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Design Note

UCC3972 BiCMOS Cold Cathode Fluorescent Lamp Driver Controller, Evaluation Board and List of Materials

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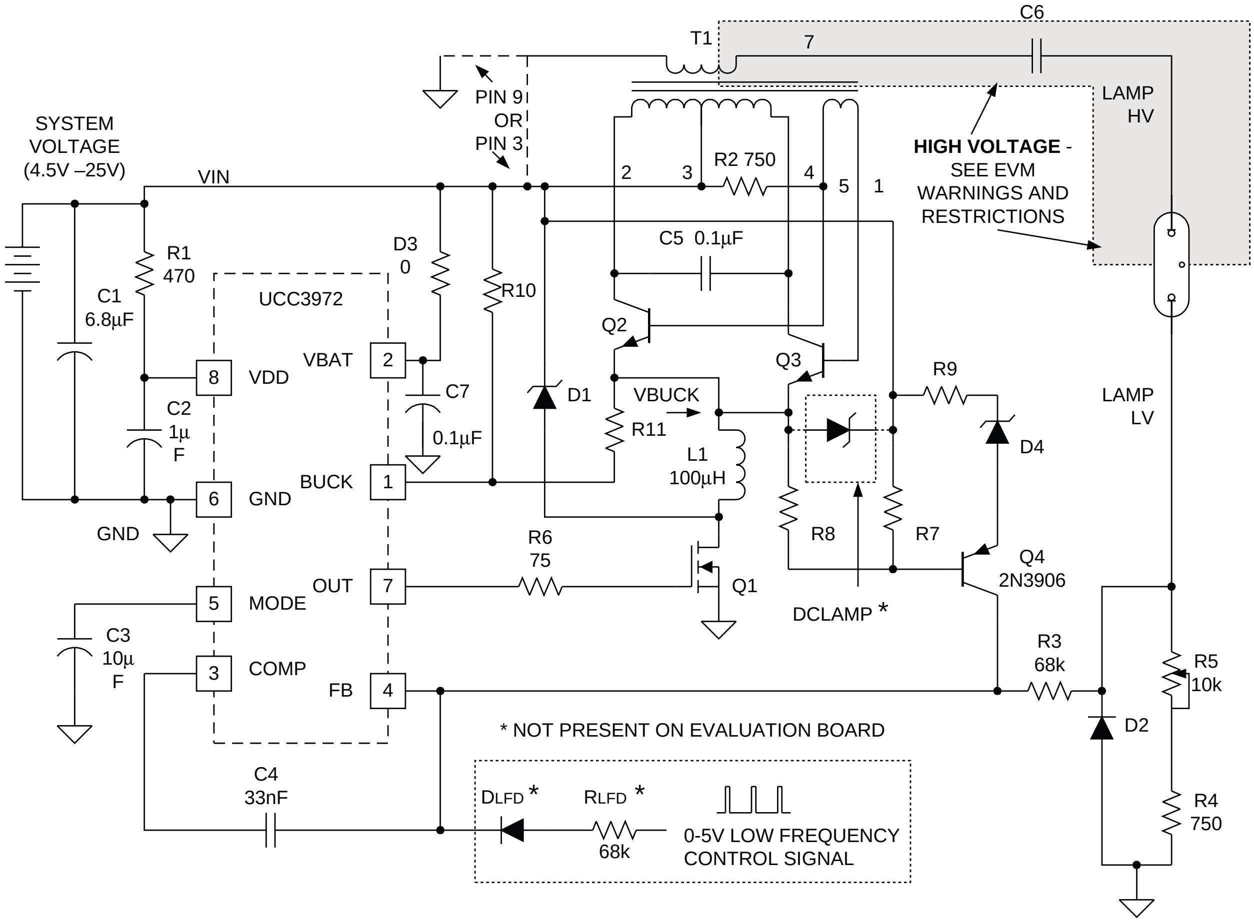
Introduction

The UCC3972 demo board is a DC/AC inverter module used to drive a cold cathode fluorescent lamp (CCFL) typically used as the back-light source for the LCD panel in a notebook computer. The principle of operation for the current fed push-pull inverter is explained in the applications section of the UCC3972 data sheet and will not be repeated here. A complete schematic for the demo board is given in Figure 1 and a parts list is provided in Table 2. As explained in the text that follows, the board components can be easily modified to implement alternate dimming techniques and to operate with higher voltage lamps.

Transformer Selection / Lamp Striking Voltage

The peak voltage available to strike the lamp is a function of the minimum DC input voltage and the turns ratio of T1.

$$V_{STRIKE} = \pi \bullet V_{IN(\min)} \bullet \frac{N\,\mathrm{sec}}{N\,\mathrm{pri}}\ \mathrm{Peak} \tag{1}$$



Note: High-voltage component. See EVM Warnings and Restrictions at the back of this document.

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Figure 1. Evaluation board schematic.

The transformer provided on the board (Coiltronics CTX210652) has a 67:1 turns ratio, relating the entire secondary turns to the primary. A 4.5V input will provide 950V peak [670V rms] to strike the lamp. If a higher striking voltage is required, a Coiltronics CTX210659 (100:1 turns ratio) can be substituted for T1 to give 1400 peak volts [1000V rms] with a 4.5V input. As shown in equation 1, a higher minimum input voltage will also provide a higher available strike voltage.

The CTX210652 transformer internally connects one side of the secondary winding to the primary center tap terminal (pin 3). The demo board will also accept Coiltronics transformers with a floating secondary:

CTX210655 [67:1 turns ratio]

CTX210657 [86:1 turns ratio]

CTX210659 [100:1 turns ratio]

If the floating secondary transformers are used, one side of the secondary (pin 9) is connected to ground on the demo board as shown in Figure 1. The footprint on the demo board accepts a 2.4 watt transformer, high power or multiple lamp designs may require a larger transformer.

Lamp Voltage / Ballast Capacitor Selection

The transformer's RMS secondary voltage during normal operation is given in equation 2 (the capacitor voltage is 90 degrees out of phase with the lamp voltage):

$$V\sec = \sqrt{{V_{LAMP}}^2 + \left(\frac{I_{LAMP}}{2\pi f_{RES} \bullet C_{BALLAST}}\right)^2}\ \text{RMS} \qquad (2)$$

In order to provide sinusoidal lamp current, the ballast capacitor (C6) voltage should be approximately 1.5 times the lamp voltage at rated current. Table 1 gives recommendations for the ballast capacitor (C6) based on RMS lamp voltage assuming 50kHz operation. A 33pF capacitor is provided on the demo board, allowing sinusoidal operation for a 300V lamp. If either T1 or C6 is changed on the demo board, resonant capacitor C5 may need to be modified to maintain the resonant frequency and sinusoidal operation (see UCC3972 data sheet).

Table 1. Recommended ballast capacitor based on lamp voltage.

RMS Lamp Voltage @ 5mA	Ballast Capacitor Value
200V	47pF
300V	33pF
375V	27pF
475V	22pF
575V	18pF
700V	15pF
1000V	10pF

Clamp Circuit Operation

Referring to Figure 1, an external voltage clamp circuit has been added to the demo board, consisting of D4, Q4, R7, R8, and R9. The circuit limits the maximum transformer voltage during startup, allowing an extended time period for striking the lamp. Open lamp detection is disabled for a startup period set by C3. A 10uF capacitor allows 1 second in which to strike the lamp, where R7 and R8 monitor the voltage between VBAT and the buck node of the resonant tank. If the resulting voltage at the base of Q4 is equal to the zener (D4) voltage plus the V_{BE} of Q4, the clamp circuit will activate limiting the voltage in the resonant tank. When the clamp activates, Q4 is turned on and additional current (set by R9) is allowed into the feedback capacitor. The peak clamp voltage is given by:

$$V_{CLAMP} = V_{IN} - V_{BUCK} \qquad (3)$$

$$= \left(\frac{R7 + R8}{R7}\right) \bullet \left(V_{ZENER} + V_{BE[Q4]}\right)^{\text{Peak}}$$

The peak clamped buck voltage for the demo board is approximately 13V, with a 67:1 turns ratio on T1 and 68kΩ resistors for R7 & R8, the resulting clamped peak secondary becomes 1700V [1200V rms] during the startup period. Figure 2 shows the clamp circuit controlling the tank voltage during a 1 second start-up under an open lamp condition with a 20V input. The bottom trace shows the MODE pin voltage, notice that the converter shuts down after the mode pin reaches 3V because the open lamp trip level (explained in the next section) is set less than the clamp voltage level. Since this photo was taken with a digital scope, trace 1 shows aliasing.

For systems where V_{IN} has a wide dynamic range, a zener diode (D_{CLAMP}) can be added to the demo board as shown in Figure 1. The zener provides a high speed clamp when power is initially applied to the board and before the voltage clamp can regulate the feedback loop. D_{CLAMP} can be a small 250mW zener since it will only conduct for a few resonant cycles before the voltage clamp takes effect. D_{CLAMP}'s value should be a few volts greater than the voltage clamp (15V would be good for this example).

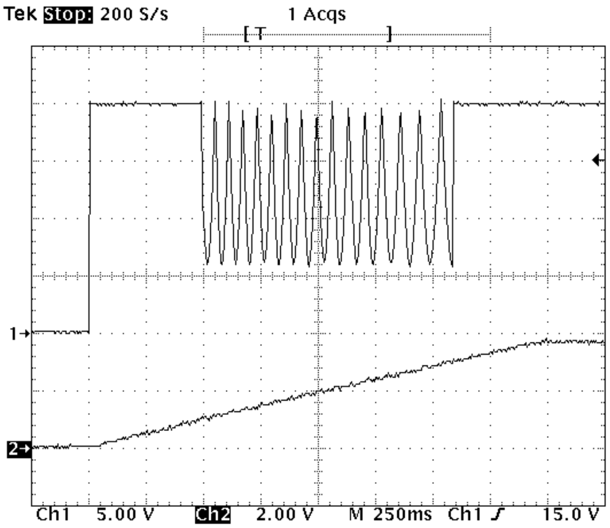


Figure 2. V_{BUCK} and V_{MODE} during open lamp start-up.

Setting the Open Lamp Trip Level

The buck voltage is monitored by an internal 7V comparator to detect an open lamp. The actual trip voltage across the resonant tank is set with an external resistor divider R10 and R11.

$$V_{OPENLAMP} = V_{IN} - V_{BUCK_{\text{Peak}}} = \left(\frac{R10 + R11}{R10}\right) \bullet 7V \qquad (4)$$

The demo board is initially populated with R10 at 2kΩ and R11 at 1kΩ, resulting in a 10.5V trip level across the tank. With a 67:1 turns ratio, the open lamp will trip at a peak secondary of 1400V [1000V rms]. R10 and R11 should be in the 1kΩ – 5kΩ range, to guarantee sharp zero crossing edges at the buck pin of the IC. In most applications the peak clamp voltage (see previous section) would be set to a higher level than the open lamp trip voltage, ensuring the converter would shut down after the one second blank time if a true open lamp existed. If the open lamp voltage is increased, the peak clamp circuit voltage (equation 3) would need to be increased accordingly. The optimum clamp and open lamp voltages will depend on the maximum secondary operating voltage (equation 2) and the strike voltage requirements of the lamp.

Dimming the Lamp

Lamp current is controlled with a single turn trimpot (R5). Lamp current is sensed by R4 and R5 and rectified by D2. The resulting voltage is averaged by R3 and C4 and compared to 1.5V by the error amplifier at pin 4. The resulting RMS lamp current becomes:

$$I_{LAMP} = \frac{\left[1.5 + \frac{V_{D2}}{2}\right] \bullet \pi}{\sqrt{2(R4 + R5)}} \qquad (5)$$

With R4 at 750Ω and VD2 = 0.6V, maximum lamp current is 5.3mA. If R5 is dialed to 10kΩ, minimum lamp current is 370µA. This translates to a 14:1 dimming range.

Low Frequency Dimming

To implement low frequency dimming on the demo board, R5 should be dialed to 0Ω to set maximum lamp brightness. An external network consisting of RLFD (68kΩ) and DLFD (1n4148 or equivalent) needs to be added to the demo board as shown in Figure 1. A low frequency square wave (0-5V for example) applied to the network will modulate the lamp current between zero and full intensity at the desired frequency. A low frequency repetition rate of greater than 120Hz is recommended to avoid visible flicker. Five Volts at RLFD will force the lamp current to zero, where 0V at RLFD will force maximum lamp current. The duty cycle of the square wave will determine the lamp brightness as a percent rated lamp current.

Since the feedback loop does not need to operate with minimum lamp current as with analog dimming, the feedback capacitor C4 can be reduced to 6.8nF to improve the response time when the lamp re-strikes. This modification allows a wider dynamic range of average lamp current. Low frequency dimming waveforms are shown in the datasheet.

If an initial one second strike period is required for the lamp, C3 and the mode pin can be used to blank open lamp as with analog dimming. RLFD should be held to 0V during the initial strike period, however, to guarantee the lamp will have up to one second of uninterrupted voltage.

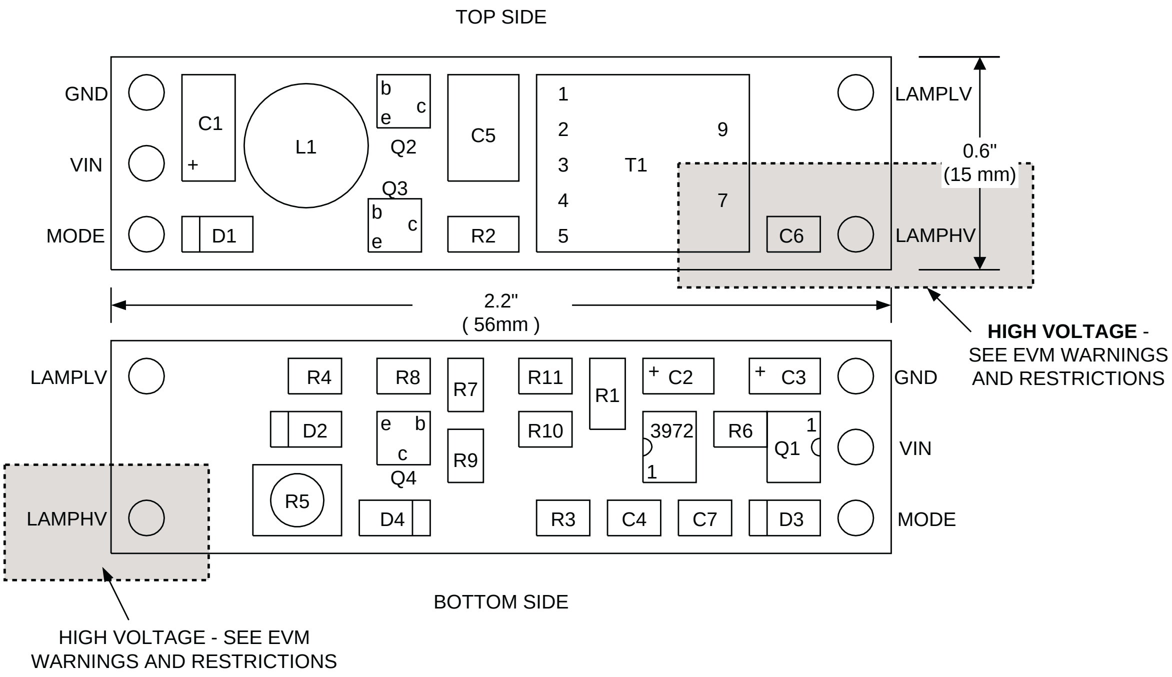
Shunt Regulator

The UCC3972 contains an internal shunt regulator allowing the demo board to operate with a DC input voltage between 4.5V and 25V. The regulator does not activate or degrade efficiency, however, until the input voltage reaches 18V. Typically this would only occur when a battery charger is powering the notebook. For applications where the input voltage is always less than 18V, the internal shunt regulator is not needed and R1 can be shorted.

Demo Board Component Placement

Figure 3 shows the component placement for the demo board. Pin numbers and component polarities are also shown.

For complete details about the operation of the UCC3972, BiCMOS Cold Cathode Fluorescent Lamp Driver Controller, please refer to the UCC3972 Datasheet.



Note: High-voltage component. See EVM Warnings and Restrictions at the back of this document.

Figure 3. Parts placement for the UCC3972 demo board.

Table 2. UCC3972 evaluation board list of materials.

Reference Designator	Description	Part Value	Manufacturer	Part Number
C1	Tantalum Capacitor	6.8µF 35V, C case	AVX (803)-448-9411	TAJC685K035
C2	Ceramic Capacitor	1µF, 35V, A case	AVX	TAJA105K035
C3	Tantalum Capacitor	10µF 6V, A case	AVX	TAJA106K006
C4	Ceramic Capacitor	33nF, 0805		
C5		0.1µF	(see data sheet for suggested vendors)	
C6	Ceramic Capacitor	33pF, 3kV, 1808	Murata	GHM1038SL330J3K
C7	Ceramic Capacitor	0.1µF, 0805		
D1	Schottky Diode	40V, 1A	Internationall Rectifier (310) 322-3331	IR10MQ040
D2	Diode	SOD-123	Motorola	MMSD914T1
D3		0Ω 0805		
D4	Zener Diode	5.6V , SOD-123,	Motorola	MMSZ4690T1
L1		100µH	Sumida (847) 956-0666	CD75-101KC
Q1	N-channel MOSFET	Micro 8	Int'l Rectifier	IRF7603
Q2, Q3	BJT Transistor		Zetek	FMMT619
Q4	PNP Transistor	3906, Sot-23	Motorola	MMBT3906LT1
R1	Resistor	470Ω, 1206		
R2, R4	Resistor	750Ω, 1206		
R3, R7, R8	Resistor	68kΩ, 0805		
R5	Resistor	10k trimpot, 4mm x 4mm, single turn	Phillips Components (800) 447-3762	ST4-A-103
R6	Resistor	75Ω, 0805		
R9	Resistor	10k, 0805		
R10	Resistor	2kΩ, 0805		
R11	Resistor	1kΩ, 0805		
T1	CCFL	Xfrm	Coiltronics (561)241-7876	CTX210652

DYNAMIC WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the input voltage range of 5 V to 24 V and the output voltage range of 0 V to 1000 V.

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative.

During normal operation, some circuit components may have case temperatures greater than 70°C. The EVM is designed to operate properly with certain components above 70°C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

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