International Rectifier

APPLICATION NOTE

Application Note AN-1069

Electronic Transformer Applications

By Peter Green

Table of Contents

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Electronic Transformer Applications

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Introduction

For practical product designs based around the IR2161, the IRPLHALO1E circuit topology may not contain all of the required functionality. In this application note we have some additional circuit ideas that can solve some of the design problems that may be encountered.

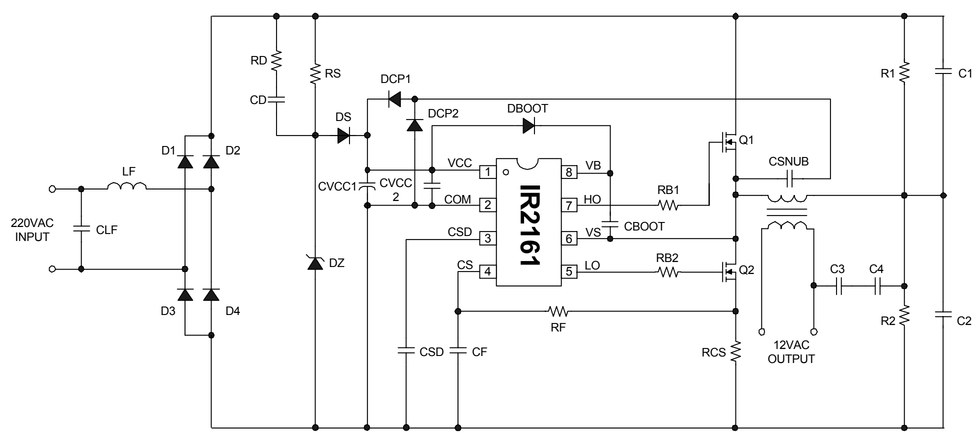

Fig. 1 IRPLHALO1E Basic Circuit Schematic

Protection Issues for IR2161 Halogen Circuits

Open Circuit Protection

In some designs it has been found that the MOSFETs overheat under a continuous open circuit condition. This depends largely on the size of the MOSFETs and the value of the snubber capacitor CSNUB. In the IRPLHALO1E design the value of CSNUB has been kept very small in order to allow the adaptive dead-time circuit to function over as wide a range of loads as possible. In this case the VCC supply current has to be augmented by the current from RD and CD to be sufficient to operate the IR2161 and surrounding circuitry.

It is also known that when the load is reduced below a certain level, the adaptive dead-time function within the IR2161 is no longer able to operate due to the fact that the VS voltage no longer slews all the way down to COM but instead starts to ring out into an oscillation. In this case the dead time becomes a fixed default value of approximately 1.2uS. When there is no load there has to be hard switching of the MOSFETs because commutation is impossible under this condition. Consequently high dV/dT occurs at VS causing large transient currents to flow through CSNUB and the parasitic capacitances in the MOSFETs. Therefore in a higher power design where the MOSFETs need to have a larger die size to support the current, the parasitic capacitances are higher and the value of CSNUB also needs to be higher in order to provide the greater supply current needed at VCC to provide the necessary gate drive. In this situation the transient currents in the MOSFETs under an open circuit condition cause serious overheating and eventual damage. A method has been devised that allows the open circuit condition to trigger the short circuit protection feature of the IC and cause it to go into the 50ms on and 1s off auto restarting mode, therefore preventing the MOSFETs from overheating.

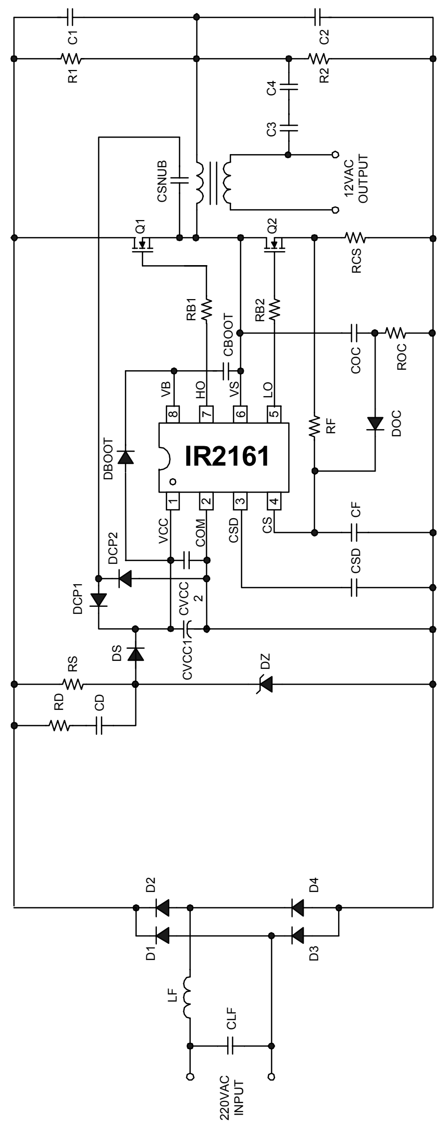

Fig. 2 Halogen Convertor with Open Circuit Protection

The capacitor COC can be a small value, e.g. 100pF to minimize the additional snubbing capacitance added and ROC can be in the order of ohms e.g. 10R to develop a voltage peak sufficiently high to conduct through the diode DOC, which can be a 1N4148. The transient voltages will charge CF above the short circuit threshold under conditions of total hard switching and cause the IR2161 to shut down as if a short circuit had occurred. The values of COC and ROC must be selected so that under normal operating conditions the voltage developed at the anode of DOC due to the dV/dT at VS when soft switching is occurring is not sufficient to trigger the short circuit protection.

Short Circuit Protection

It has been found that if the basic halogen circuit as shown above is subjected to a continuous short circuit, the MOSFETs Q1 and Q2 will gradually heat up under normal self-resetting operation. The MOSFETs can eventually reach a very high temperature and fail. This effect is compunded by the fact that as MOSFETs increase in temperature, the RDS(on) value also increases, which results in additional losses and even more heating. In some designs, where there are no heat sinks on the MOSFETs this can be a problem.

It should also be noted that gate drive resistors are essential to prevent high dv/dt from occuring that can cause the HO output to miss pulses under short circuit condition. If this situation arises the shut down circuit will fail to operate correctly within the IR2161. The choice of gate drive resistors depends on the MOSFETs used. In some cases 33R has been found to be more reliable than 22R. The tradeoff is that the MOSFETs will run slightly hotter the larger the gate drive resistors. The designer should carry out tests with the system driving a short circuit load for several minutes to determine that the MOSFET temperature remains within acceptable limits and operation remains stable.

Thermal Shutdown

One simple method of avoiding the MOSFETs reaching excessive temperature during a prolonged short circuit condition is to make use of the thermal shutdown feature of the IR2161. If the MOSFETs reach a sufficiently high temperature, some of the heat is conducted through the Copper traces of the PCB to the die of the IC itself. If the die becomes suffieciently hot, the thermal shutdown will operate and the IC will shut down before the MOSFETs are damaged. This shutdown is latching until the line voltage is re-cycled.

This method relies heaviliy on there being very good thermal conduction between the IC and the power MOSFETs. In order to optimize this, the copper trace from the VS pin to the two MOSFETs must be short and utilize as much copper area as possible.

The effectiveness of this method depends very much on the type of MOSFETs used and the layout of the PCB.

Extending the Resetting Time

Here the reset time of the shutdown circuit is greatly extended by adding a resistor of high ohmic value between the CSD pin of the IR2161 and VCC. This effectively prolongs the time taken for the CSD capacitor to discharge from 12V to 2.5V during the resetting phase of the shutdown sequence. It has negligable effect on the time that the IC takes to shutdown under short circuit but increases the re-start time from 2S to several seconds more. A 22M resistor will extend the reset time without preventing the IC from resetting altogether.

The idea here is to reduce the heating of the power MOSFETs under a continuous short circuit condition by allowing the devices more time to cool between the periods when the system is operating and delivering a high current. In this way it should be possible to greatly slow down the heating of the devices under this condition.

Latched Shutdown

In designs where the power switches are small and not able to survive a continuous short circuit condition the solution is to make the shutdown latching so that the supply voltage must be switched off and then back on again in order for the system to begin operating again.

The IR2161 has a latching shutdown feature that can be triggered by applying a voltage above 9V to the CS pin for more than 1uS. This threshold is too high to allow the latching shutdown function of the IR2161 to be used from the current sense pin voltage or the voltage developed across ROC in the circuit of *Fig 2*. The intention for this function was that it should be activated by external circuitry in specialized applications where a higher fault voltage is available.

Consequently an additional circuit has been devised that uses a small SCR connected from VCC to COM that can be configured to shut down in the event of a short circuit. It is very important to add some delay to ensure that the system will never shut down due to the inrush current at switch on that occurs if the lamps are cold. This latched shutdown method is described in detail in the following section describing the self dimming circuit.

Self Dimming

In some applications it is necessary for an electronic transformer to be dimmable from a built in potentiometer. This is possible to implement with the IR2161.

The circuit shown in *Fig .5* has been found to be very effective. It is able to provide flicker free dimming from 100% to zero output. A low cost dual comparator IC has been added, which has open collector or drain outputs. The additional circuitry can be supplied from VCC without drawing excessive current, although the value of RS needs to be reduced to around 56K (a lower value may be necessary) to supply the extra current needed. A ramp waveform, synchronized to the line voltage

half-cycle is generated at CT. This signal is fed into the second comparator where the other input is a DC control voltage derived from the potentiometer, producing a line locked rectangular waveform at the output, with a variable duty cycle. When this output is high, the CS pin is pulled above the short circuit threshold through D6, causing the IR2161 to shut down. In order for this circuit to operate the shut down delay must be greatly reduced and so CSD has to be reduced to 1nF. A parallel resistor RDS of 1M is also added to provide a quick discharge for CSD when the voltage from D6 drops again. R8 needs to be low enough in value for a sufficiently high voltage to appear at CS when the comparator output is high, considering that RF effectively provides a 1K pull down to COM. R8 should not be any lower than is necessary to provide about 1.5V at CS when the comparator output is high, to minimize the current drawn from VCC.
This dimming function works very well but unfortunately also prevents the short circuit protection

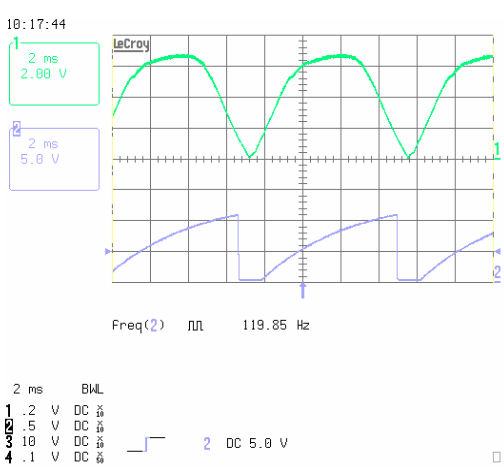

Fig. 3
Green: Signal at R3/R4
Blue: Signal at R7/CT

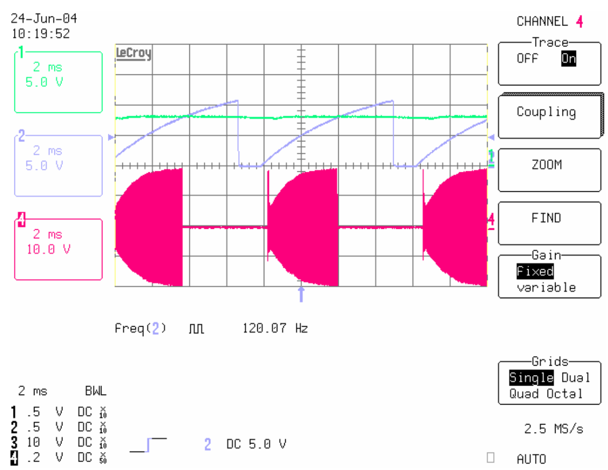

Fig. 4
Green: RV1 Output
Blue: Signal at R7/CT
Red: Transformer Output

from operating. To overcome this shortcoming, an external short circuit protection circuit has been added. In the event of a short circuit, SCR1 will fire and pull VCC down below the UVLO- threshold, shutting down the IR2161. The current from RS will maintain the holding current of SCR1 so that the AC supply would have to be switched off and then switched back on again in order for the circuit to operate again.
In the example shown here trailing edge dimming has been implemented as this produces fewer

harmonics on the ac line current waveform and requires less filtering. It is possible to produce a leading edge version using the same circuit by reversing the inputs to the second comparator.

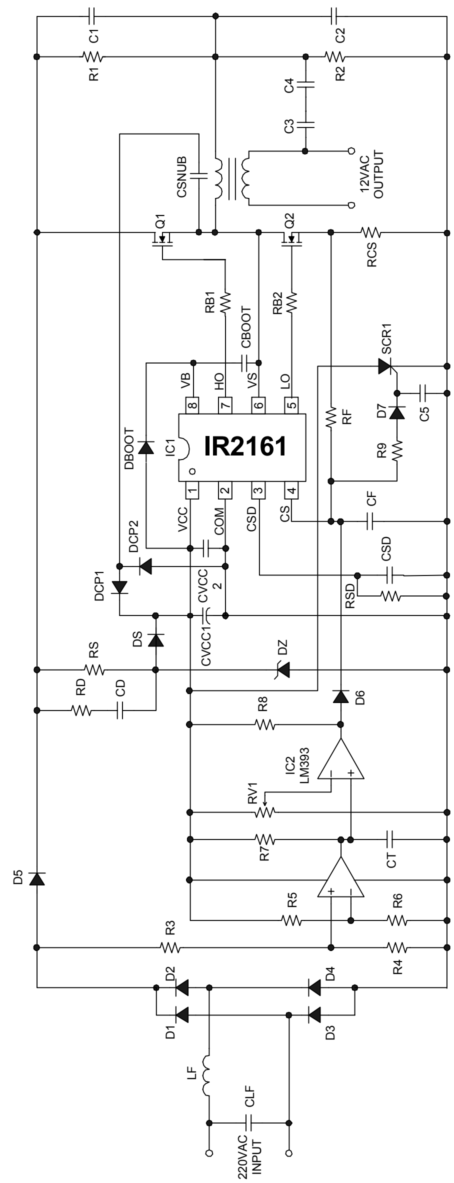

Fig .5 Self Dimming Electronic Transformer

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 Self Dimming Electronic Transformer (*Fig. 5)* Issue:A Peter Green June 2004

Item	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	2	CF,CSD
5	Capacitor	100nF, 25V	C317C104M5U5CA	Kemet	3	CVCC2,C5,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	Capacitor	47nF, 25V	C317C473M5U5CA	Kemet	1	CT
10	Diode	1000V, 1A	1N4007-T	Diodes Inc	6	D1-5,DS
11	Diode	600V, 1A	1N4937-T	Diodes Inc	1	DB
12	Diode	75V, 500mW	!N4148-T	Diodes Inc	4	DCP1,DCP2,D6,D7
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	190190760000	Kaschke (equivalent also available from Vogt)	1	T1
16	Resistor	470K, 1W	5073NW470K0J12AFX	BC Components	2	R1,2
17	Resistor	56K, 3W	2322 329 03563	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	2	RF,R6
21	Resistor	100K, 1W	5073NW100K0J12AFX	BC Components	2	R3,R7
22	Resistor	2K2, 1W	5073NW2K200J12AFX	BC Components	1	R4
23	Resistor	10K, 1W	5073NW10K00J12AFX	BC Components	3	R5,R8,R9
24	Resistor	1M, 1W	5073NW1M000J12AFX	BC Components	1	RSD
25	Pot	100K	EVM-4LGA00B15	Panasonic ECG	1	RV1
26	SCR	2N5064	2N5064RLRA	ON Semi	1	SCR1
27	IC	Controller	IR2161	IR	1	In Socket
28	IC Socket	8 Pin DIP	2-641260-1	Amp Tyco Electronics	1	IC1
29	IC	Dual Comparator	LM393	STM	1	IC2
30	FETs	400V	IRF740	IR	2	Q1,2
31	Connector	5 Way	236-105	Wago	1	P1
32	Connector	6 Way	236-106	Wago	1	P2

Implementation of DALI with the IR2161

DALI (Digitally Addressable Lighting Interface) is a method of dimming through a serial digital bus and can be implemented into the system using an extension of the circuit concepts desribed in the above section *Self Dimming.* The section of circuitry containing the dual comparators is now no longer necessary and may be replaced with a micro controller. There is a wide choice of micro controllers available many of which contain very useful additional hardware such as comparators that could be used to realize the shutdown circuitry in the micro controller instead of with an extra circuit as shown in *Fig .5.* One IO port from the micro controller will be fed through a diode into the CS pin of the IR2161 to enable and disable the IR2161. The value of CSD will need to be 1nF and RSD of 1M would need to be included. The resistors dividing down from the DC bus at the cathodes of D1, D2 and D6 of *Fig .5* may be used to provide line voltage cycle zero crossing detection. It would be advisable to clamp the signal with a 5.6V zener diode to prevent possible excess voltage from being applied to the microcontroller IO input.

It would also be necessary to derive a 5V supply from VCC for the microcontroller. This could probably be implemented with a simple resistor and zener diode arrangement. It is important that the micro controller is powered at all times even when the system is switched off, although in this state it can be in a low power sleep mode. If necessary an auxiliary winding could be added to the output transformer to provide additional VCC supply current when the system is running and if this is used the charge pump would no longer be necessary.

With regard to programming the micro controller, a very similar code to that used in International Rectifier's reference design DALI ballast *IRPLDIM2* could be used. One important change to be made would be that the PWM output that controls the dimming level would need to be synchronized to the line frequency and used to drive the IR2161 CS pin directly prviding phase cut dimming. This allows flicker free dimming to be obtained.

The schematic shown in *Fig .6* illustrates how the DALI section of circuitry from reference design kit *IRPLDIM2* could be inserted into an electronic transformer based around the IR2161. It is important to be aware that *the software that operates the IRPLDIM2 reference design will not operate in this case without modification.* It is also important to consider that the circuit shown in *Fig .6* is only an example of how DALI could be implemented and is not necessarily the best choice.

In addition this implementation also utilizes the micro controller for the shutdown function. The signal at the current sense is fed into one of the IO ports of the PIC16F628. This microcontroller can be configured so that inputs RA0 and RA3 form the inputs of a comparator and therefore the voltage set by the R6/R7 divider sets the threshold for the current sense. It is also advisable to increase the value of CF to remove the high frequency component of the signal. The micro controller needs to monitor the peak current and would be able to do this more easily. The software can be programmed with a delayed shutdown and auto restart operation as required of simply to shutdown completely.

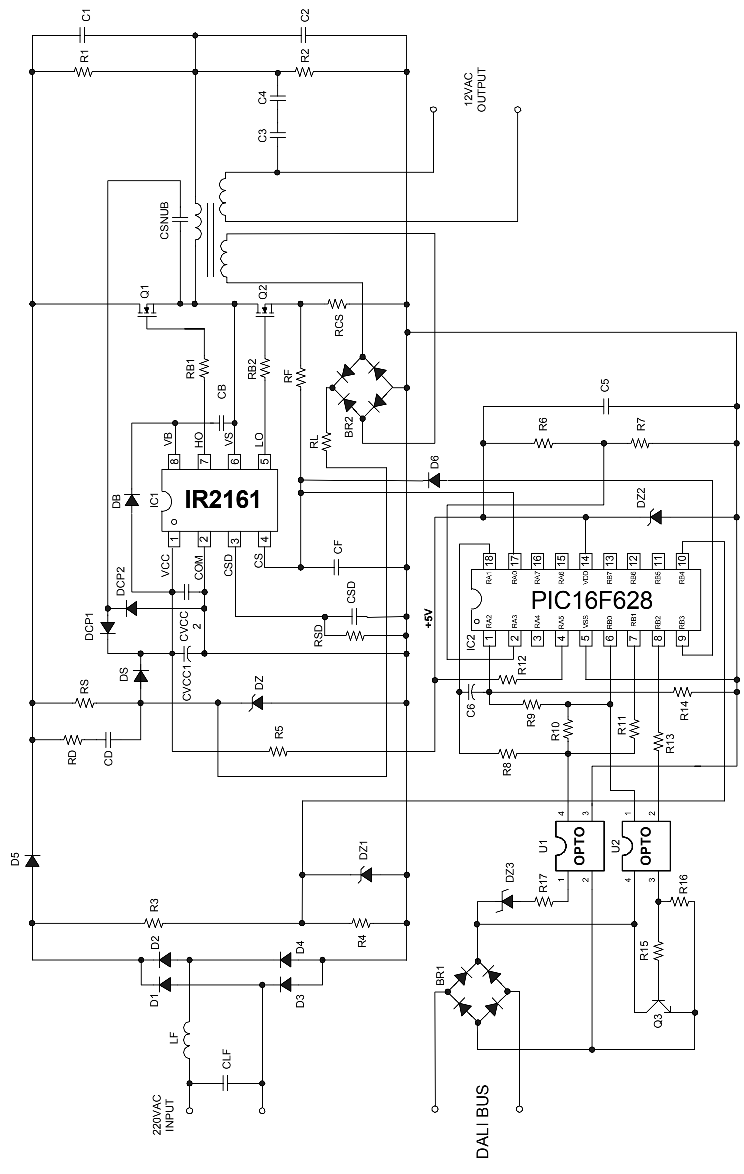

Fig .6 DALI Electronic Transformer

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 DALI Electronic Transformer (*Fig. 6)* Issue:A Peter Green June 2004

Item	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	3	CF,CSD,C6
5	Capacitor	100nF, 25V	C317C104M5U5CA	Kemet	3	CVCC2,C5,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	6	D1-5,DS
10	Diode	600V, 1A	1N4937-T	Diodes Inc	1	DB
11	Diode	75V, 500mW	!N4148-T	Diodes Inc	4	DCP1,DCP2,D6,D7
12	Zener	16V, 1W	1N4745A-T	Diodes Inc	2	DZ
13	Zener	5V1, 500mW	1N5231B-T	Diodes Inc	3	DZ1,2,3
14	Bridge	200V, 0.5A	MBS2	General Inst	2	BR1,2
15	Inductor	Vertical E20 Iron powder	094094912000	Kaschke	1	LF
16	Transformer				1	T1
17	Resistor	470K, 1W	5073NW470K0J12AFX	BC Components	2	R1,2
18	Resistor	56K, 3W	2322 329 03563	BC Components	1	RS
19	Resistor	270R, 3W	2322 329 03271BC	BC Components	1	RD
20	Resistor	22R, 1206, SMD	ERJ-8GEYJ220V	Panasonic ECG	2	RB1, RB2
21	Resistor	0R33, 0.5W	ALSR1F-.33R-ND	Huntingdon Electric Inc	1	RCS
22	Resistor	1K, 1W	5073NW1K000J12AFX	BC Components	1	RF
23	Resistor	100K, 1W	5073NW100K0J12AFX	BC Components	4	R3,R6,R7,R10
24	Resistor	2K2, 1W	5073NW2K200J12AFX	BC Components	2	R4,25R13
25	Resistor	10K, 1W	5073NW10K00J12AFX	BC Components	4	R5,R8,R11,R12
26	Resistor	1M, 1W	5073NW1M000J12AFX	BC Components	1	RSD
27	Resistor	360K, 1W	5073NW360K0J12AFX	BC Components	1	R9
28	Resistor	75K, 1W	5073NW75K00J12AFX	BC Components	1	R14
29	SCR	2N5064	2N5064RLRA	ON Semi	1	SCR1
30	IC	Controller	IR2161	IR	1	In Socket
31	IC Socket	8 Pin DIP			1	IC1
32	IC	Microcontroller	PIC16F628-I/P	Microchip	1	In Socket
33	IC Socket	18 Pin DIP			1	IC2
34	Optocoupler	4 Pin DIP	PC357WT	Sharp	2	U1,2
35	FETs	N-Channel 400V	IRF740	IR	2	Q1,2
36	Transistor	NPN	FMMT491ACT-ND	Zetex	1	Q3

Line Voltage Compensation

Line voltage compensation has not generally been provided in electronic transformers. For optimum performance the lamps should be driven at their correct power rating, which means that the RMS output voltage of the transformer needs to be within reasonable limits. Since there is some degree of load regulation in any electronic transformer, the reality is that most designs can provide the correct output voltage over a range of loads from 20% to maximum, but only provided the AC input voltage is fixed. Therefore a transformer rated for 230VAC will provide a low light output if used with a 220VAC supply and overdrive the lamps, shortening the lamp life, if used from a 240VAC supply.

In certain high end applications it may be desirable to introduce some additional regulation that allows the transformer to operate over a range of input voltage as well as load. The most effective way of doing this is by adding a regulated power factor correcting boost converter at the front end that would produce a smooth and regulated DC bus. Such front end pre-regulators are commonly used in electronic ballasts for Fluorescent and HID applications and are based on industry standard low cost power factor control ICs. The drawback is that an additional inductor is required.

This approach would allow a simple electronic transformer circuit as shown in *Fig 1. or 2.* to be added to the back end where the only changes required would be to the output transformer turns ratio and possibly the value of RCS.

Unfortunately this solution is likely to be cost prohibitive in most applications and in addition would not allow the electronic transformer to be dimmable from a phase cut dimmer any longer, unless some additional circuitry were to be added.

Another possibility is to sense the output voltage and provide some feedback that reduces the output if the voltage at the lamps becomes too high. The difficulty here is accurately detecting the output voltage. A circuit has been experimented with which provides limited performance. In order to achieve very accurate control, it may be necessary to include an expensive true RMS to DC conversion IC at the output. However, it is possible to provide reasonable feedback information by using a diode and RC integrator arrangement at the output to produce a DC voltage that tracks the AC output. A low cost method of feedback would be to use an opto isolator, however this must be rated to a high isolation voltage inorder to comply with safety standards for electronic transformers.

Regulation by frequency

The circuit shown in *Fig .7* shows a method of adjusting the output voltage by pulling down on the CS pin when the voltage increases to a certain point. This will cause the frequency to increase and as a result the output voltage will drop again due to the primary leakage inductance of the output transformer.

The method used to sense the output voltage relies on peak detection and is not particularly accurate, however it may be sufficiently accurate for the application and can probably be optimized further. A DC voltage is produced at C7, which is roughly proportional to the RMS output of the transformer. This voltage is divided down and fed into IC3, a low cost industry standard programmable zener diode with 1% tolerance. The reference voltage is 2.5V, which when exceeded causes the device to conduct from cathode to anode like a regular zener diode. When IC3 conducts there is current in the diode of the opto isolator thus causing the opto transistor to switch on and pull down on the CS pin of the IR2161.

This circuit also prevents the shutdown circuit of the IR2161 from operating in the normal way and therefore the external SCR based protection circuit also needs to be added.

The performance results obtained from this circuit depend greatly on the amount of leakage inductance of the output transformer, because the more leakage inductance there is, the more voltage shift will be obtained by adjusting the frequency. The accuracy of the sensing method of the output voltage is also a major contributing factor in the performance of this circuit.

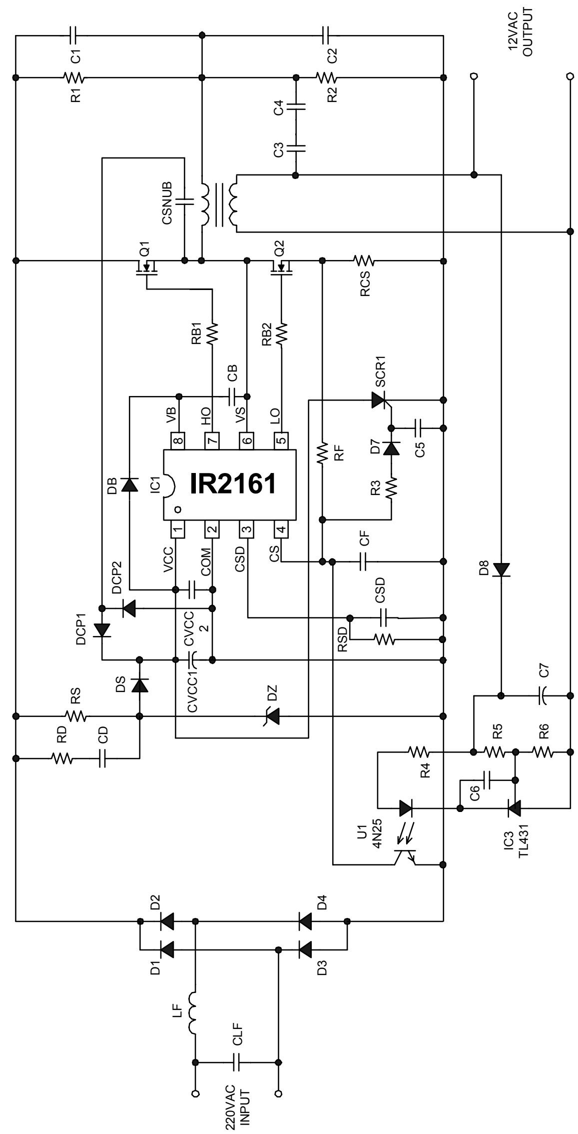

Fig 7. Regulation of the frequency

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 Frequency Regulating Electronic Transformer (*Fig. 7)* Issue:A Peter Green June 2004

Item	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	2	CF,CSD
5	Capacitor	100nF, 25V	C317C104M5U5CA	Kemet	4	CVCC2,C5,6,CB
6	Capacitor	330nF, 400V	ECQ-E4334KF	Panasonic ECG	1	CD
7	Capacitor	22uF, 50V, Radial	T350F226K016AS	Kemet	2	CVCC1,C7
8	Capacitor	150pF, 500V, Ceramic	D151K20Y5PL63L6	BC Components	1	CSNUB
9	Capacitor	47nF, 25V	C317C473M5U5CA	Kemet	1	CT
10	Diode	1000V, 1A	1N4007-T	Diodes Inc	6	D1-5,DS
11	Diode	600V, 1A	1N4937-T	Diodes Inc	1	DB
12	Diode	75V, 500mW	!N4148-T	Diodes Inc	5	DCP1,DCP2,D6,D7, D8
13	Zener	16V, 1W	1N4745A-T	Diodes Inc	2	DZ
14	Inductor	Vertical E20 Iron powder	094094912000	Kaschke	1	LF
15	Transformer				1	T1
16	Resistor	470K, 1W	5073NW470K0J12AFX	BC Components	2	R1,2
17	Resistor	56K, 3W	2322 329 03563	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	Resistor	2K2, 1W	5073NW2K200J12AFX	BC Components	1	R4
22	Resistor	10K, 1W	5073NW10K00J12AFX	BC Components	3	R3,R5,R10
23	Resistor	1M, 1W	5073NW1M000J12AFX	BC Components	1	RSD
24	Resistor	Select on Test			1	R6
25	SCR	2N5064	2N5064RLRA	ON Semi	1	SCR1
26	IC	Controller	IR2161	IR	1	In Socket
27	IC Socket	8 Pin DIP	2-641260-1	Amp Tyco Electronics	1	IC1
28	Zener Ref	TL431	TL431ACLP	Fairchild	1	IC2
29	Optocoupler	6 Pin DIP	4N25	Isocom	1	U1
30	FETs	400V	IRF740	IR	2	Q1,2

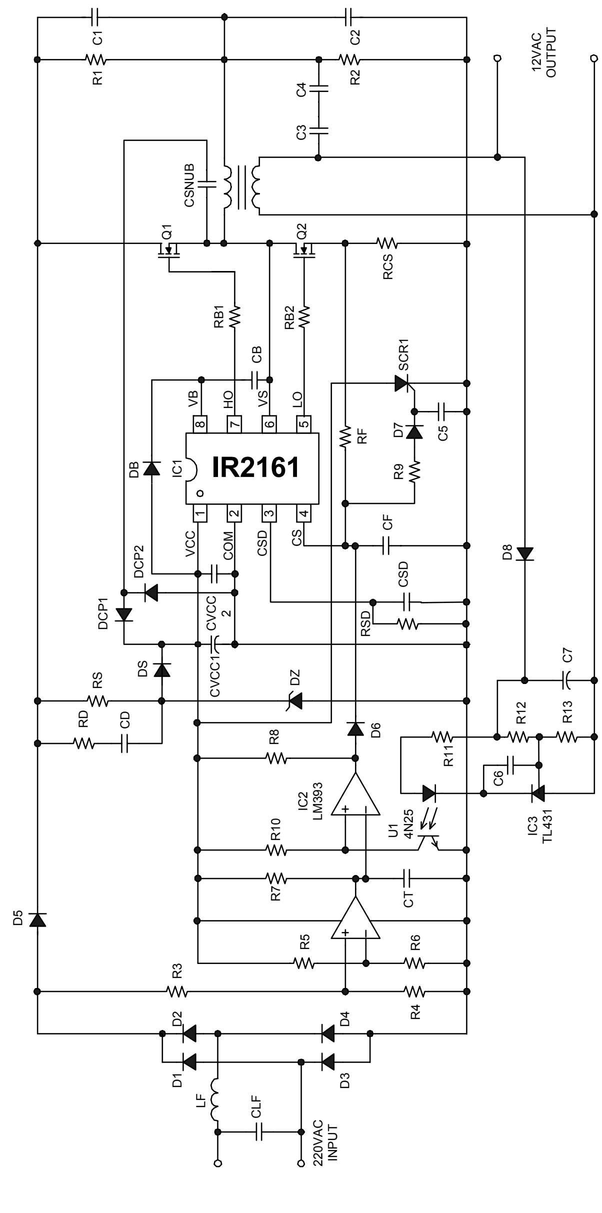

Fig 8. Regulation by phase cutting.

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   Phase Cut Regulating Electronic Transformer (*Fig. 8)* Issue: A   Peter Green June 2004

Item	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	2	CF,CSD
5	Capacitor	100nF, 25V	C317C104M5U5CA	Kemet	4	CVCC2,C5,6,CB
6	Capacitor	330nF, 400V	ECQ-E4334KF	Panasonic ECG	1	CD
7	Capacitor	22uF, 50V, Radial	T350F226K016AS	Kemet	2	CVCC1,C7
8	Capacitor	150pF, 500V, Ceramic	D151K20Y5PL63L6	BC Components	1	CSNUB
9	Diode	1000V, 1A	1N4007-T	Diodes Inc	6	D1-5,DS
10	Diode	600V, 1A	1N4937-T	Diodes Inc	1	DB
11						
12	Diode	75V, 500mW	!N4148-T	Diodes Inc	5	DCP1,DCP2,D6,D7, D8
13	Zener	16V, 1W	1N4745A-T	Diodes Inc	2	DZ
14	Inductor	Vertical E20 Iron powder	094094912000	Kaschke	1	LF
15	Transformer				1	T1
16	Resistor	470K, 1W	5073NW470K0J12AFX	BC Components	2	R1,2
17	Resistor	56K, 3W	2322 329 03563	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	2	RF,R6
21	Resistor	100K, 1W	5073NW100K0J12AFX	BC Components	2	R3,R7
22	Resistor	2K2, 1W	5073NW2K200J12AFX	BC Components	2	R4,R11
23	Resistor	10K, 1W	5073NW10K00J12AFX	BC Components	4	R5,R8,R9,R12
24	Resistor	1M, 1W	5073NW1M000J12AFX	BC Components	1	RSD
25	Resistor	Adjust on Test			1	R13
26	SCR	2N5064	2N5064RLRA	ON Semi	1	SCR1
27	IC	Controller	IR2161	IR	1	In Socket
28	IC Socket	8 Pin DIP	2-641260-1	Amp Tyco Electronics	1	IC1
29	IC	Dual Comparator	LM393	STM	1	IC2
30	Zener Ref	TL431	TL431ACLP	Fairchild	1	IC3
31	FETs	400V	IRF740	IR	2	Q1,2

Regulation by phase cutting

Another approach is shown in *Fig. 8* in which the adjustment range of the output can be whatever is required because the output is phase cut as in the self dimming circuit of *Fig .5.* This method can give better regulation if transformers that have low leakage inductance are used, than the frequency adjustment method of *Fig .8* however in order to be effective the output voltage measuring circuit would need some optimization. However current harmonics are introduced on the AC line where this method is used but not with regulation by frequency modulation.

Sensing the output with an additional winding

It is also possible to avoid using an opto isolator for sensing the output voltage, by adding an additional winding to the output transformer. This provides a very cheap method of obtaining an isolated feedback voltage, but is not able to provide a feedback voltage that is perfectly coupled with the secondary and therefore error is introduced.

It would be possible to use this sensing method with either the circuit of *Fig. 7* or *Fig. 8* and take out the opto isolator. This method could be accurate enough depending on the performance requirements of the design. It has the additional advantage that it could also be used to supply some power to drive VCC and therefore the charge pump could be removed and RS made larger.

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