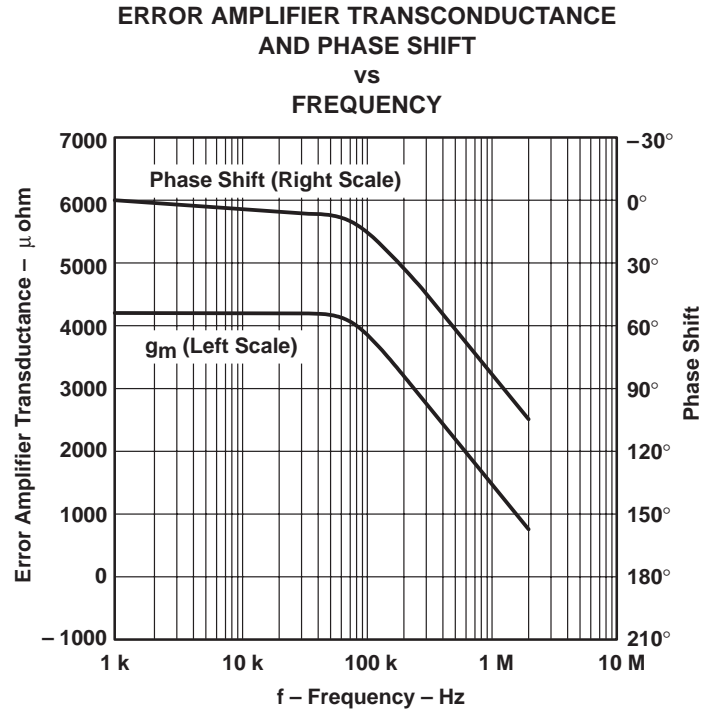


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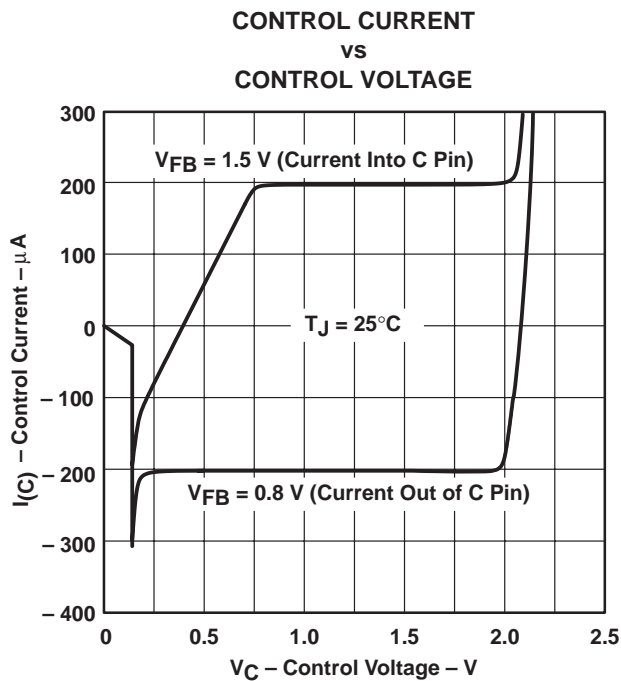


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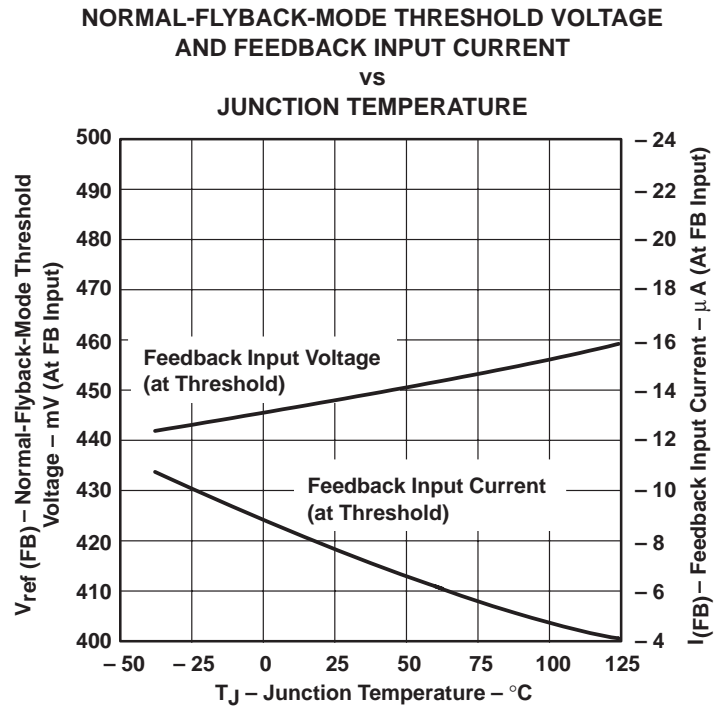


Figure 8

# LT1072, LT1072HV 1.25-A HIGH-EFFICIENCY SWITCHING REGULATORS

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## TYPICAL CHARACTERISTICS

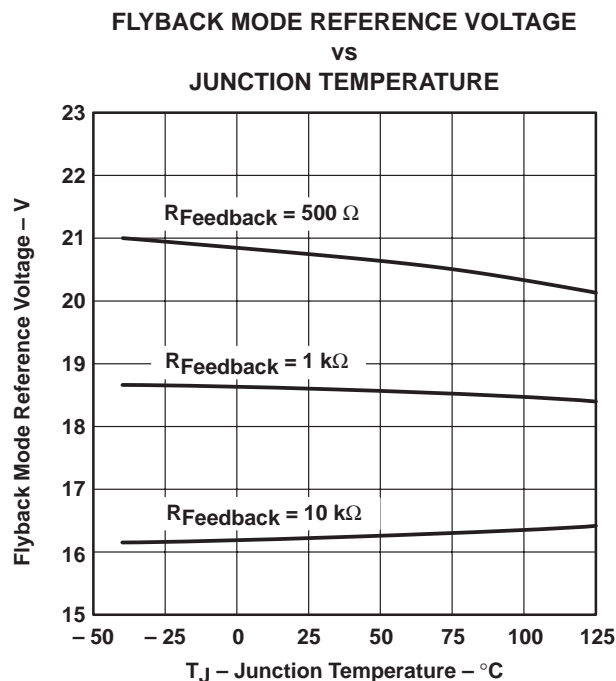


Figure 9

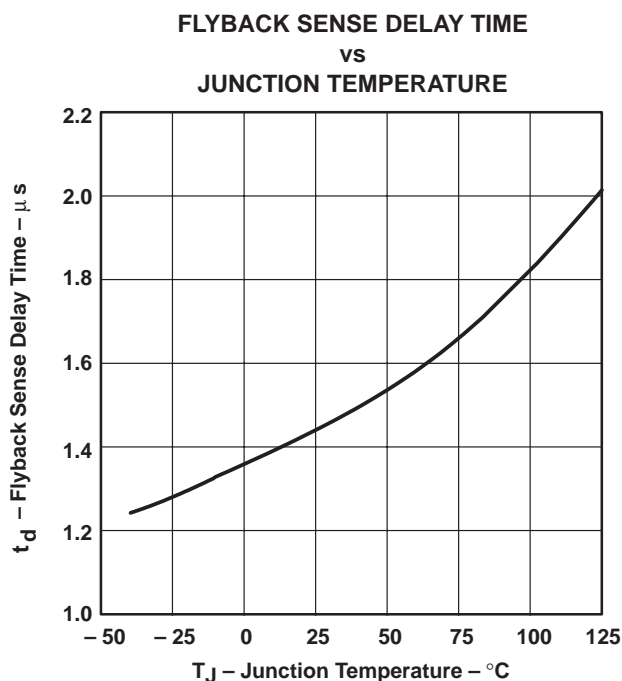


Figure 10

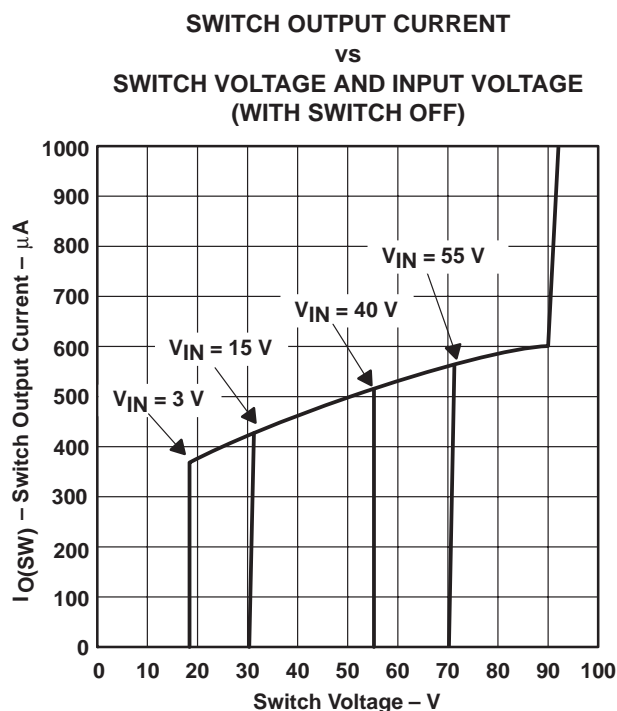
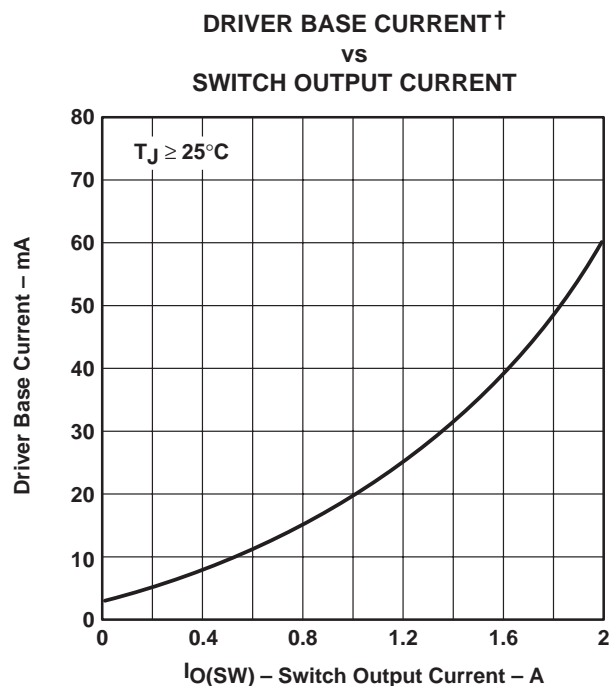


Figure 11



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

Figure 12

## TYPICAL CHARACTERISTICS

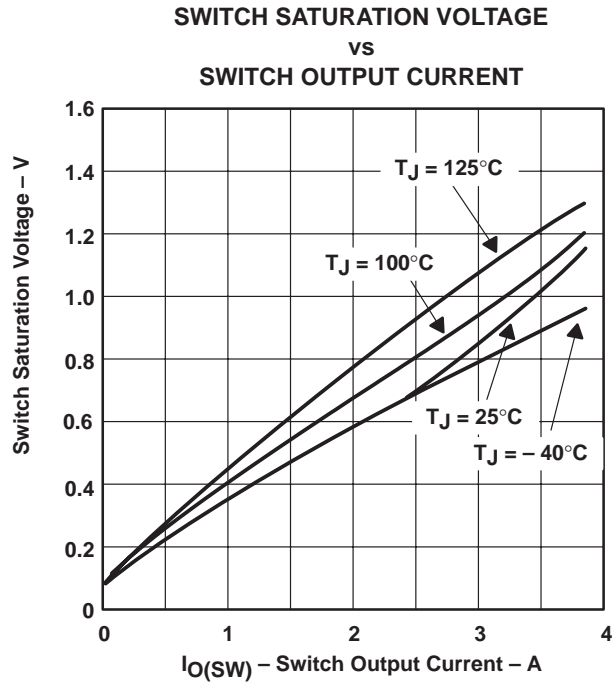


Figure 13

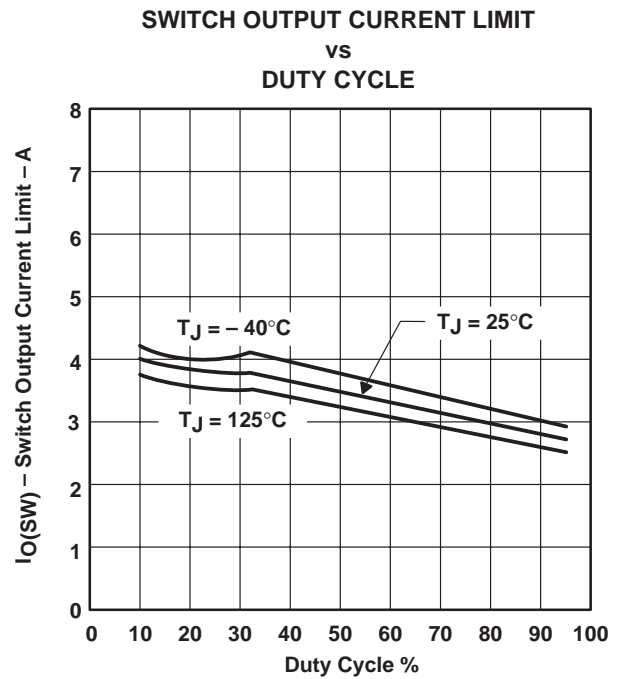


Figure 14

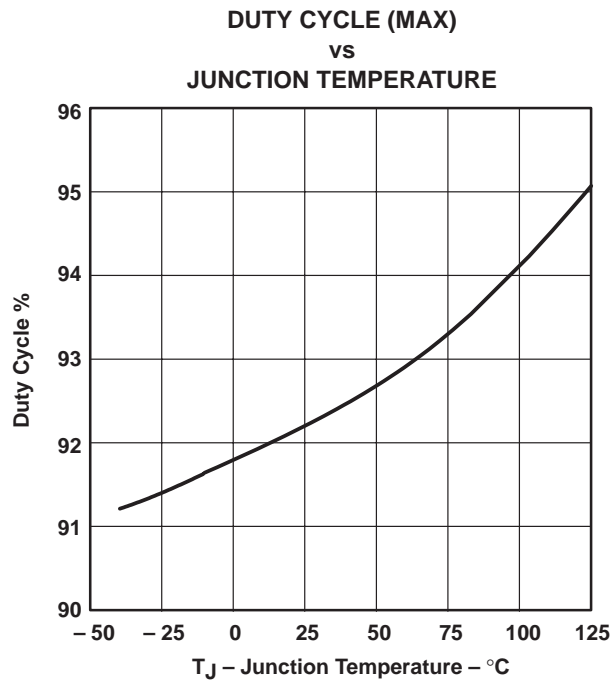


Figure 15

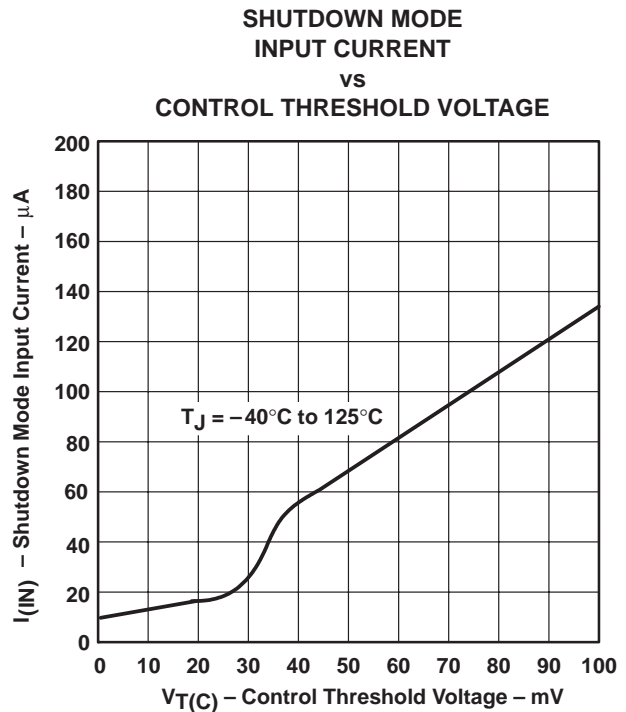


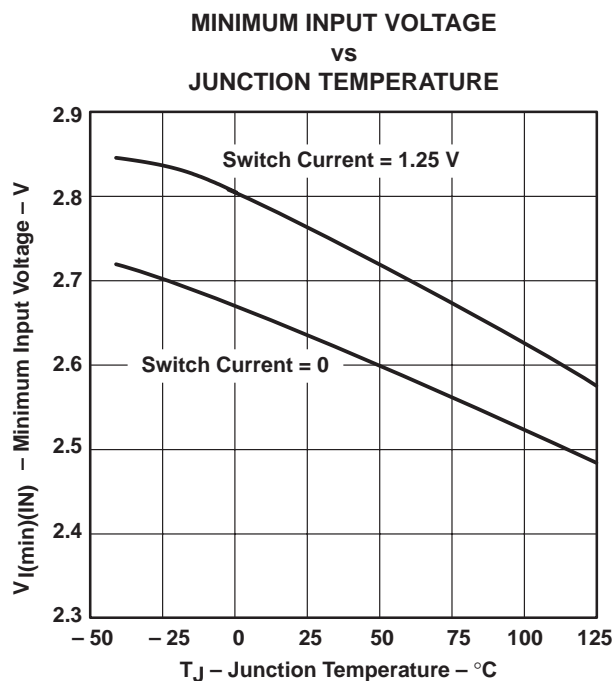
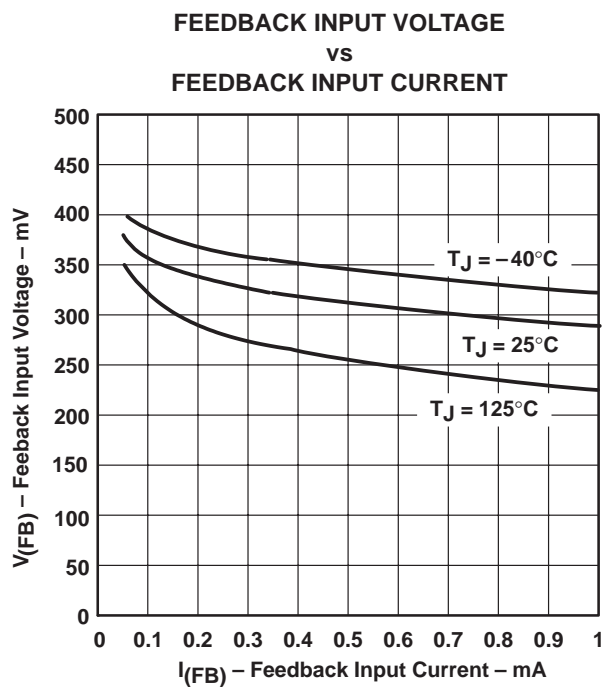
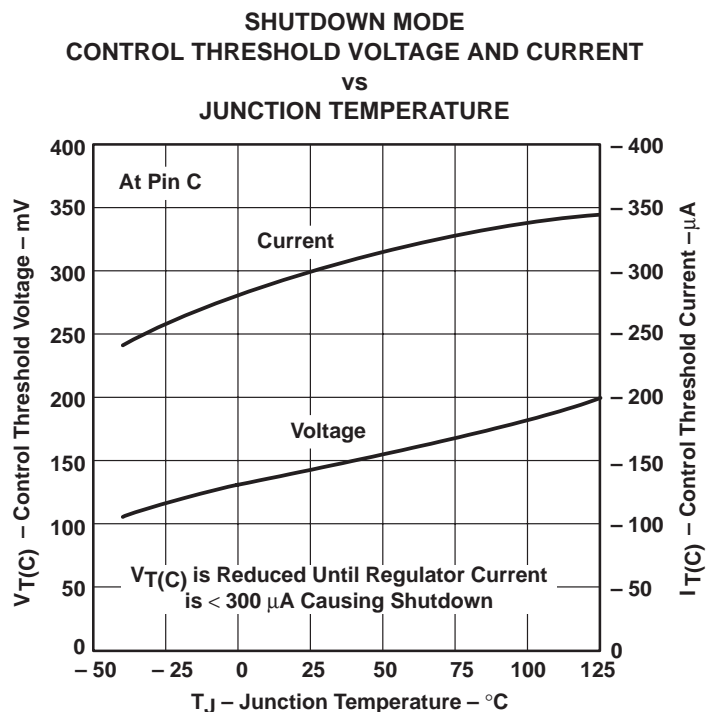
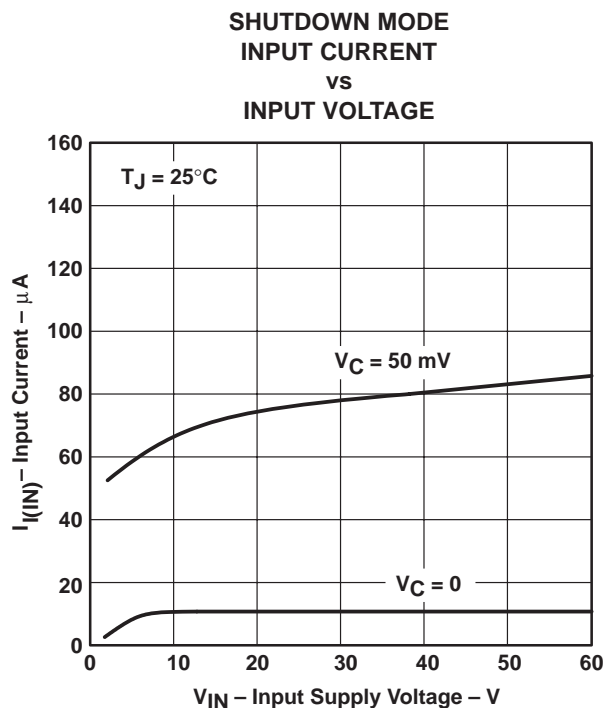
Figure 16

# LT1072, LT1072HV

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### TYPICAL CHARACTERISTICS



## TYPICAL CHARACTERISTICS

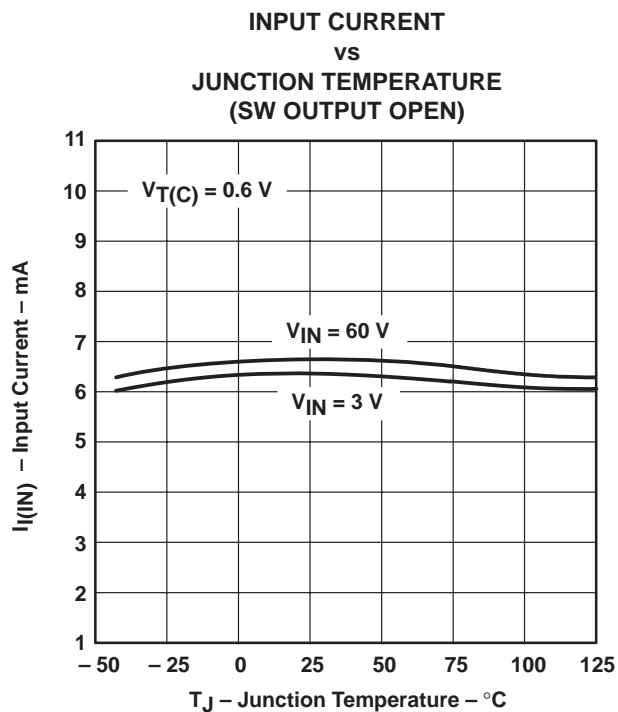
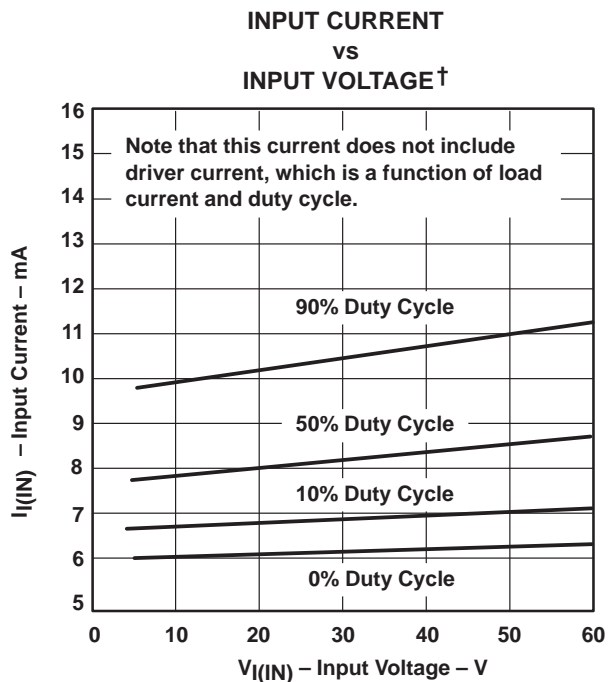


Figure 21



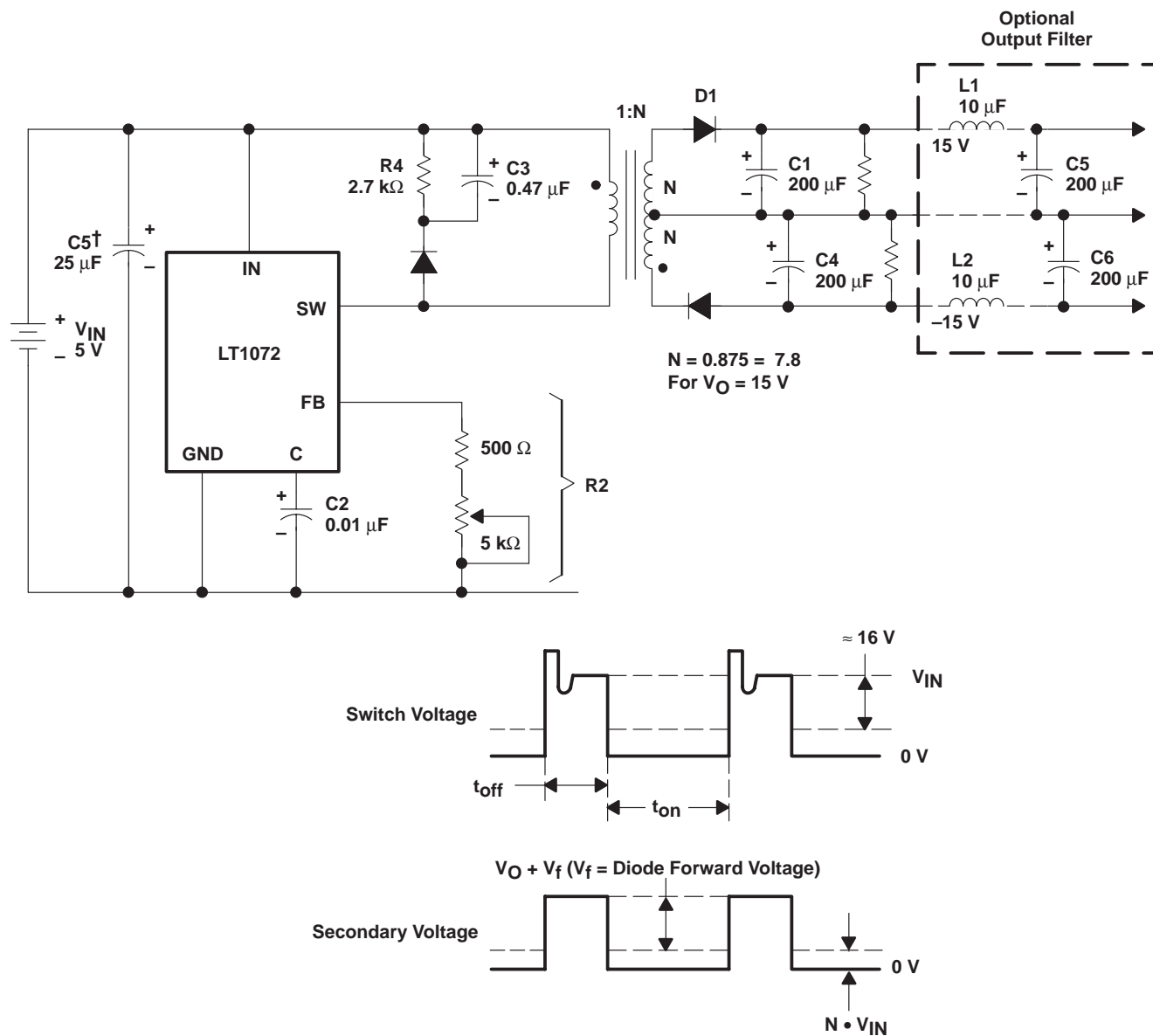
<sup>†</sup> Under very low output current conditions, duty cycle for most circuits will approach 10% or less.

Figure 22

# LT1072, LT1072HV 1.25-A HIGH-EFFICIENCY SWITCHING REGULATORS

SLVS071A – NOVEMBER 1989 – REVISED AUGUST 1995

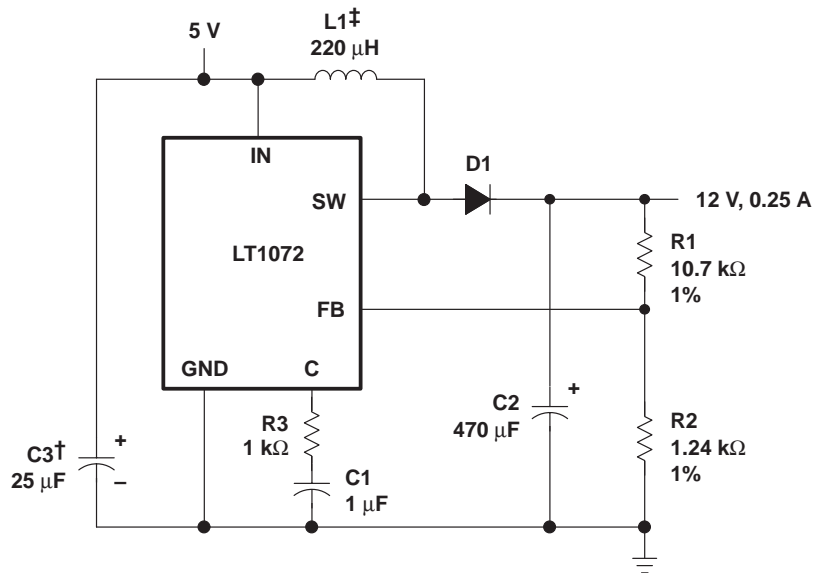
## APPLICATION INFORMATION



† Capacitors are required if input leads  $\geq 2$  inches.

Figure 23. Totally Isolated Converter

## APPLICATION INFORMATION



† Capacitor is required if input leads  $\geq 2$  inches.

‡ Pulse Engineering 52626

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





## PACKAGING INFORMATION

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
LT1072CP	OBSOLETE	PDIP	P	8		TBD	Call TI	Call TI
LT1072IP	OBSOLETE	PDIP	P	8		TBD	Call TI	Call TI

<sup>(1)</sup> The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

<sup>(2)</sup> Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS) or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

<sup>(3)</sup> MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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## P (R-PDIP-T8)

## PLASTIC DUAL-IN-LINE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. Falls within JEDEC MS-001

For the latest package information, go to [http://www.ti.com/sc/docs/package/pkg\\_info.htm](http://www.ti.com/sc/docs/package/pkg_info.htm)

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