LTC1697

ABSOLUTE MAXIMUM RATINGS

(Notes 1, 2)

V_{IN} Voltage .... −0.5V to 6V
V_C, OV_{SEN}, C_{DIM}, R_{PROG}, SW
   Voltages .... −0.5V to (V_{IN} + 0.3V)
$\overline{SHDN}$, V_{DIM} Pins .... −0.5V to 6V
LAMP Pin ....−0.5V to 0.5V
Operating Temperature Range (Note 5) ...−40°C to 85°C
Storage Temperature Range ....−65°C to 125°C
Lead Temperature (Soldering, 10 sec).................. 300°C

PACKAGE/ORDER INFORMATION

```
          TOP VIEW
   C_DIM  1 ┌─────┐ 10  SHDN
   V_DIM  2 │     │  9  R_PROG
   0V_SEN 3 │     │  8  V_C
   SW     4 │     │  7  V_IN
   GND    5 └─────┘  6  LAMP

        MS PACKAGE
   10-LEAD PLASTIC MSOP

      T_JMAX = 125°C,
   θ_JA = 160°C/W 1 LAYER BOARD
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ORDER PART NUMBER
LTC1697EMS

MS PART MARKING
LTZR

Consult LTC Marketing for parts specified with wider operating temperature ranges.

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. 2.8V < V_{IN} ≤ 5.5V unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{IN}	Operating Supply Voltage Range	(Note 2)	●	2.8		5.5	V
V_{UVLO}	Undervoltage Lockout		●			2.77	V
$I_{Q-\overline{SHDN}}$	Quiescent Current - $\overline{SHDN}$	$\overline{SHDN}$ = 0V; V_{DIM} = 0V			1	2	μA
$I_{Q-Active}$	Quiescent Current - Active	V_C = 0V, $\overline{SHDN}$ = V_{IN} = V_{DIM} = 4.2V (Note 4)			0.9	1.5	mA
I_{LEAK}	Switch Leakage				0.1	1	μA
R_{ON}	Switch On Resistance	V_{IN} = 4V			0.18		Ω
I_{MAX}	Switch Current Limit		●	0.9	1.6		A
% DC	Duty Cycle		●	0		95	%
f_{SWITCH}	Switching Frequency		●	240	300	370	kHz
f_{DIM}	Dimming PWM Frequency	C_{DIM} = 0.022μF (Note 3)	●	190	250	310	Hz
V_{DIM}	V_{DIM} Input Voltage	Dimming PWM Duty Cycle = 0% Dimming PWM Duty Cycle = 100%			1.0 2.0		V V
I_{DIM}	V_{DIM} Input Bias Current	V_{DIM} = 2V				±1	μA
R_{LAMP}	Internal R_{LAMP} Resistance	LAMP Pin to GND			50	60	Ω
$I_{L(ERROR)}$	Lamp Current Accuracy	|1− $I_{LAMP(AVG)}$/(32/6.4k)| • 100% (Note 6) I_{LAMP} = 5mA	●		2	6	%
$R_{P(RANGE)}$	Programming Resistor Range	(Note 10)	●	6.4		16	kΩ
$V_{\overline{SHDN}-H}$	$\overline{SHDN}$ Input High			1.2			V
$V_{\overline{SHDN}-L}$	$\overline{SHDN}$ Input Low (Note 9)					0.4	V
$I_{\overline{SHDN}}$	$\overline{SHDN}$ Input Current	$V_{\overline{SHDN}}$ = V_{IN}	●		0.1	1	μA
I_{OVSEN}	Overvoltage Sense Protect Current (Note 7)	I_{LAMP} = 5mA, R_{PROG} = 6.4k	●	16.65	21.5	26.35	μA
V_{OVSEN}	Overvoltage Sense Pin Voltage		●	0.95	1.2	1.5	V
$V_{DIM(SD-I)}$	Passive Shutdown Voltage (Note 8)		●			0.4	V
$V_{DIM(SD-H)}$	Not in Passive Shutdown		●	1.05			V

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LINEAR TECHNOLOGY

ELECTRICAL CHARACTERISTICS

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

Note 2: All voltages specified with respect to GND pin.

Note 3: The dimming PWM frequency is set by the equation $5Hz/C_{DIM}(\mu F)$.

Note 4: Actual operating current will be higher due to lamp operating current.

Note 5: The LTC1697 is guaranteed to meet performance specifications from 0°C to 70°C. Specifications over the −40°C to 85°C operating temperature range are assured by design, characterization and correlation with statistical process controls.

Note 6: $I_{LAMP(AVG)}$ = the average of the magnitude (absolute value) of the positive and negative lamp current flowing into and out of the LAMP pin.

Note 7: For currents at or above $I_{OVSEN(ON)}$, the switch duty cycle will be 0%.

Note 8: At V_{DIM} voltages below $V_{DIM(\overline{SHDN}ON)}$ the LTC1697 behaves as if the $\overline{SHDN}$ pin was pulled low.

Note 9: To minimize I_Q shutdown, pull the $\overline{SHDN}$ pin below 0.1V.

Note 10: $2mA \le I_{LAMP} \le 5mA$.

PIN FUNCTIONS

C$_{DIM}$ (Pin 1): Dimming Capacitor. Connect the pin to GND with a 0.022μF capacitor (nominal). The value of capacitance on the C$_{DIM}$ pin determines the dimming PWM frequency. The transfer function of capacitance to frequency is $5Hz/C_{DIM}(\mu F)$.

V$_{DIM}$ (Pin 2): Dimming Control Pin. The V$_{DIM}$ pin controls the duty cycle of the dimming PWM. It ranges from 0% at V$_{DIM}$ = 1V to 100% at V$_{DIM}$ = 2V. If the V$_{DIM}$ voltage is <0.4V the LTC1697 will enter shutdown mode after ≈50ms.

OV$_{SEN}$ (Pin 3): Overvoltage Sense Pin. Protects the high-voltage transformer from the overvoltage condition that occurs when the lamp is open or not present. This pin is connected through a resistor to the emitters of the drive transistors of the Royer oscillator.

SW (Pin 4): Switch Pin. Connect the inductor and optional Schottky diode here. Minimize trace length to keep EMI and high frequency ringing down.

GND (Pin 5): Signal and Power Ground for the LTC1697.

LAMP (Pin 6): Lamp Current Feedback Pin. Connect this pin to the CCFL lamp.
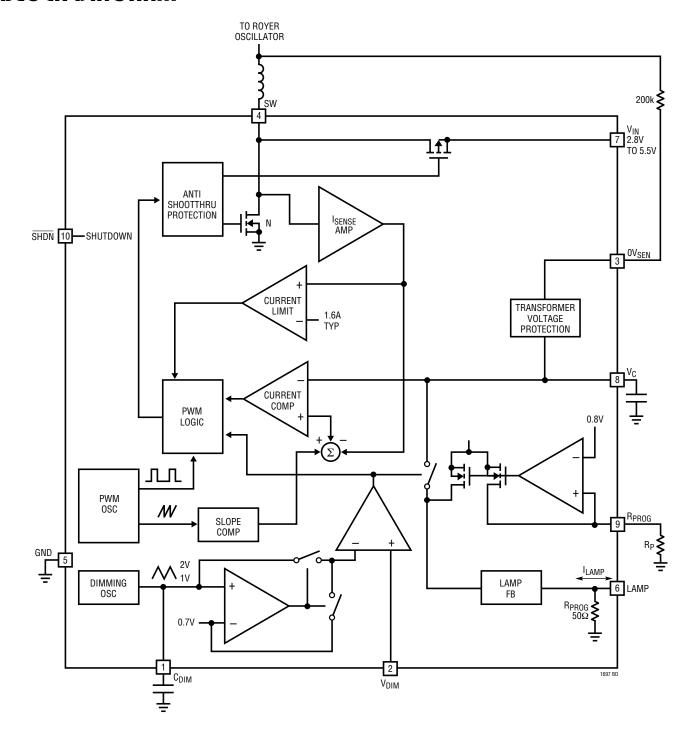
V$_{IN}$ (Pin 7): Input Supply Pin.

V$_C$ (PIN 8): Compensation Node. Connect this pin to GND through a 0.1μF capacitor. See Application Information section. A frequency compensation network is connected to this pin to compensate the loop. See the section "V$_C$ Compensation" for guidelines.

R$_{PROG}$ (Pin 9): Lamp Current Programming. Connect this pin to GND with a 6.4k 1% resistor (nominal). See Application Information section for resistor selection.

$\overline{SHDN}$ (Pin 10): Shutdown. Grounding this pin shuts down the LTC1697. Tie to >1V to enable.

LTC1697

BLOCK DIAGRAM

TO ROYER
OSCILLATOR

SW
4

200k

V_{IN}
2.8V
TO 5.5V
7

ANTI
SHOOTTHRU
PROTECTION

N

I_{SENSE}
AMP

$0V_{SEN}$
3

$\overline{SHDN}$ 10 — SHUTDOWN

CURRENT
LIMIT

1.6A
TYP

TRANSFORMER
VOLTAGE
PROTECTION

V_C
8

CURRENT
COMP

PWM
LOGIC

Σ

0.8V

PWM
OSC

SLOPE
COMP

R_{PROG}
9

R_P

GND
5

DIMMING
OSC

2V
1V

0.7V

LAMP
FB

I_{LAMP}

6 LAMP

R_{PROG}
50Ω

1
C_{DIM}

2
V_{DIM}

1697 BD

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APPLICATIONS INFORMATION

Background

Current generation handheld computers and instruments typically use backlit liquid crystal displays (LCDs). Cold cathode fluorescent lamps (CCFLs) provide the highest available efficiency for backlighting the display, where providing the most light out for the least amount of input power is the most important goal. These lamps require high voltage AC to operate, mandating an efficient high voltage DC/AC converter. The lamps operate from DC, but migration effects damage the lamp and shorten its lifetime. Lamp drive should ideally contain zero DC component. In addition to good efficiency, the converter should deliver the lamp drive in the form of a sine wave. This minimizes EMI and RF emissions, which can interfere with other devices and degrade overall operating efficiency. Sinusoidal CCFL drive also maximizes current-to-light conversion in the lamp. The circuit also permits lamp intensity control from zero to full brightness with no hysteresis or "pop-on."

The small size and battery-powered operation associated with LCD-equipped apparatus dictate low component count and high efficiency for these circuits. Size constraints place severe limitations on circuit architecture and long battery life is usually a priority. Handheld portable computers offer an excellent example. The CCFL and its power supply can be responsible for almost 50% of the total battery drain.

The CCFL regulator drives an inductor that acts as a switch-mode current source for a current-driven Royer-class converter with efficiencies as high as 90%. The control loop forces the CCFL PWM to modulate the average inductor current to maintain constant current in the lamp. This constant current and the resulting lamp intensity is programmable. Lamp intensity is further controlled by modulating the current to the Royer converter at 150Hz to 500Hz.

Operation

The LTC1697 is a fixed frequency, current mode regulator. Such a switcher controls switch duty cycle directly by switch current rather than by output voltage. Referring to the block diagram for the LTC1697, the NMOS switch turns ON at the start of each oscillator cycle. The NMOS switch turns back OFF when switch current reaches a predetermined level.

Current Sensing

Lossless current sensing converts the peak current signal to a voltage which is summed with the internal slope compensation. This summed signal is compared to V_C to provide a peak current control command for the PWM.

Current Limit

The current limit amplifier will shut the NMOS switch off once the current exceeds the current limit threshold. The current amplifier delay to the output is typically 50ns.

Synchronous Rectifier

The LTC1697 operates as a synchronous converter. When the NMOS switch turns OFF as mentioned above, the PMOS switch turns ON. This gives a low resistance current path for the inductor current back to V_{IN}.

Dimming PWM

An on-chip PWM dimming circuit enables and disables the current mode regulator for each dimming cycle. It also disconnects the feedback network from the compensation node (V_C) to reduce slew time at the next enable time. The oscillator for the dimming PWM produces a triangle wave whose frequency is determined by an external capacitor on the C_{DIM} pin. The dimming PWM frequency is equal to $5Hz/C_{DIM}(\mu F)$ with its duty cycle set by the voltage on the

LTC1697

APPLICATIONS INFORMATION

V_{DIM} pin where DC = 0% at V_{DIM} = 1V and DC = 100% at V_{DIM} = 2V. If desired, the internal dimming PWM can be overridden by grounding the C_{DIM} pin and applying the input PWM signal to the V_{DIM} pin. This external PWM signal should be in the range of 150Hz to 500Hz.

Lamp Feedback

In a typical application, the LAMP pin is connected to the low voltage side of the lamp. The lamp pin is internally connected to ground by a ~50Ω resistor. This resistor will limit the voltage on the LAMP pin to ±0.35V for a 5mA$_{RMS}$ lamp current. The lamp feedback circuit removes a current from V_C approximating 1/40 of the absolute value of the current through the 50Ω resistor.

Current Programming Input (R_{PROG})

The I_{LAMP} current is set with an external resistor connected between this pin and ground. $I_{LAMP} = 32V/R_{PROG}$.

V_C Compensation

The V_C node is the point where the lamp feedback current, the programming current, and the control for the switching controller meet. A single capacitor must be connected from the V_C pin to ground to compensate the feedback loop. Careful consideration should be given to the value of capacitance used. A large value (1μF) will give excellent stability at high lamp currents but will result in degraded line regulation. On the other hand, a small value (10nF) will result in overshoot and poor load regulation. The value chosen will depend on the maximum load current and dimming range. After these parameters are decided upon, the value of the V_C capacitor should be increased until the line regulation becomes unacceptable. A typical value for the V_C capacitor is 0.1μF. For further information on compensation please refer to Application Note 65 or consult the factory.

OV$_{SEN}$ Operation

The OV$_{SEN}$ pin can be used to protect the high voltage transformer from an overvoltage condition that can occur when the lamp is open or not present. Connect this pin through a resistor to the emitters of the drive transistors of the Royer oscillator. The voltage at the OV$_{SEN}$ pin is specified by V_{OVSEN}. The duty cycle of the LTC1697 SW pin will be 0% when the current flowing out of the OV$_{SEN}$ pin reaches I_{OVSEN} (protect). See the manufacturers transformer specifications for transformer voltage ratings.

Thermal Shutdown

This IC includes overtemperature protection that is intended to protect the device during momentary overload conditions. Junction temperature will exceed 125°C when overtemperature protection is active. Continuous operation above the specified maximum operating junction temperature may result in device degradation or failure.

Shutdown Operation

There are two ways to place the LTC1697 in shutdown. The $\overline{SHDN}$ pin can be pulled below $V_{\overline{SHDN}-1}$, or the V_{DIM} pin can be pulled below $V_{DIM(SD-I)}$ for more than approximately 50mS. For normal operation, both pins must be pulled high. The $\overline{SHDN}$ pin must be pulled above $V_{\overline{SHDN}-H}$, and the V_{DIM} pin must be pulled above $V_{DIM\ (SD-H)}$.
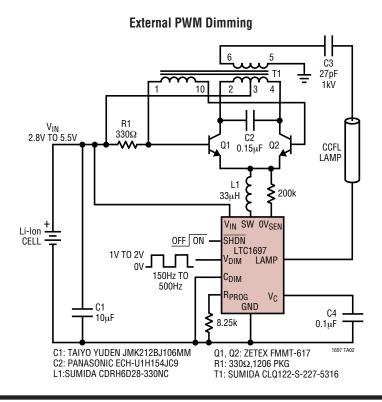
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PACKAGE DESCRIPTION

MS Package
10-Lead Plastic MSOP
(Reference LTC DWG # 05-08-1661)

$\frac{0.889 \pm 0.127}{(.035 \pm .005)}$

$\frac{5.23}{(.206)}$ MIN

$\frac{3.20 - 3.45}{(.126 - .136)}$

$\frac{0.305 \pm 0.038}{(.0120 \pm .0015)}$ TYP

$\frac{0.50}{(.0197)}$ BSC

RECOMMENDED SOLDER PAD LAYOUT

DETAIL "A"

$\frac{0.254}{(.010)}$

0° – 6° TYP

GAUGE PLANE

$\frac{0.53 \pm 0.152}{(.021 \pm .006)}$

DETAIL "A"

$\frac{0.18}{(.007)}$

$\frac{3.00 \pm 0.102}{(.118 \pm .004)}$ (NOTE 3)

10 9 8 7 6

$\frac{0.497 \pm 0.076}{(.0196 \pm .003)}$ REF

$\frac{4.90 \pm 0.152}{(.193 \pm .006)}$

$\frac{3.00 \pm 0.102}{(.118 \pm .004)}$ (NOTE 4)

1 2 3 4 5

$\frac{1.10}{(.043)}$ MAX

$\frac{0.86}{(.034)}$ REF

SEATING PLANE

$\frac{0.17 - 0.27}{(.007 - .011)}$ TYP

$\frac{0.50}{(.0197)}$ BSC

$\frac{0.127 \pm 0.076}{(.005 \pm .003)}$

MSOP (MS) 0603

NOTE:
1. DIMENSIONS IN MILLIMETER/(INCH)
2. DRAWING NOT TO SCALE
3. DIMENSION DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS.
   MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.152mm (.006") PER SIDE
4. DIMENSION DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSIONS.
   INTERLEAD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.152mm (.006") PER SIDE
5. LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.102mm (.004") MAX

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TYPICAL APPLICATION

External PWM Dimming

C1: TAIYO YUDEN JMK212BJ106MM
C2: PANASONIC ECH-U1H154JC9
L1: SUMIDA CDRH6D28-330NC

Q1, Q2: ZETEX FMMT-617
R1: 330Ω,1206 PKG
T1: SUMIDA CLQ122-S-227-5316

1697 TA02

RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1170/LT1170HV	5A, 100kHz High Efficiency Switching Regulator	V_{IN}: 3V to 40V/60V, $V_{OUT(MAX)}$ = 65V/75V, I_Q = 6mA, I_{SD} = <50μA, N8, S16, TO220-5, DD Packages
LT1182/LT1183	CCFL/LCD Contrast Switching Regulators, CCFL Switch: 1.25A, LCD Switch: 625mA	V_{IN}: 3V to 30V, $V_{OUT(MAX)}$ = 60V, I_Q = 6mA, I_{SD} = 35μA, SO-16 Package
LT1184/LT1184F	1.25A, 200kHz, CCFL Current Mode Switching Regulator	V_{IN}: 3V to 30V, $V_{OUT(MAX)}$ = 60V, I_Q = 6mA, I_{SD} = 35μA, SO-16 Package
LT1186/LT1186F	1.25A, 100kHz, DAC Programmable CCFL Current Mode Switching Regulator	V_{IN}: 4.5V to 30V, $V_{OUT(MAX)}$ = 60V, I_Q = 6mA, I_{SD} = 35μA SO-16 Package
LT1372/LT1372HV/ LT1377	1.5A, 500kHz/1MHz, High Efficiency Switching Regulator	V_{IN}: 2.7V to 30V, $V_{OUT(MAX)}$ = 35V, I_Q = 4mA, I_{SD} = <12μA N8, S8 Packages
LT1373/LT1373HV	1.5A, 250kHz High Efficiency Switching Regulator can Regulate Positive or Negative Outputs	V_{IN}: 0.5V to 5V, $V_{OUT(MAX)}$ = 35V, I_Q = 1mA, I_{SD} = <12μA N8, S8 Packages
LT1768	High Power CCFL Controller for Wide Dimming Range and Maximum Lamp Lifetime	V_{IN}: 8V to 24V, $V_{OUT(MAX)}$ = 28V, I_Q = 7mA, I_{SD} = 65μA SSOP-16 Package
LT1786F	1.25A, 200kHz, SMBus Controlled CCFL Switching Regulator Precision 100mA Full Scale Current	V_{IN}: 4.5V to 30V, $V_{OUT(MAX)}$ = 60V, I_Q = 6mA, I_{SD} = 150μA SO-16 Package

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