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REFERENCE DESIGN

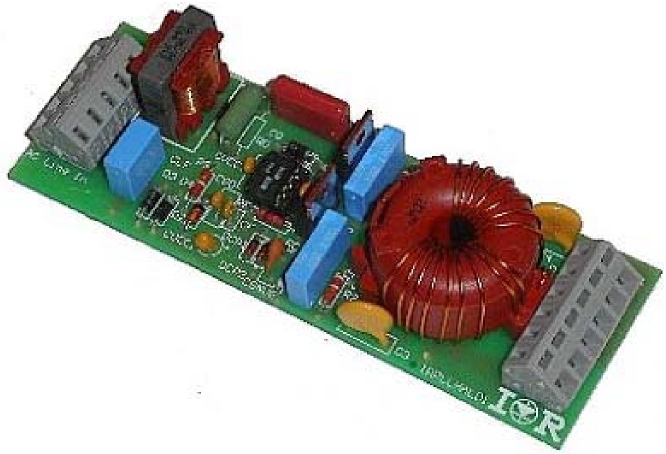
IRPLHALO1E revB

International Rectifier • 233 Kansas Street, El Segundo, CA 90245 • USA

100VA dimmable electronic convertor for low voltage lighting

By Peter Green

TOPICS COVERED



Introduction

Until now, almost all electronic convertors (often called electronic transformers) for Low Voltage filament lamp applications have up to now been based around self-resonating bipolar transistor half-bridge circuits. A new approach, using power MOSFETs driven by a control IC incorporating additional functionality tailored to this application, is realized in the IR2161 and demonstrated in a typical application by the IRPLHALO1E reference design kit.

The IR2161 is a dedicated intelligent half bridge driver IC for a Halogen convertor (1) or “Electronic Transformer” targeted at medium and high end performance low voltage lighting applications.

The goal has been to incorporate as much functionality as possible within a low cost 8 pin DIP or SOIC package to allow reliability and performance advantages over existing circuit designs with a lower component count.

Electronic transformers are commonly used in place of wire wound step down transformers in order to provide the correct supply for low voltage (generally 12V) filament lamps such as Dichroic Halogen that are widely used.
The advantages are:
1) Small size and weight
2) Fault protection circuitry
3) Safety because of low output voltage

(1) Throughout this data sheet "convertor" is spelled in accordance with standard IEC 61047 "DC or AC supplied convertors for filament lamps – Performance requirements".

Electronic transformers have become popular for low voltage lighting applications. The range of products available ranges from very small 50W units, capable of driving only a single 50W lamp to 300W units capable of driving up to 6 X 50W lamps. In many applications the lamps are attached to a track system in which the supply rails are exposed. Since the voltage is only approximately 12V this does not present any safety problem.

The electronic transformer is generally smaller and lighter than a wire wound equivalent and may be equipped with short circuit and thermal protection, which are generally not included when a wire wound transformer is used. Generally a well-designed electronic transformer may be dimmed with a triac based leading edge phase cut dimmer (as can a wire wound transformer) or by a trailing edge transistor dimmer.

Functional description of the IR2161 based Halogen convertor

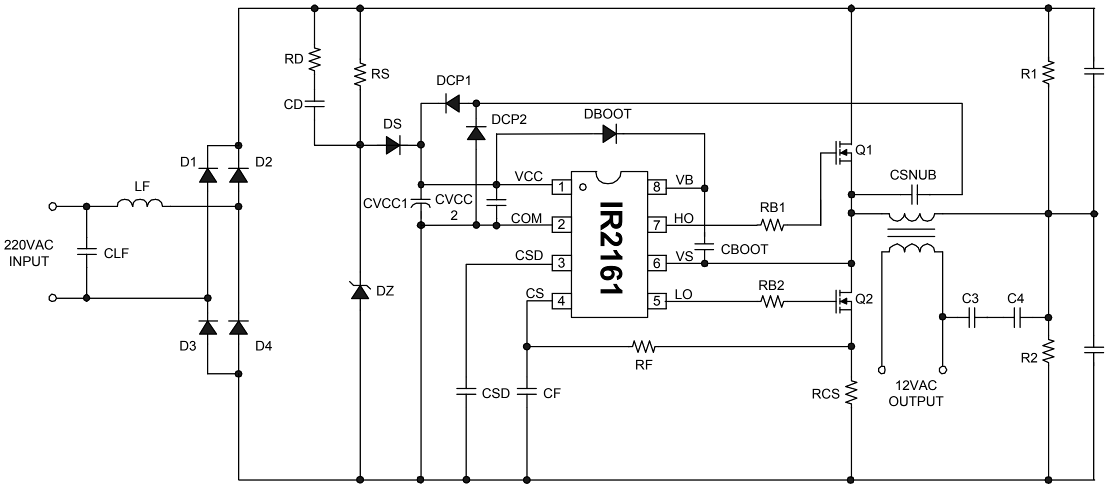


Fig. 1 IRPLHALO1E Circuit Schematic

The IR2161 provides low and high side output drives for the half-bridge MOSFETs or IGBTs. The output from the half bridge is connected to a high frequency stepdown transformer, which supplies approximately 12Vrms at the output to drive the lamps. The IR2161 also incorporates all of the protection features needed in the system without the need for very many external components.

At switch on the frequency sweeps from a high frequency around 125kHz down to the normal operating frequency 30 to 40kHz over a period of approximately 1 second. Because of the leakage inductance in the transformer this causes the output voltage at the lamp to start at a reduced value and gradually increase to the 12V nominal level. This reduces the inrush current at switch on. When the lamp is cold the filament resistance is lower which tends to cause high inrush currents that can cause false tripping of the shutdown circuit.

The IC includes a short circuit protection that operates if a high current is detected for approximately 50mS causing the outputs to switch off. Similarly if an >50% overload is detected for more than approximately 500mS then the outputs will switch off. It should be noted that the shutdown time under an overload condition will be reduced depending on the magnitude of the overload.

This dual mode shutdown circuit will protect the circuit from all output fault conditions and will function when the convertor is dimmed, unlike the self-oscillating solution and it will also protect the system from a short circuit at the end of the output leads.

An electronic transformer is normally required to provide a reasonably consistent output voltage over a range of loads and so the IC senses the load through the current sense resistor and increases the frequency as the load is reduced thus providing compensation for the output transformer load regulation. There is also some modulation of the frequency through the line voltage half-cycle to spread the harmonics and reduce the size and cost of the EMC filtering components required.

The IR2161 includes all necessary protection features and also allows the convertor to be dimmed externally with a standard phase cut dimmer for leading or trailing edge. This IC provides the advantage of longer lamp life due to soft start and output voltage shift (load regulation) compensation. It causes the convertor to run with optimized harmonic behavior (i.e. almost unity power factor) also at higher loads (solution with bipolar devices can have harmonics problems for high loads due to the fact that the oscillator start-stop every half cycle, causing cross over distortion).

The IC also includes adaptive dead time to realize soft-switching and allow cool running MOSFETs (and improves the EMI behavior due to frequency modulation during the line voltage half cycle).
Some points to consider when comparing a Halogen convertor circuit design with an electronic ballast for fluorescent lamps:

- Filament Lamp is a *Resistive* Load
- No Preheat / Ignition is required
- DC Bus is full wave rectified line without smoothing
- Close to *Unity Power Factor* is inherent in system
- Can be dimmed with *Triac* (standard domestic type) dimmer
- Dimming is achieved by *PHASE CUTTING* of the AC line
- Output is isolated *Low Voltage*
- Protection required against output short circuit or overload not open circuit.
- Shutdown must be *Auto-Resetting*

The protection circuitry is auto-resetting so that if the output is short circuited the system will periodically try to restart and then shut down again. When the short-circuit is removed the lamp will be able to come back on again without the need for cycling the AC supply off and back on again to reset. The external capacitor at the CSD pin is used in several different operating modes allowing the IC to be limited to 8 pins. The CSD pin is connected to different circuit blocks during different modes, controlled by internal control logic.

The current sense (CS) input is connected to the voltage compensation and shutdown circuit blocks. The CSD capacitor is switched between different circuits through internal transmission gates. The oscillator is voltage controlled and its input is connected to the CSD capacitor during normal operation. In case of overtemperature or external shutdown, the IC will go into a fault mode. In this mode the IC is in latched shutdown and will restart only after resetting the mains. In case of overvoltage or overload, the IC will go into a auto-resetting fault.

The different modes of operation of the IC and the system implications are described here:
(See also the IR2161 data sheet)

Supplying VCC to the IR2161

The under-voltage lockout mode (UVLO) is defined as the state the IC is in when VCC is below the turn-on threshold of the IC. To identify the different modes of the IC, refer to the State Diagram shown in the IR2161 data sheet. The IR2161 under voltage lock-out is designed to maintain an ultra low supply current under 300uA and to guarantee the IC is fully functional before the high and low side output drivers are activated.

The capacitor (CVCC) is charged by current through supply resistor (RS) minus the start-up current drawn by the IC. This resistor charges CVCC to the UVLO+ threshold, at which point the IR2161 starts to operate and the LO and HO outputs become active. In a Halogen convertor it is important to consider that the DC bus is completely unsmoothed and has a full wave rectified shape. CVCC should be large enough to hold the voltage at VCC above the UVLO threshold for one half cycle of the line voltage as it will only be charged at the peak. A charge pump consisting of CSNUB connected to two diodes, DCP1 and DCP2, feeds current back from the half bridge (VS) to VCC and sustains the supply to the IC after it has been initially started. This arrangement avoids the necessity for RS to supply all the current to VCC, which would require RS to dissipate around 2W in a 220VAC supplied system. This is undesirable as 2W power dissipated as heat within the convertor adds significantly to the temperature rise. When selecting the value of RS, the trade-off is between power dissipation and the ability of the convertor to start up when connected to a dimmer that is set to a very low level. When a dimmer is set close to minimum and the supply to the convertor is switched on, only a small voltage will appear on the DC bus and so RS must be small enough for this to provide sufficient starting current for VCC. However the smaller the value of RS is, the more power it will dissipate. It should be noted that the above considerations are important in a 220VAC supplied system, but in a 120VAC supplied system a charge pump would not be necessary and RS could supply VCC without dissipating significant power. Other considerations such as the high primary current become more problematic in a 120VAC system.

An external 16V zener diode DZ has been added to avoid the need for the internal zener to dissipate power (it should be rated at 1.3W). The resistor RD in series with CD is necessary if the convertor is required to operate from a triac based (leading edge) phase cut dimmer. When the triac fires at a point during the mains half-cycle the high dv/dt allows a large current to flow through this path to rapidly charge CVCC to the maximum VCC voltage. In this way each line half cycle, the system will receive a fast pull up on VCC when the traic in the dimmer is fired.

The external zener DZ will prevent possible damage to the IC by shunting excess current to COM. Once the capacitor voltage on VCC reaches the start-up threshold the IC turns on and HO and LO begin to oscillate. A bootstrap diode (DB) and supply capacitor (CB) comprise the supply voltage for the high side driver circuitry. To guarantee that the high-side supply is charged up before the first pulse on pin HO, the first pulse from the output drivers comes from the LO pin. During under voltage lock-out mode, the high and low-side driver outputs HO and LO are both low.

Soft Start Operation

The soft start mode is defined as the state the IC is in at switch on of the system when the lamp filament is cold. As with any type of filament lamp the Dichroic Halogen lamp has a positive temperature coefficient of resistance such that the cold resistance (at switch on when the lamp has been off long enough to cool) is much lower than the hot resistance when the lamp is running. This normally results in a high inrush current occurring at switch on. Under worst-case conditions this could potentially trigger the shut down circuit. To overcome this problem the IR2161 incorporates the soft start function.

When the IC starts oscillating the frequency is initially very high (about 125kHz). This causes the output voltage of the convertor to be lower since the HF transformer in the system has a fixed primary leakage inductance that will present a higher impedance at higher frequency allowing less

AC voltage to appear across the primary. The reduced output voltage will naturally result in a reduced current in the lamp which eases the inrush current thus avoiding tripping of the shutdown circuit and easing stress on the lamp filament as well as high current in the half bridge MOSFETs (M1 and M2). The frequency sweeps down gradually from 125kHz to the minimum frequency over a period of around 1s (for a CSD capacitor of 100nF). During this time the external capacitor at the CSD pin charges from 0V to 5V controlling the oscillator frequency via the internal voltage controlled oscillator (VCO). The value of CSD will determine the duration of the soft start sweep. However since it also governs the shut down circuit delays the value should be kept at 100nF to achieve the correct operation.

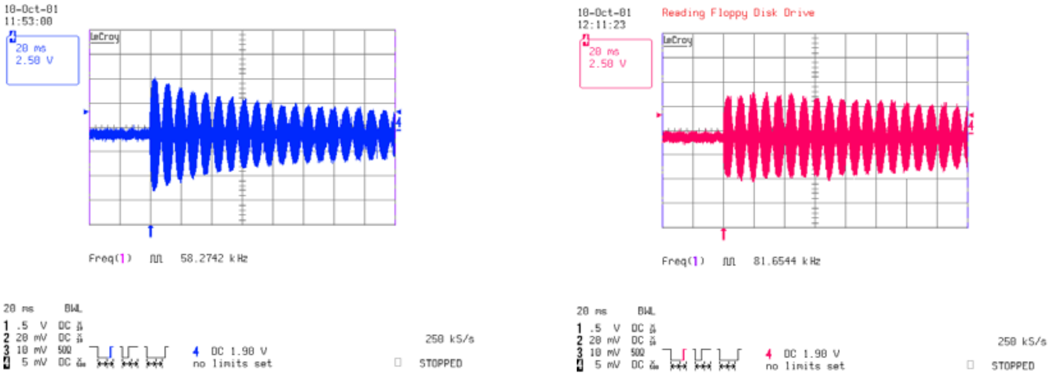


Fig. 2 Startup current without and with soft start function

Run Mode

When soft start is completed the system switches over to run mode. During this time the system provides some regulation of the output voltage of the convertor from minimum to maximum load. In this type of system it is desirable that the voltage supplied to the lamp does not exceed a particular limit. If the lamp voltage becomes too high the temperature of the filament runs too high and the life of the lamp is significantly reduced. The problem is that the output transformer is never perfectly coupled so there will always be a degree of load regulation. The transformer has to be designed such that the lamp voltage at maximum load is sufficiently high to ensure adequate light output.

At minimum load the voltage will consequently be higher and is likely to exceed the maximum desired lamp voltage. The load current is sensed via the current sense resistor (RCS). The peak current is detected and amplified within the IC then appears at the CSD pin during voltage compensation mode. The voltage across the CSD capacitor will vary from 0V if there is no load to approximately 5V at maximum load.

This is provided that the correct value of current sense resistor has been selected for the maximum rated load and line voltage supply of the convertor. This should be 0.33 Ohm (0.5W) for a 100W system running from a 220-240V AC line. (It should be noted that the RCS resistor value is also critical for setting the limits for the shut down circuit).

In run mode the oscillator frequency will vary from approximately 30kHz when VCSD is 5V (maximum load) to around 60kHz when VCSD is 0V (no load). The result of this is that at lighter loads, for example if only a single 35W lamp is connected to a 100W convertor, the frequency will shift upwards so that the output voltage falls below the maximum that is acceptable for the lamp. This provides sufficient compensation for the load to ensure that the lamp voltage will always be within acceptable limits but does not require a complicated and expensive system involving feedback from the output.

An additional internal current source has been included to discharge the external capacitor. This will provide ripple at twice the line frequency if CSD is 100nF.

The advantage of this frequency modulation (or “dither”) is that during the line voltage half cycle the oscillator frequency will vary by several kHz, thus spreading the EM conducted and radiated emissions over a range of frequency and avoiding high amplitude peaks at certain frequencies. In this way the filter components used may be similar to those used in a common bipolar self-oscillating system.

Shut Down operation
The IR2161 contains a dual mode auto-resetting shutdown circuit that detects either a short circuit or overload condition at the output. The load current detected at the CS pin is used to sense these conditions. If the output of the convertor is short-circuited, a very high current will flow in the half bridge and the system must shut down within a few mains half cycles otherwise the MOSFETs will rapidly be destroyed due to excessive die temperature. The CS pin has an internal threshold of approximately 1.0V so that if the voltage exceeds this level for more than 50mS the system will shut down.

A delay is included to prevent false tripping either due to lamp inrush current at switch on (this current is still higher than normal with the soft start operation) or transient currents that may occur if an external triac based phase cut dimmer is being used.

There is also a lower threshold of 0.5V, which has a much longer delay before it shuts down the system. This provides the overload protection if an excessive number of lamps is connected to the output or the output is short-circuited at the end of a length of cable that has sufficient resistance to prevent the current from being large enough to trip the short circuit protection. Under this condition there is also an excessive current in the half bridge that is sufficient to cause heating and eventual failure but over a longer period of time. The threshold for overload shutdown is approximately 50%

above maximum load with a delay of approximately 0.5s. This is based on a current waveform that has a sinusoidal envelope with a high frequency square wave component with 50% duty cycle.

Both shutdown modes have auto reset, which allows the oscillator to start again approximately 1s after shutting down. This is so that if the fault condition is removed the system can start operating normally again without the line voltage having to be switched off and back on again. It also provides a good indication of overload to the end user as all the lamps connected to the system will flash on and off continuously if too many are connected.

The shut down circuit also uses the external CSD capacitor for it's timing functions. When the 0.5V threshold is exceeded at CS the CSD is internally disconnected from the voltage compensation circuit and connected to the shutdown circuit. The oscillator operates at minimum frequency when the CSD capacitor is required for shutdown circuit timing. When the 0.5V threshold is exceeded the IR2161 charges CSD rapidly to 4V.

When the shutdown threshold of 0.5V is exceeded the CSD capacitor is charged by current source I_OL and when the threshold of 1.2V is exceeded it is charged by I_SD as well. If 1.2V is exceeded CSD will charge from 4V to 12V in approximately 50ms. When 0.5V is exceeded but 1.0V is not, CSD charges from 4V to 12V in approximately 0.5s. The timing accounts for the fact that high frequency pulses with approximately 50% duty cycle and a sinusoidal envelope appear at the CS pin. The values of I_SD and I_OL take into account that only at the peak of the mains will the comparator outputs go high and effectively the capacitor will be charged in steps each line half cycle.

If a fault is detected but disappears before CSD reaches 12V then CSD will discharge to 2.5V and then the system will revert to compensation mode without interruption of the output.

Similarly when the system starts up again after a delay the CSD capacitor will be internally switched back to the voltage compensation circuit. If the fault is still present the system will immediately switch CSD back to the shutdown circuit.

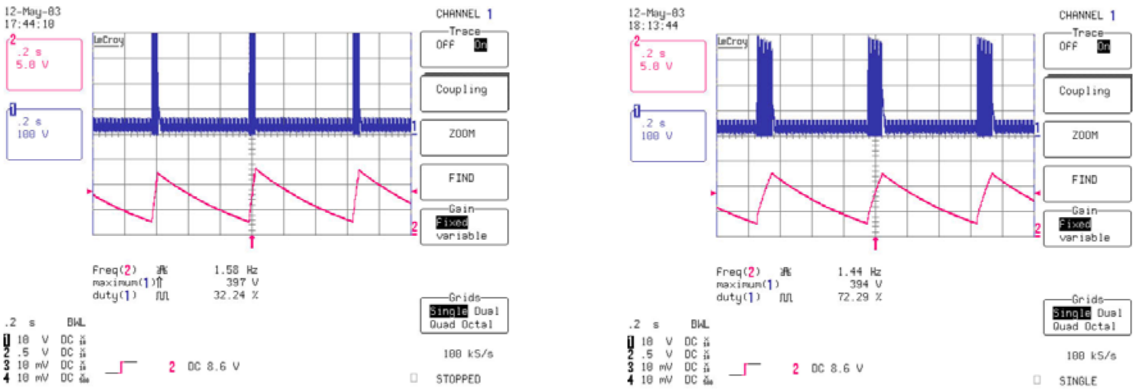


Fig. 3 Short circuit and Overload detection

The red trace shows the output current during both types of fault mode and the blue trace shows the charging and discharging of the CSD capacitor.

The IR2161 can be shut off by applying a voltage above 0.5VCC to the CS pin. This will cause the system to go directly to fault mode after approximately 1uS such that it is necessary for VCC to be re-cycled off and on to restart the system.

The IR2161 also includes over temperature shutdown, which latches the convertor off when the die temperature of the IC exceeds 130-140°C. It is assumed that the die temperature will be approximately 20°C above the ambient temperature inside the convertor. It is also true that depending on layout, heat will be transferred from other devices through the PCB traces into the IC raising the temperature. It may be possible to utilize this behavior to cause the IC to shutdown if high temperatures from the MOSFETs are conducted to the IC.

Calculating RCS

The value of the current sense resistor RCS is critical to achieve correct operation in the IR2161 based Halogen convertor.

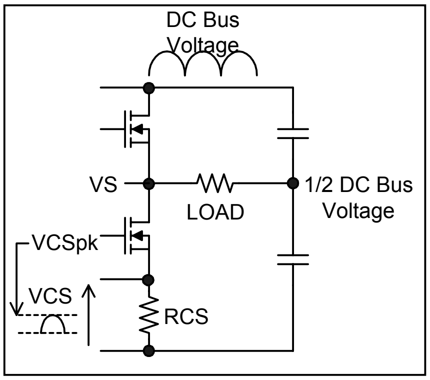


Fig. 4 Calculation of the peak half bridge current

Ignoring the output transformer we can assume for this calculation that the load is connected from the half bridge to the mid point of the two output capacitors and that the voltage at this point will be half the DC bus voltage. The RMS voltage of the DC bus is the same as that of the AC line so we can see that the RMS voltage across the load shown in Figure 4, will be half the RMS voltage of the line. The load is the maximum rated load of the convertor. The current in Rcs will be half the load current given by :

$$I_{CS(RMS)} = \frac{P_{LOAD}}{V_{AC}}$$

Since the load is resistive the current waveform will have a sinusoidal envelope and so the peak can be easily determined taking into account that the current is has a high frequency component with an approximate 50% duty cycle :

$$I_{CS(PK)} = 2\sqrt{2} \times I_{CS(RMS)}$$

Therefore:

$$V_{CS(PK)} = I_{CS(PK)} \times R_{CS}$$

For correct operation at maximum load the peak voltage should be 0.4V.
The calculation can be simplified by combining the formulae,

$$R_{CS} = \frac{0.4 \cdot V_{CS}}{2 \cdot \sqrt{2} \cdot P_{LOAD}}$$

which can be simplified to:

$$R_{CS} = 0.141 \cdot \frac{V_{AC}}{P_{LOAD}}$$

Example

For a 100W convertor working from a 230VAC supply the current sense resistor would need to be

$$\frac{0.141 \times 230}{100} = 0.324\Omega$$

The nearest preferred value in the E12 range is 0.33 Ohms.

The power dissipation in Rcs should also be considered and is given by

$$P_{CS} = \left(\frac{P_{LOAD}}{V_{AC}} \right)^2 \times R_{CS}$$

In this case :

$$\left(\frac{100}{230} \right)^2 \times 0.33 = 0.062W$$

It is important to bear in mind that the resistor must be rated to handle this current in a high ambient temperature as well as the high currents that occur for a short period under short circuit conditions.

IMPORTANT NOTE
The filter resistor RF should be 1K, which is needed to protect the CS input from negative going transients. CF should be 1nF and is also necessary to filter out switching transients that can impair the operation of the shutdown circuit.

Output Transformer Selection
The size of the core and design of the output transformer need to be seleted bearing in mind the throughput power at maximum load. The core may be a toroid, a pair of E-cores, or any other shape. The turns ratio can be easily determined by the ratio of half the AC line RMS input voltage and the required output, which is usually (but not always) 12V. When the correct number of turns for the primary has been determined, it is simple to calculate the number of secondary turns.

The number of turns required for the primary should be calculated so that at the minimum frequency the transformer will not saturate at the peak voltage, i.e. half the peak DC bus voltage.

It is important to bear in mind that the peak voltage at the DC bus occurs during dimming with a leading edge, triac type, dimmer where the firing angle is at the peak of the line. This is because a transient is produced when the triac is fired and so an additional voltage is added to the DC bus voltage. As a rule the MOSFET breakdown voltage may be used to calculate the primary turns such that the core will not saturate at minimum frequency and maximum temperature.

If the core saturates a large current will flow in the half bridge and may trigger the short circuit protection when the convertor is connected via a dimmer.

The transformer selection procedure is as follows:

1. Select the correct core size for the maximum load at 30kHz. Use the manufacturer's core data to determine the maximum throughput power at this frequency.

2. Calculate the number of turns required at the primary

$$Np(\min) = \frac{Vpk \cdot Ton(\max)}{2 \cdot B(\max) \cdot Ae}$$

   Where Bmax (maximum flux density in Teslas) can be obtained from the core manufacturers data for the Ferrite material operating at a temperature of 100 degrees C and Ae is the cross sectional area of the magnetic path in mm^2.
   Vpk may be considered to be 400V and Ton(max) may be considered to be 18uS.

3. Calculate the number of turns required at the secondary.

$$Ns = \frac{2.Np.Vout(rms)}{Vac(rms)}$$

4. Determine the leakage inductance.

   This can only be done by measurement. Simply short out the secondary and measure the primary inductance with an LCR bridge. The amount of leakage inductance depends on the physical construction of the transformer, the better the primary and secondary windings are coupled, the lower the leakage inductance will be. However, in this application some leakage inductance is desirable to limit the primary current if the secondary is short circuited. It is also important to consider that a high isolation breakdown voltage (4kV) is required in this application between the primary and secondary windings, for safety certification of the convertor. This means that winding the primary and secondary close together is not possible and therefore, some leakage inductance will result.

   In some designs the output transformer is purposely designed to have a high leakage inductance in order to limit the primary current under short circuit conditions and therefore allow smaller half bridge MOSFETs to be used. In this case the short circuit primary current may be too small to trigger the short circuit protection, the result being that the system will take longer to shut down because only the overload threshold is exceeded at the CS pin. This is unlikely to cause any problems but should be considered.

The IRPLHALO1E reference design board uses a toroidal output transformer that has the secondary windings spread over as much of the core as possible to minimize the leakage inductance, which is inherently high in such constructions. This allows sufficient current to shut down the convertor rapidly when the output is short circuited.

Note

Ready wound toroidal output transformers as used in the IRPLHALO1E design kit are available from Vogt or Kaschke. These have many advantages including high isolation breakdown capability because of the moulded plastic separator between the primary and secondary.

Short circuit current

The short circuit current that appears at the primary is dependent on the primary leakage inductance of the output transformer as well as the value of the half bridge capacitors. The half bridge capacitors should be kept as small as possible in order to limit this current. However, they also need to be large enough to be able to handle the ripple current, i.e. half the primary current flowing in each capacitor at the IR2161 oscillator frequency.

Adaptive Dead Time

Because of the fact that the DC bus voltage varies during the mains half cycle the dead time may need to vary in order to achieve soft switching all of the time. The IR2161 has an adaptive dead time system that detects the point at which the voltage at the half bridge slews to 0V (COM) and sets the LO output high at this point. There is an internal sample and hold system that allows the same delay to be used to set HO high after LO has gone low. This reacts on a cycle-by-cycle basis of the oscillator and therefore will adjust the dead time as necessary regardless of external conditions.
The designer does not need to take into account parasitic capacitances in the MOSFETs or leakage inductance in the output transformer and set the dead time accordingly.

The system is designed operate down to dead times of less than 250nS which should be low enough to accommodate the output transformer leakage inductance and parasitic MOSFET capacitances of a practical Halogen convertor. If the ADT function does not operate the dead time reverts to a preset fixed value that will, in most cases, prevent serious losses due to hard switching. The slew rate can easily be increased, if necessary, by increasing the value of the *snubber* capacitor. This does, however result in the failure of the VS voltage to slew completely at reduced loads and so CSNUB should be kept as low as possible, but high enough to maintain the supply for the charge pump to VCC. Some of the supply current may also be provided through RD and CD allowing the charge pump to provide only part of it and hence the value of CSNUB can be as low as 220pF.

In the event of the voltage at the half bridge failing to slew all the way down to COM the adaptive dead time circuit will time out after 1 to 1.5uS and switch on the relevant MOSFET thus operating with hard switching. This could happen during the first few cycles after start up. It should never be the case in normal running conditions unless the load is very light or the primary leakage inductance is excessive or that an unnecessarily large snubber capacitor is present.

This system avoids the need for an external resistor to program the dead time and contributes with the multi functional nature of CSD to the IR2161 being realized with only 8 external pins.

Dimming

Almost any Halogen convertor available can be dimmed by an external *phase cut* dimmer that operates in *trailing edge* mode. This means that at the beginning of the line voltage half cycle voltage the switch inside the dimmer is *closed* and mains voltage is supplied to the convertor allowing the convertor to operate normally. At some point during the half cycle the switch inside the dimmer is *opened* and voltage is no longer applied. The DC bus inside the convertor almost immediately drops to 0V and the output is no longer present. In this way bursts of high frequency output voltage are applied to the lamp. The RMS voltage across the lamp will naturally vary depending on the phase angle at which the dimmer switch switches off. In this way the lamp brightness may easily be varied from zero to maximum output.

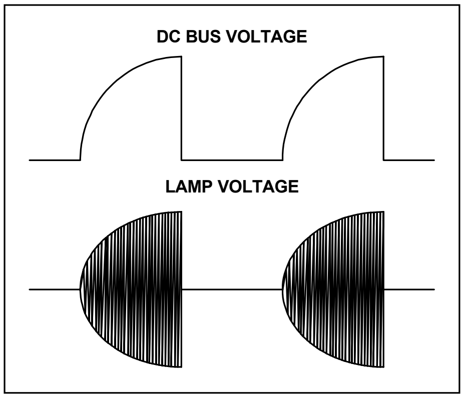


Fig. 5 Trailing Edge Dimming

Trailing edge dimmers are less common however than leading edge dimmers. This is because they are more expensive to make and need to incorporate a pair of MOSFETs or IGBTs whereas a leading edge dimmer is based around a single *triac*.

Conversely many Halogen convertors are not able to operate with leading edge dimmers because of the fact that they are based around a triac. It is possible however to design a Halogen convertor that will work effectively with a triac based dimmer by paying attention to design the input filter components correctly and to ensure that at the *firing* point of the triac the oscillator will start up rapidly. In the IR2161 based system this is easy to achieve through the addition of RD and CD which conduct a large current

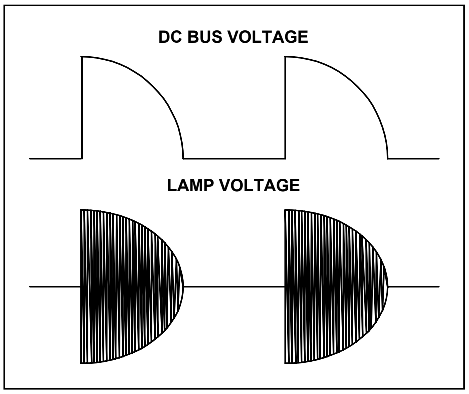


Fig. 6 Leading Edge Dimming

to VCC due to the high dv/dt that occurs when the triac fires and the bus voltage rises rapidly from zero to the AC line voltage. If the VCC voltage falls below UVLO- during the time when the triac in the dimmer is off the soft start will not be initiated when voltage because the soft start circuit is not reset until VCC drops approxmately 2V below UVLO-. This takes some time as the VCC capacitor discharges very slowly during UVLO micro-power operation. The intermediate period is referred to as Standby mode.

During dimming the voltage compensation circuit will cause a frequency shift upward at angles above 90° because the peak voltage at CS will be reduced, however this will not have a noticeable effect on the light output.

The problem associated with operation of Halogen convertors with triac dimmers is due to the fact that after a triac has been fired it will conduct until the current falls below its *holding current*. If the load is purely resistive (as in a filament lamp directly connected to the dimmer) this will naturally happen at the end of the line voltage half cycle as the current has to fall to zero. In a Halogen convertor it is necessary to place a capacitor and inductor at the AC input to comply with regulations regarding EM *conducted emissions.* This means that when the line voltage falls to zero there could still be some current flowing that is enough to keep the triac switched on and so the next cycle will follow through and not be *phase cut* as required. This can happen intermittently resulting in flickering of the lamps. The way to avoid the problem is to ensure that the product has the smallest possible filter capacitor CF and to state a minimum load for the convertor. This would be typically one third of the maximum load to avoid problems of this kind.

EMC Issues

The IRPLHALO1E demo board has not been EMC tested although a filter capacitor CLF and inductor LF are fitted. The capacitor value may not be increased beyond a certain point to improve filtering as this causes problems when dimming with triac type phase cut dimmers, i.e. that the phase shift introduced can prevent the triac current dropping below its holding current at the end of the line voltage half cycle and so the dimmer no longer functions. In order to prevent this, the proportion of resistive load presented to the dimmer output must be sufficient for the capacitance. A good rule of thumb to apply is that no more than 1nF of capacitance should be used per Watt of the maximum power rating of the convertor, e.g. for a 100W convertor, use a 100nF capacitor. This should allow dimming to work even at reduced loads without any difficulties. The filter inductor value should be increased to reduce the conducted emmissions below the limits of the applicable EMC standard. The inductor should have a powdered Iron core rather than Ferrite as this can handle a much larger current before saturating.

Layout Issues

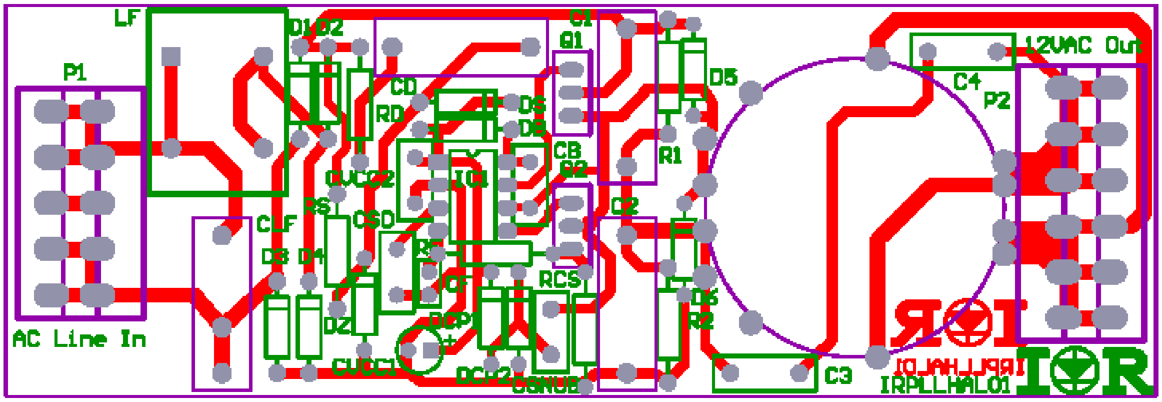


Fig. 7 IRPLHALO1E PCB Layout

It is very important when laying out the PCB for the IR2161 to consider the following points:

1. CVCC2 must be as close to the IC as possible
2. CSD should be as close to the IC as possible.
3. C1 and C2 should be placed close to the MOSFETs Q1 and Q2 and close to RCS and the output transformer primary, so that the primary high frequency current path may be as short as possible.
4. CF should be placed close to the IC so that one side can be very close to the current sense (CS) pin and the other side as close to the IC COM pin as possible.
5. The traces leading from the transformer secondary to the output need to carry a large current and so should be made as large as possible.
6. Large creepage and clearance distances must be left between the primary and secondary side of the transformer to accommodate the 4kV isolation breakdown requirement.
7. Sufficient space must be left between traces connected to the low side and the high side outputs of the IC. Also any traces carrying high voltage from the AC line or the DC bus must have sufficient spacing from low voltage traces to prevent the possibility of arcing.

Component Selection

It is important to consider the selection of componets, particularly capacitors. These need to be rated for at least 100ºC and in the case of the two half bridge capacitors C1 and C2 they must be suffieciently for the high frequency ripple current at this temperature. As in most electronic power applications, capacitors and resistors are the components most likely to fail due to stress over time and and high operating temperatures. Careful selection of these will significantly increase the reliability of the product.

The following component values have been selected for a 100W maximum load at 230VAC line input. The circuit will need to be optimized for the maximum load required to obtain best performance.

Bill of Materials

em	Device type	Description	Part no	Manufacturer	No of devices in circuit	References
1	Capacitor	100nF, 400V	2222 383 00104	BC Components	2	C1,2
2	Capacitor	100nF, 275V, X2	2222 338 26104	BC Components	1	CLF
3	Capacitor	1.5nF, 400V	ECK-D3D152KBP	Panasonic ECG	2	C3,4
4	Capacitor	1nF, 50V	K102J15C0GF5TH5	BC Components	1	CF
5	Capacitor	100nF, 25V	C317C104M5U5CA	Kemet	3	CVCC2,CSD,CB
6	Capacitor	330nF, 400V	ECQ-E4334KF	Panasonic ECG	1	CD
7	Capacitor	22uF, 50V, Radial	T350F226K016AS	Kemet	1	CVCC1
8	Capacitor	150pF, 500V, Ceramic	D151K20Y5PL63L6	BC Components	1	CSNUB
9	Diode	1000V, 1A	1N4007-T	Diodes Inc	5	D1-4,DS
10	Diode	600V, 1A	1N4937-T	Diodes Inc	1	DB
11	Diode	600V, 1A	1N4937-T	Diodes Inc	Not Fitted	D5,6
12	Diode	75V, 500mW	!N4148-T	Diodes Inc	2	DCP1,DCP2
13	Zener	16V, 1W	1N4745A-T	Diodes Inc	2	DZ
14	Inductor	Vertical E20 Iron powder	094094912000	Kaschke	1	LF
15	Transformer	78T, 8T, 12V out 190.763	190190763000	Kaschke (equivalent also available from Vogt)	1	T1
16	Resistor	470K, 1W	5073NW470K0J12AFX	BC Components	2	R1,2
17	Resistor	220K, 1W	5073NW220K0J12AFX	BC Components	1	RS
18	Resistor	270R, 3W	2322 329 03271BC	BC Components	1	RD
19	Resistor	22R, 1206, SMD	ERJ-8GEYJ220V	Panasonic ECG	2	RB1, RB2
19	Resistor	0R33, 0.5W	ALSR1F-.33R-ND	Huntingdon Electric Inc	1	RCS
20	Resistor	1K, 1W	5073NW1K000J12AFX	BC Components	1	RF
21	IC	Controller	IR2161	IR	1	In Socket
22	IC Socket	8 Pin DIP	2-641260-1	Amp Tyco Electronics	1	IC1
23	FETs	400V	IRF740	IR	2	Q1,2
24	Connector	5 Way	236-105	Wago	1	P1
25	Connector	6 Way	236-106	Wago	1	P2
26	PCB		IRPLLHALO1		1	

References

IR2161 preliminary data sheet – International Rectifier Corp (2003)

Halogen Convertor Control IC – Powersystems World presentation notes (2003)