AN IMPROVED ELECTRONIC BALLAST FOR FLUORESCENT LAMP

By

MURNI YAHYA

FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
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(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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Electrical & Electronics Engineering Programme
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Approved:

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Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

June 2008

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Murni Yahya

ABSTRACT

Ballast is a device needed to energize fluorescent lamps during operation. In fluorescent lighting systems, the ballast provides the proper voltage to start the lamp and then regulates the electric current flowing through the lamp to stabilize output. There are two types of ballast for fluorescent lamp: electromagnetic ballast and electronic ballast. Even though the electronic ballast has many advantages compared to electromagnetic ballast, it has high purchase cost and can only connect to one or two lamps. Therefore this project will be focusing to design electronic ballast which has high efficiency, cost effective and can operate multiple lamps. The end result of this project is the simulation result and the prototype of the product. The design process will include procedures such as research, calculation, simulation of Pspice and construction of the electronic ballast circuit. After some research, it was found that the combination of power factor correction (flyback converter) and self-oscillating inverter can build the electronic ballast which meets this project's requirement. The combination of all the circuits has been successfully simulated in Pspice software and result was obtained. The electronic components such as resistors, inductors, capacitor, and MOSFETs were bought and the prototype of the electronics ballast was built. The cost used to build the circuit is calculated and compare with the price of the electronic ballast in the market. The efficiency of the electronic ballast was calculated.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Fluorescent lamp which was introduced commercially in 1940s [1] has become the most popular and most versatile package of light available in the market. This is because fluorescent lamp has high luminous efficiency, energy-saving and long lamp lifetime compared to other types of lamp. [2 - 6] The fluorescent lamp is three to four times more energy efficient compared to the incandescent lamps and its efficiency can be further increased by operating it at a high frequency, more than 25kHz. [3]

When fluorescent lamp starts to operate, the gas inside it will grow warmer. As the gas heats, the electrical resistance of the gas goes down and this will allow more current to flow. Therefore, the gas will become even hotter and thus allows even more current. This phenomenon is called as negative resistance which can make the fluorescent lamp destroy itself. [3- 4]

In order to solve the negative resistance problem, ballast, as shown in Figure 1, has been introduced so that each lamp can only draw a certain amount of electricity no matter how hot the gas is by limiting the current flow to the lamp. [4, 11] In other words, ballast is an electrical device that supplies sufficient voltage to start the flow of arc current in a fluorescent lamp and at the same time limit the current flow to the lamp to stabilize the output. The simplest ballast is inductive reactor or choke. [3-4]

Figure 1: Ballasts [5]

In the dictionary, the term 'ballast' refers to the heavy objects that are at the bottom of a large ship to stabilize the ship's vessel. The ballast in electrical term has the same concept as the ship's ballast which is to stabilize the lamp operation. [4]

1.2 Problem Statements

Even though electronic ballast is better in many ways than electromagnetic ballast, it still has certain weaknesses such as high purchase cost. The high purchase cost or initial cost [2] is the reason electronic ballast cannot compete with electromagnetic ballast. [6]

From literature review, electronic ballast can only operate one or two fluorescent lamps. [7, 8] The cost of electronic ballast will be expensive when it is used to supply a small output power (one or two lamps). In order to decrease the cost, the electronic ballast must be able to supply multiple lamps. [8]

For example, if there are ten fluorescent lamps that need to be installed, the minimum numbers of electronic ballasts that needed in the lighting system are five if one electronic ballast can connect to two fluorescent lamps. If the price for one electronic ballast is RM170, then the total cost that has been spent for ballasts in order to install the lighting system is RM850. If the number of lamps that can be connected to one or two ballast is increased to four lamps, and then the total cost that has been spent is just RM510, a reduction 40% of the cost.

1.3 Objective and Scope of Study

The objective of this project is to design and build a prototype of electronic ballast circuit for fluorescent lamp which has high efficiency, cost effective and can operate more lamps compared to the electronic ballast which is available in the market today.

In order to achieve the objective, the author studied and analysed the differences between electromagnetic ballast and electronic ballast and identify main components in electronic ballast such as Power Factor Correction (PFC) and inverter. The author also studied several alternatives of suitable lamp arrangements to make the electronic ballast can be operated for multiple lamps. Then, the author designed the electronic ballast circuit with suitable software and finally builds its prototype.

CHAPTER 2
LITERATURE REVIEW

2.1 Electromagnetic Ballast

There are two types of ballasts namely electromagnetic ballast and electronic ballast. The more traditional is electromagnetic ballast which uses a core and coil assembly transformer that provides minimum functions of starting and operating the lamp. [1] Electromagnetic ballast is cheap, quite heavy and generates lots of heat during the operation, thus it has low efficiency. [1, 2, 7, 9] In the electromagnetic ballast, there is a transformer or similar magnetic coil that operates at 50 or 60Hz which generates a low frequency humming noise when operating. [2, 11] Figure 2 shows electromagnetic ballast which is available in the market.

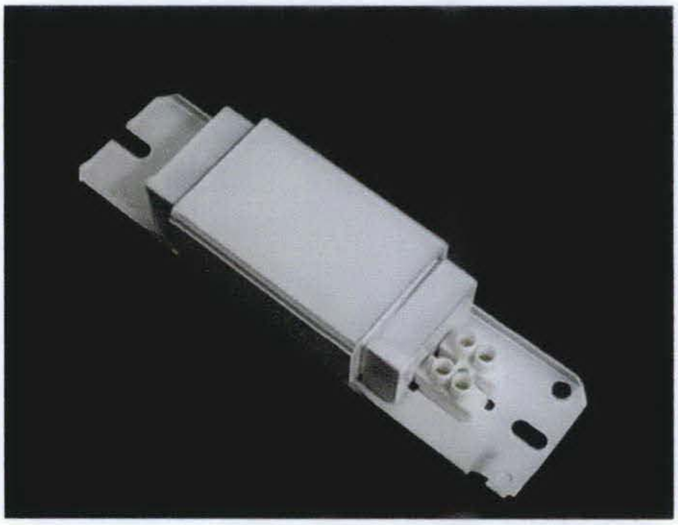

Figure 2: An electromagnetic ballast [10]

2.2 Electronic Ballast

Electronic ballast contains semiconductors and other electronic components as shown in Figure 3. Its weight is typically 50% less than electromagnetic ballast and can be squeezed into smaller spaces. It has no audible noise as in the electromagnetic ballast. In fact, electronic ballast actually does produce some noise because there still is a transformer inside the switching power supply in the ballast. However, the sound that does escape the enclosure of an electronic ballast fixture is above the human hearing range. [7,11]

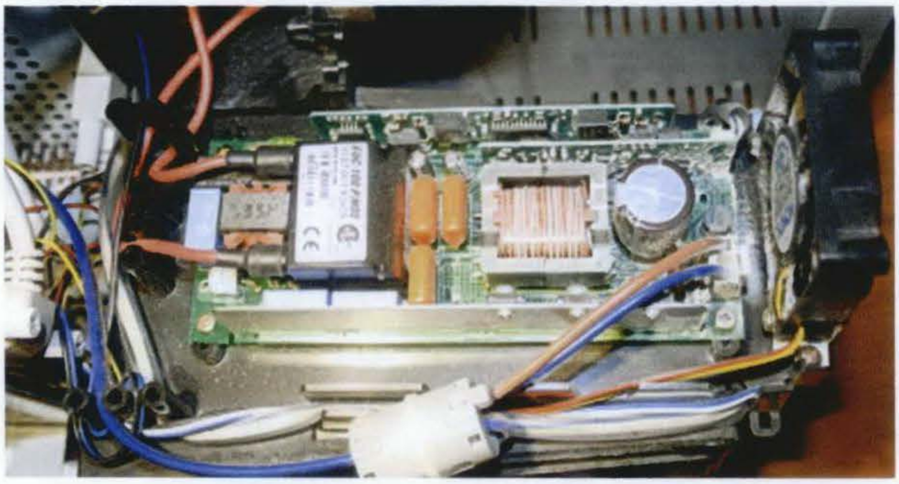

Figure 3: Electronic components inside electronic ballast [12]

Since the electronic ballast operates in low temperature, 30 degree Celsius (30°C) lower than electromagnetic ballast, it generates less heat making it more efficient. The electronic ballast is operating in high frequency, 20 kHz until 60 kHz this will reduce the electrical operating losses and make it more efficient. [4,13]

Although the purchase cost of electronic ballast is higher compared to electromagnetic ballast its operating cost and maintenance cost is lower than electromagnetic ballast, thus an overall lower cost. [1] The detailed calculations on life cycle cost based on 20 years service life for electronic ballast in comparison to conventional electromagnetic ballast as given in Appendices. The following aspects were taken into considerations:

i) Initial capital/installation cost

ii) Maintenance cost

iii) Operation or energy cost

The 20-year life cycle cost for a 2 x 36W indoor fluorescent light fitting equipped with electronic ballast (RM1,150.16) is considerably lower than the one equipped with electromagnetic ballast (RM1,432.40).

2.3 Comparison between electromagnetic ballast and electronic ballast

Electronic ballasts offer numerous benefits in comparison to conventional electromagnetic ballasts as given in the Table 1.

Table 1 : Comparison between electromagnetic ballast and electronic ballast

Criteria	Electromagnetic Ballast	Electronic Ballast
Heat	Wastes internal energy which generates about 30 °C more heat.	Reduced internal losses to less than 8 watts results in 5-10 percent less air conditioning costs.
Light Flicker	Operates at 50 Hz frequency which can cause light flicker	Operates at 20k -60 kHz which produces virtually no detectable flicker
Noise	Vibration of electromagnetic field causes humming noise.	No audible noise
Weight	Heavy components coated in heavy protective material.	Weights about half as much as electromagnetic type.

2.4 Basic Construction of Electronic Ballast Circuit

Nowadays, inverters are used for energizing the lamp because of the rapid development of power electronics technology. These inverter systems are now referred as the electronic ballast and can eliminate the conventional magnetic ballast's disadvantages. [7]

Figure 4 shows a functional block diagram of the electronic ballast. The main power will supply alternating current, (AC) voltage and then rectified to a directing current, (DC) voltage using power factor correction rectifier. [7]

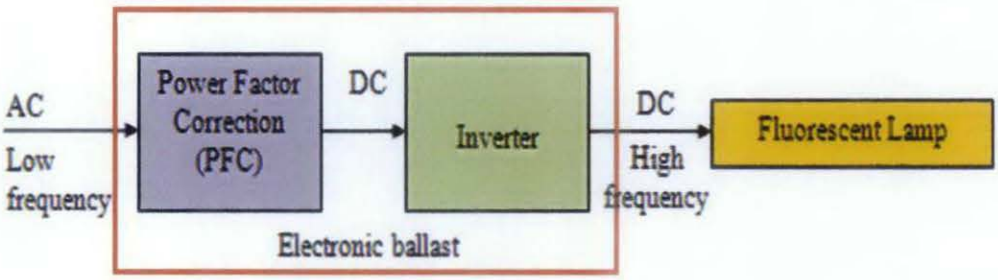

Figure 4: Schematic diagram of electronic ballast

Then, the DC voltage is inverted into a high frequency AC voltage to drive the fluorescent lamp. The power factor correction rectifier is to improve the input power factor to near unity. As a result, the harmonic current can be reduced. The high harmonic current will make the electromagnetic interference occur which can cause disturbance to other equipment, and do not meet international standards. [7]

2.5 Power Factor Correction (PFC)

2.5.1 Power Factor (PF)

Fluorescent lamp requires ballast (chokes) or transformer for operating which has a low lagging power factor between 0.3 until 0.5. When a fluorescent lamp is switched on, it draws apparent power, S (Unit: VA) from the mains. This apparent power consists of active power, P (unit: W) and is the reactive power, Q (Unit: VAr). Power factor or also know as PF or cos Ø is the ratio of active power to the apparent power as shown in equation (1) below. [3, 14, 15]

$$\text{Power factor (PF)} = \frac{\text{Active power}}{\text{Apparent power}} = \frac{P}{S} = \frac{P}{VI} = \cos \emptyset \dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

2.5.2 Power Factor Correction (PFC)

Ballast is an inductive component which draws reactive power (Var) from the mains. It lags behind the active power (W) by 90° as shown in Figure 5. [14]

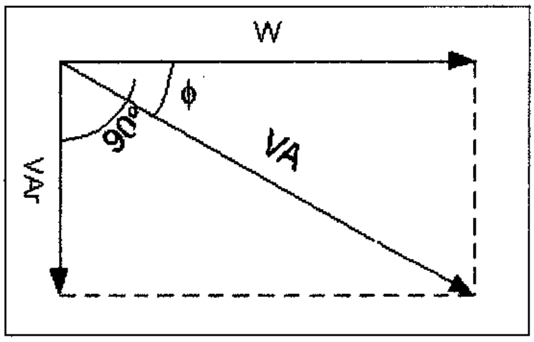

Figure 5: Relation of apparent power, reactive power and active power [14]

If a capacitor is connected across the mains, it will also draw reactive power ($VAr_{(c)}$), but it leads the active power (W) by 90°. The direction of the capacitive reactive power ($VAr_{(c)}$) is opposite to the direction of the inductive reactive power (VAr) as shown in Figure 6. [14]

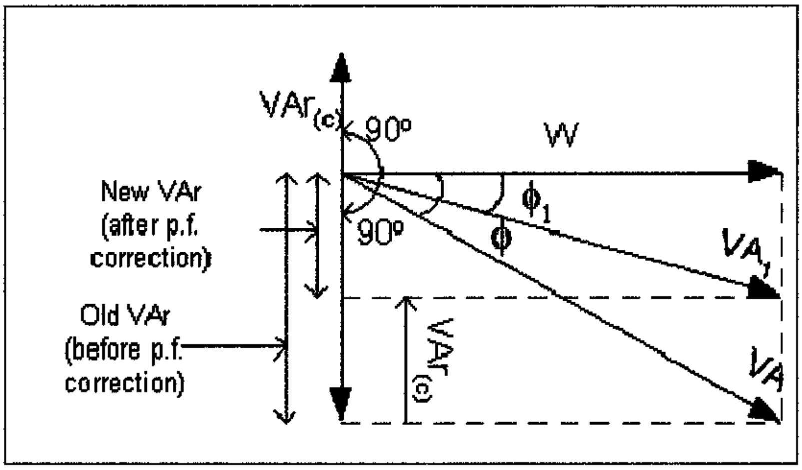

Figure 6: Corrected power factor [14]

If a suitable capacitor is connected in parallel with an inductive load, it will draw capacitive reactive power ($VAr_{(c)}$). The effective reactive power drawn by the circuit will be reduced to the extent of the capacitive reactive power ($VAr_{(c)}$), resulting in a reduction of apparent power from VA to VA_1. The phase angle between the active power and the new apparent power VA_1 will also reduce from Ø to $Ø_1$ as shown in Figure 6. As a result, the power factor will increase from cos Ø to cos $Ø_1$. Therefore, the new improved power factor can be devoted by the equation (2) below. The power factor can be improved to between 0.9 and 0.95. [14]

$$\text{New power factor (PF)} = \cos Ø_1 = \frac{W}{VA_1} \quad \text{.......................................}(2)$$

2.6 Alternatives Electronic Ballasts

In order to design the electronic ballast, some researches have been conducted. Table 2 is the summary of the methods that can be used in order to build electronic ballast for this project. There are three most important things that need to be considered in order to design electronic ballast: Power Factor Correction (PFC), inverter and lamp arrangement. The examples of PFC are boost converter, buck converter, buck-boost converter, flyback converter and valley-fill filters. The advantages and disadvantages of all of the PFC are listed in the Table 2.

Table 2: Summary of methods used to build electronic ballast

Consideration in design	Types	Method	Advantages	Disadvantages
To improve power factor correction (PFC)	Active (depend on load)	Boost converter	-Power factor nearly unity	-Expensive -Voltage and current stresses
		Buck converter	-Power factor nearly unity	-Expensive -Voltage and current stresses
		Buck-boost converter	-Power factor nearly unity	-Expensive -Voltage and current stresses
		Flyback converter	-Power factor nearly unity -Simple and flexible	-Expensive -Voltage and current stresses
	Passive (not depend on load)	Valley-fill filter	-Very low cost	-Does not meet standard requirement - Reducing the lighting efficiency - Reduced the lifetime of the lamps
Inverter	-	Self-oscillating	-Low cost, feasibility and reliability	-Limited to one lamp for one ballast because its switching frequency is dependent on the ballast load.

There are two method of power factor correction: active method and passive method. Buck converter, boost converter, buck-boost converter and flyback converter are examples of active methods. The active method depends on the load (lamp), in the other word, it does not have feedback but the passives method is independent of the load [16]. This active method is expensive and present voltage and current stresses. The valley-fill filter is an example of passive method. The valley-fill filter is cheap but it is not meet the standard requirement IEC 61000-3-2 Class C which is shown in Table 3. [17]

Table 3: IEC 61000-3-2 CLASS C STANDARD

Harmonics (n)	2	3	5	7	9	11<19
Limit (%) PF	2	30	10	7	5	3

Boost converter is more often used than flyback converter because the existing control methods make it easier to control the average inductor current than the switch current. However, for low application, flyback converter is more attractive than boost converter due to its simplicity and flexibility. In the flyback converter, the line voltage is not necessarily lower than the output voltage as in boost converter. When flyback converter operates in discontinuous-conduction mode, a unity power factor can be achieved by constant on-time control. [18]

After considering all the advantages and disadvantages, the author had decided to choose flyback converter for the PFC which will be combined with an inverter in order to build multiple lamp electronic ballast.

2.6.1 Flyback Converter

The flyback converter operates on the principles of both buck and boost converters. Its derivation is illustrated in Figure 7 (a) below depicts the basic buck-boost converter, with the switch realized using a MOSFET and diode.

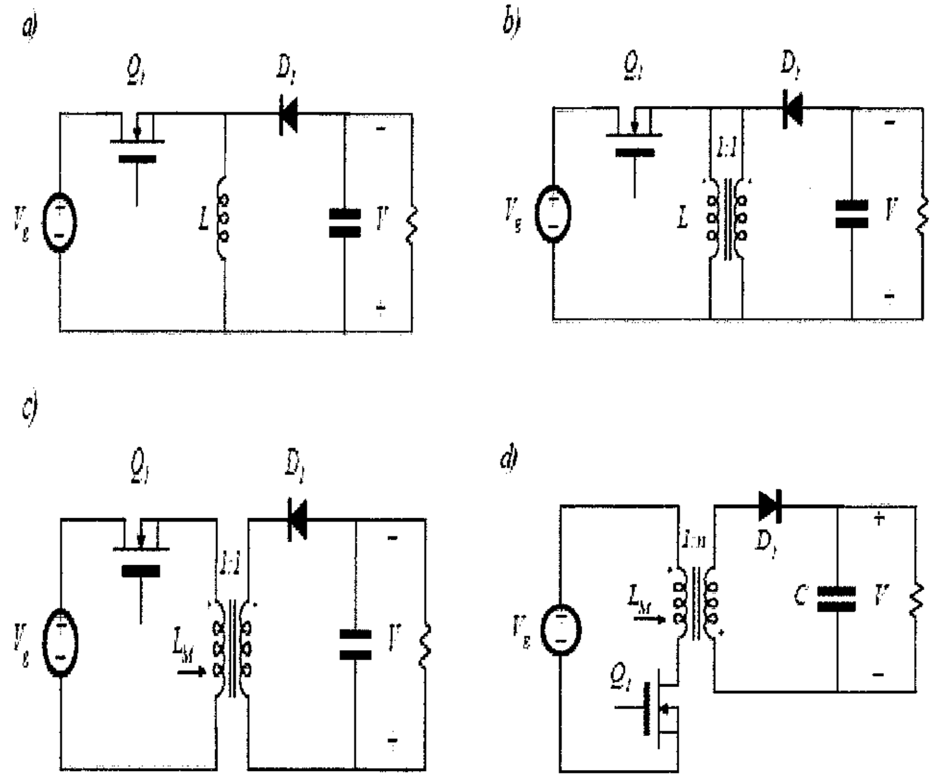

Figure 7: Derivation of the flyback converter: (a) buck-boost converter (b) inductor *L* is wound with two parallel wires (c) inductor windings are isolated, leading to the flyback converter (d) with a 1: *n* turns ratio and positive output.

In Figure 7 (b), the inductor winding is constructed using two wires, with a 1:1 turn ratio. The basic function of the inductor is unchanged, and the parallel windings are equivalent to a single winding constructed of larger wire.

In Figure 7 (c), the connections between the two windings are broken. One winding is used while the transistor *Q1* conducts, while the other winding is used when diode *D1* conducts. The total current in the two windings is unchanged from the circuit of Figure 7 (b), however, the current is now distributed between the windings differently. The magnetic fields inside the inductor in both cases are identical. Although the two-winding magnetic device is represented using the same symbol as the transformer, a more descriptive name is "two winding inductor". This device is sometimes also called a "flyback transformer". Unlike the ideal transformer, current does not flow simultaneously in both windings of the flyback transformer. [19,20]

Figure 7(d) illustrates the usual configuration of the flyback converter. The MOSFET source is connected to the primary-side ground, simplifying the gate drive circuit. The transformer polarity marks are reversed, to obtain a positive output voltage. A 1: *n* turns ratio is introduced allowing a better converter optimization. [18,19]

2.6.2 Full-wave Rectifier

The single-phase bridge circuit connection is the simplest diagrammatic layout. The bridge (full-wave or double-way) connection can be arranged to be uncontrolled, fully-controlled or half-controlled configurations. The uncontrolled circuit consists of diodes only, which means that it does not has tyristor as shown in Figure 8(a). The full-controlled circuit has tyristor in place of all diodes as shown in Figure 8(b) The half-controlled circuit has tyristor in place of half numbers of diodes, for example two tyristor and two diodes as shown in Figure 8(c). In the PFC circuit, the uncontrolled full-wave rectifier is used since it has the lowest cost. [21, 22]

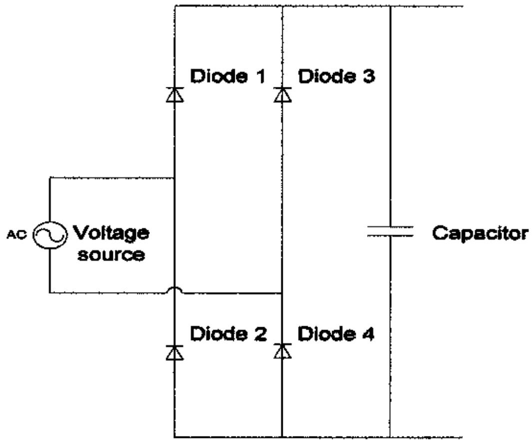

Figure 8(a): Uncontrolled single-phase diode bridge rectifier

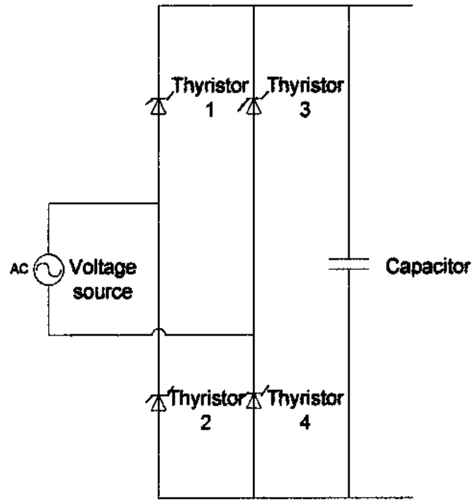

Figure 8(b): Fully-controlled single-phase bridge

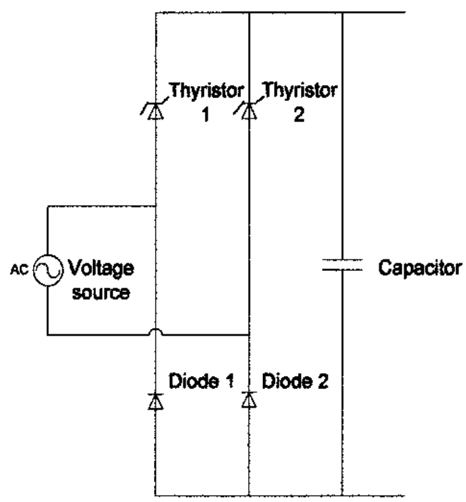

Figure 8(c): Half-controlled single-phase bridge

2.6.3 RC Snubber

RC Snubber circuit as shown in Figure 9 is used in the PFC circuit and inverter circuit because it limits the voltage rise but slow down the rate at which the MOSFET can be switched. The addition of a capacitor across the device will slow down the rise of voltage, reducing the stress on the device and reducing the switching loss. [15]

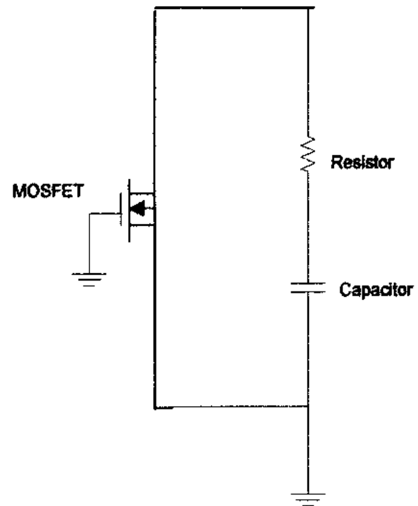

Figure 9: RC Snubber

2.6.4 Self-Oscillating

Nowadays, self-oscillating driver is widely used in industry due to its low cost, feasibility, and reliability. However, it is limited to one-lamp ballasts, because its switching frequency is dependent on the ballast load. [17] Conventional self-oscillating electronic ballast can be seen in the Figure 10.

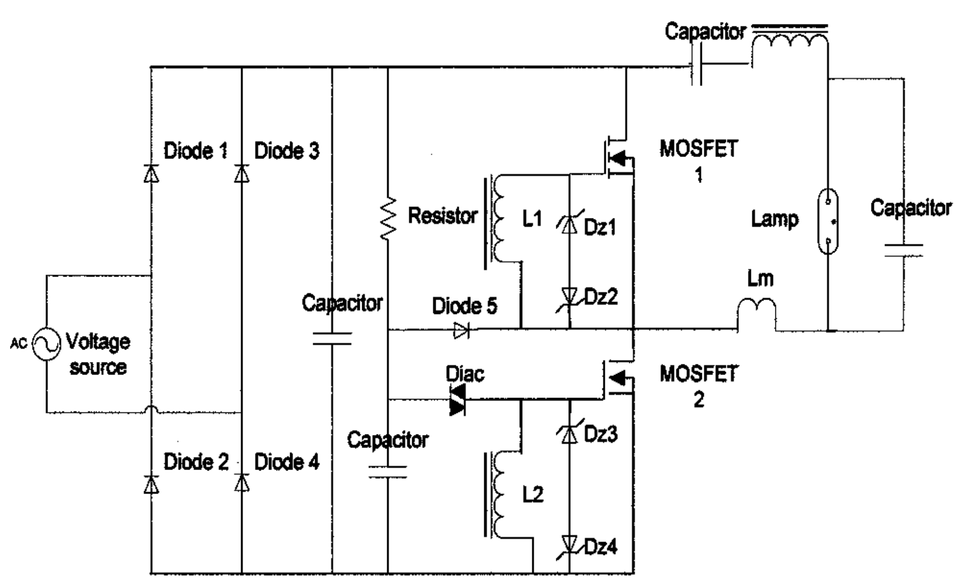

Figure 10: Conventional self-oscillating electronic ballast [17]

Due to the advance of technology, the self-oscillating driver has become smaller and compact. Integrated circuit (IC) IR2151 as shown in Figure 11 is the latest technology of self-oscillating driver and its switching frequency (fs) is 40 kHz. [13] The author was decided to use IR2151 since it can reduce the size and weight of electronic ballast.

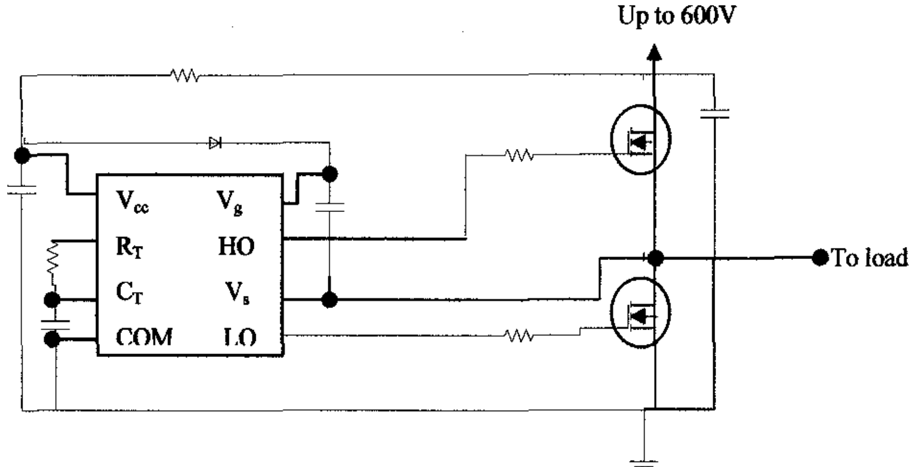

Figure 11: IR2151

2.6.5 Electromagnetic Interference (EMI) Filter

EMI is an undesirable or unwanted energy, consisting of both electric and magnetic radiation. It is a new type of pollution to our living environment that could have a harmful effect on living tissue and might lead to cancer. As a safety precaution, most industrialized nations have established standards for measuring and protecting people from exposure to unduly high levels of EMI. EMI is generated by electrical appliances (hair dryers, vacuum cleaners); electronic devices (computers, cell phones, electronic ballast) and power generating or distribution equipment (Generators, Power Plants, Power lines). [23]

EMI filter is used to eliminate the EMI in electronic ballast which is harmful to living tissues. There are many types of EMI filter such as T filter, L filter, R-C shunt filter and π filter. The L type is chosen because it is the most widely used. Figure 12(a) shows the electronic ballast circuit without the EMI filter. Figure 12 (b) shows the L type EMI filter which by adding the large value of inductor at the voltage source. [16]

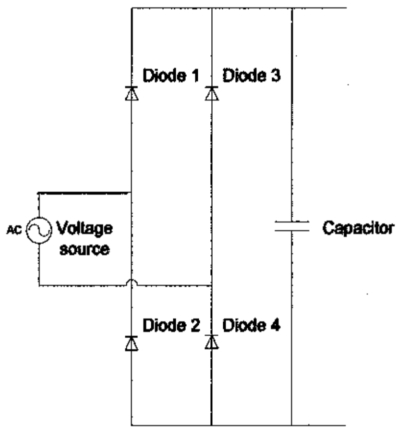

Figure 12: (a) Circuit without EMI filter

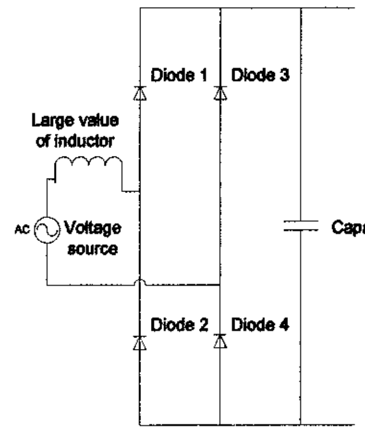

Figure 12: (b) Circuit with EMI filter

The equation (3) below is used in order to design the filter inductor (Ls) and filter capacitor (Cs) if we choose cutoff frequency (f_{cutoff}) four times smaller than switching frequency. [16]

$$f_{cutoff} = \frac{1}{2\pi\sqrt{(Ls \times Cs)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

2.7 Lamp Arrangement

In order to make the electronic ballast connects to multiple fluorescent lamps; the suitable lamp arrangement is needed. The series connection of the lamps is not suitable because if a lamp is removed from the socket, other lamps will be interrupted. The direct connection in parallel is also not suitable because it also can interrupt other lamp if a new lamp is added. In order to keep the lamps operating if a new lamp is added or the lamp is removed, a parallel connection as shown in Figure 13 is provided. [24]

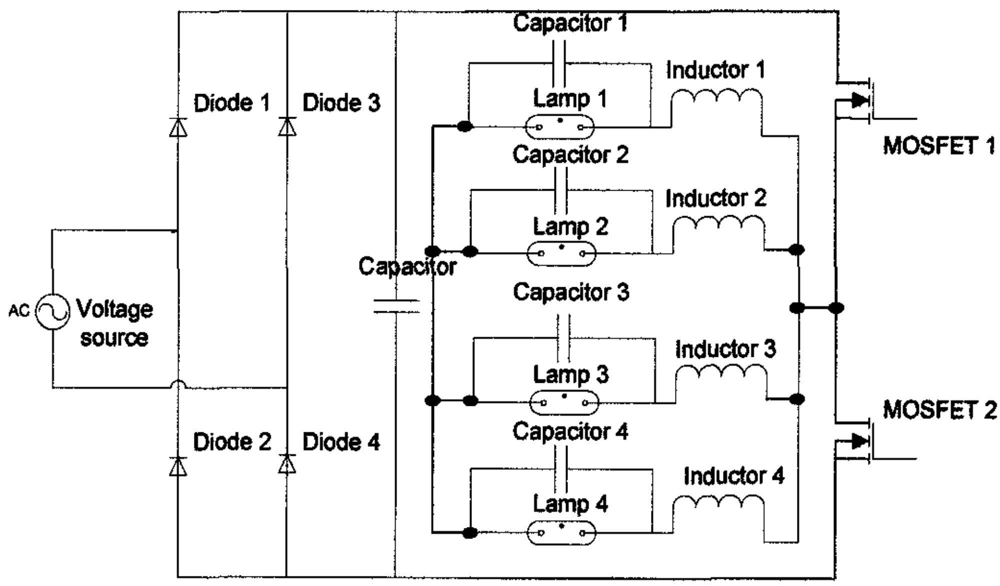

Figure 13: Suitable lamp arrangement

CHAPTER 3
METHODOLOGY

3.1 Methodology

After selecting the project title project and find the supervisor, then the author will follow the flow chart as shown in Figure 14. Literature review was conducted via books, journals and internet. After understanding the concept of electronic ballast and its main component, alternatives to design the electronic ballast was studied. Then, a simulation of the proposed circuit using Pspice was developed. After a desired result is obtained, prototype of the electronic ballast was built. Otherwise, other alternative design and simulation of the electronic ballast circuit using Pspice was continued.

In order to build the prototype, certain electronics components such as breadboard, resistors, capacitors, inductors, MOSFET, diode and so on were taken from laboratory or were bought at electronic store. Then, the electronic ballast circuit was built and then tested. Finally, results will be demonstrated in the presentation.

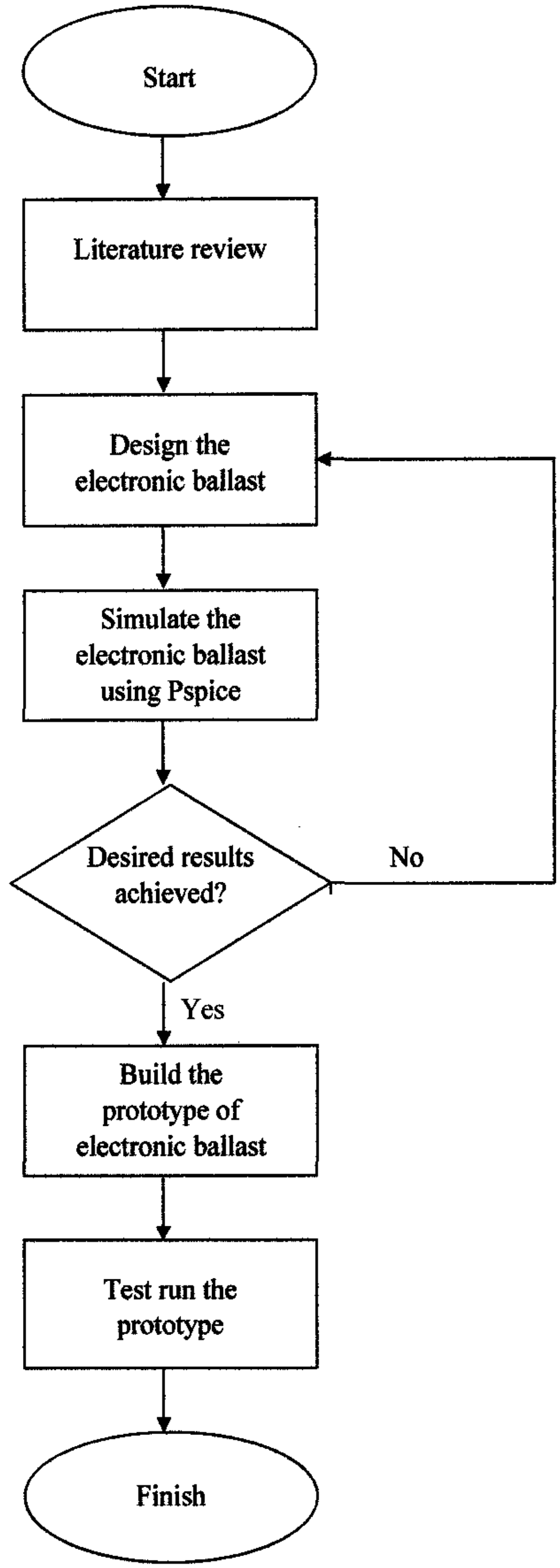

Figure 14: Flow chart

3.2 Tools or Equipments Required

In this project, software such as Microsoft Office (MS) Word, MS Excel, MS PowerPoint and Pspice (version 8) were used. The MS Word, MS Excel and MS PowerPoint are used for writing the proposal, progress report, final report etc.; for doing calculation and drawing graph for project analysis and for presentation. The Pspice helps to perform a simulation of the electronic circuit so that any problems can be overcome promptly.

Besides that, the author needs to buy electronics devices such as resistors, capacitors, MOSFET etc. or get them from laboratory. The author also need multimeter in order to check and test the prototype circuit.

CHAPTER 4
RESULT AND DISCUSSIONS

4.1 Results and Discussions

After doing some research on the alternatives to build electronic ballast, the author had decided to choose the flyback converter for Power Factor Correction (PFC) and self-oscillating for inverter. Then, the author had combined all the circuits (PFC circuit and self-oscillating inverter) as shown Figure 15.

Figure 16 shows the input voltage and input current of the electronic ballast. The input voltage is 220V and the input current is 3A with 50Hz frequency.

Figure 17 until 24 show the results obtained from the Pspice simulation. Figure 17 shows the graph of voltage lamp (output voltage) and current lamp (output current) if the electronic ballast is connected with one lamp. Figure 18 shows the graph of voltage lamp (output voltage) and current lamp (output current) if the electronic ballast is connected with two lamps. Figure 19 also shows the graph of output voltage and output current but with three lamps. The number of lamps is added one by one and the results of simulations were obtained as shown in Figure 20 until Figure 24.

From the graphs in Figure 17 until Figure 23, the author found that the output voltage is 220 Volts, (V) while the output current is multiplied by hundred because its value is very small. If we calculate the value of output current should be 1 Ampere, (A). The frequency for all those output variables as shown in Figure 17 until Figure 23 is 40 kHz. This output voltage, output current and frequency supposedly can light up the fluorescent lamps.

When the proposed electronic ballast was connected to eight lamps as shown in Figure 24, the output voltage and output current are very large which is 90kV and 500A. This happened due to the power surge construction interference. This situation has to be avoided or encounter by adding a choke.

From the results, the author can conclude that this electronic ballast can operate with multiple lamps (maximum 7 lamps). In other words, the author successfully obtained the results which meet this project's requirement (can operate with multiple lamps). The details of the results on simulation of Pspice are in Appendix.

Since the simulation results had been obtained, electronic components used in the circuit were acquired to build the circuit. The needed electronic components were obtained and the prototype of electronic ballast was built. However, the prototype of electronic ballast is not working due to the absent of flyback transformer and IR2151 as shown in Figure 25. The efficiency of the electronic ballast was calculated as follow:

$$\eta = \frac{P_{out}}{P_{in}} \times 100 = \frac{220V \times 0.1A}{220VX0.3A} \times 100 = 33.33\% \qquad (4)$$

The electronic ballast does not achieve the desired high efficiency since its efficiency is only 33.33%.

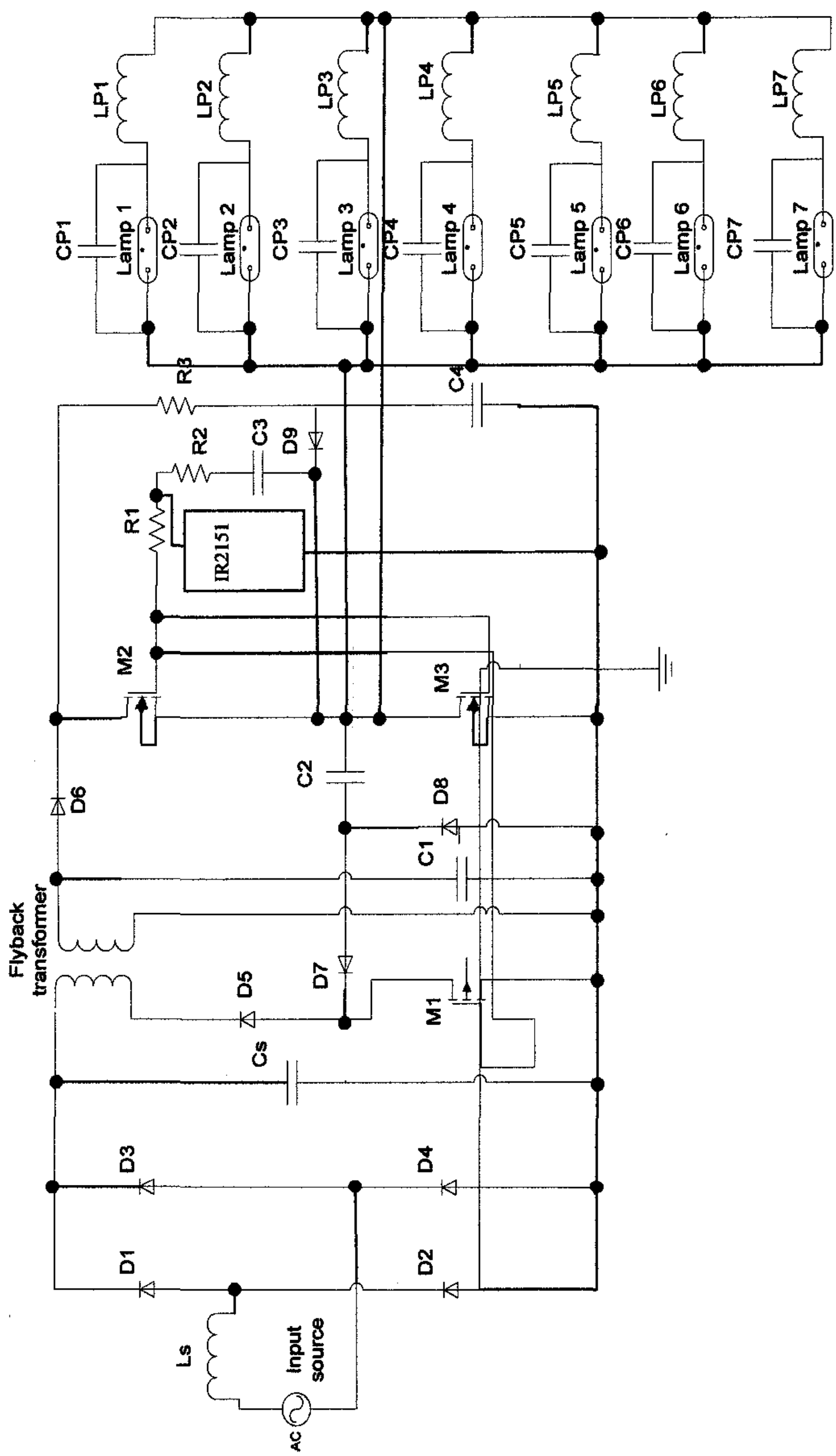

Figure 15: Proposed circuit for electronic ballast for multiple lamps

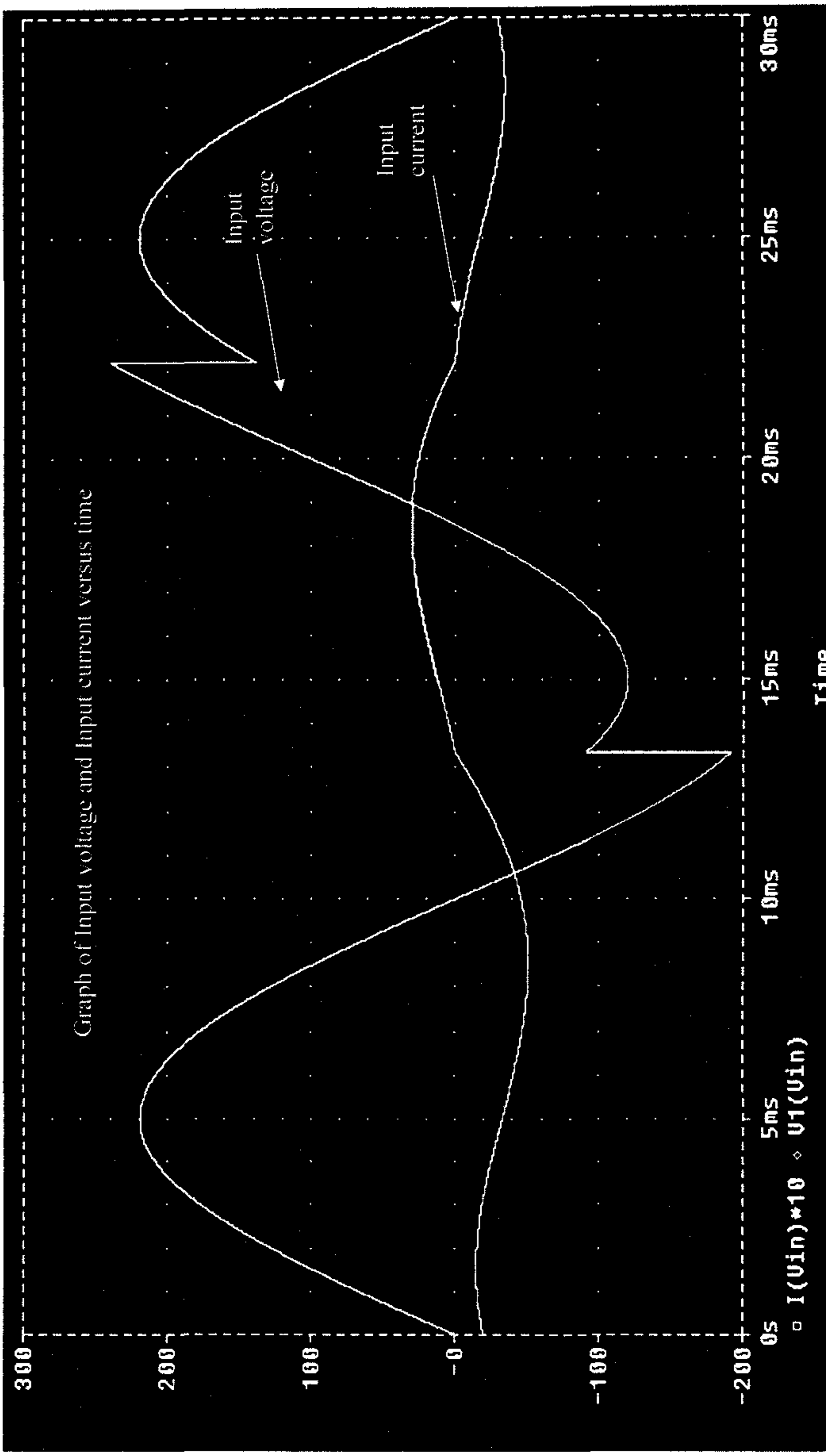

Figure 16: Graph of Input Voltage and Input Current Versus Time

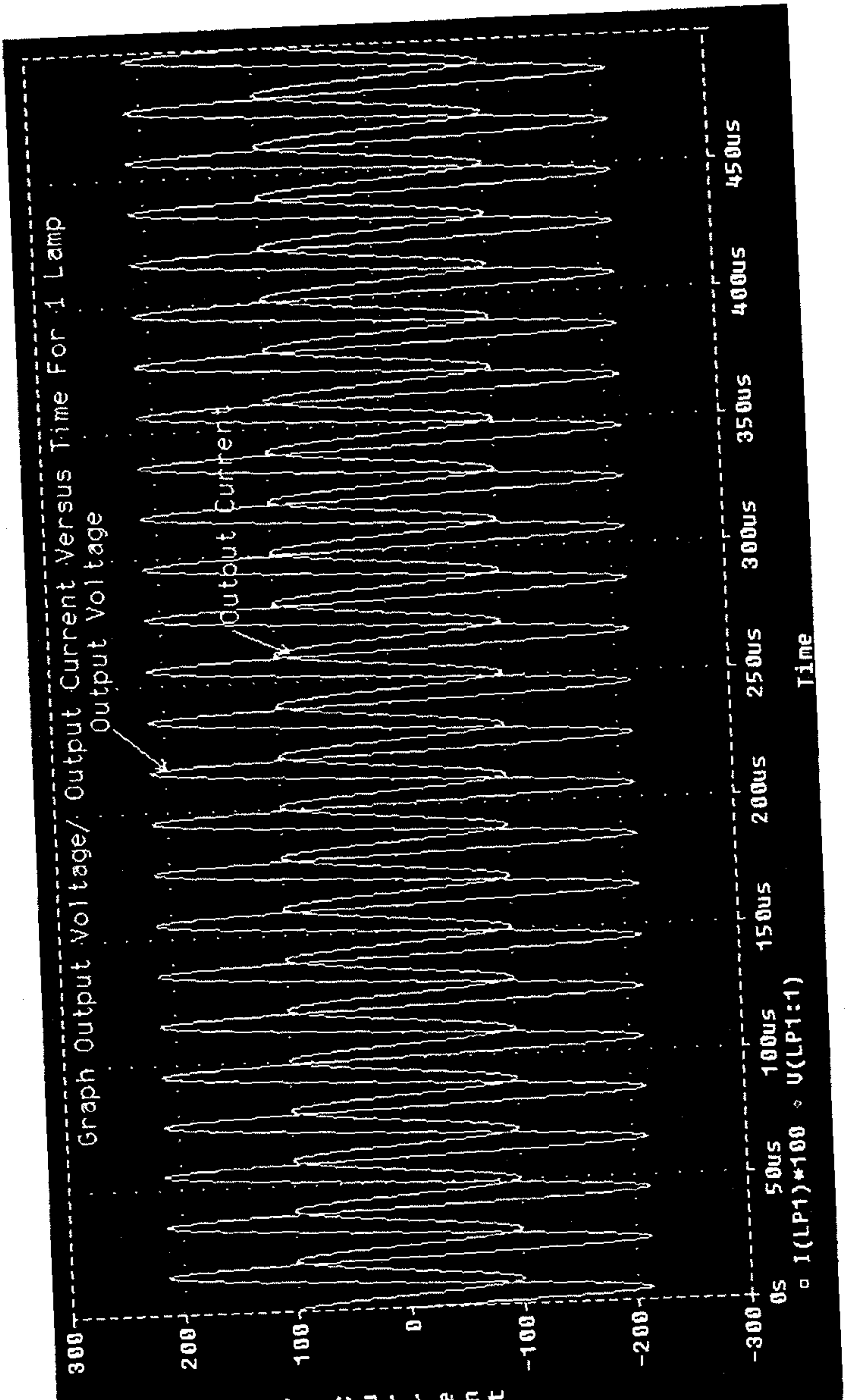

Figure 17: Graph of Output Voltage and Output Current Versus Time For 1 Lamp

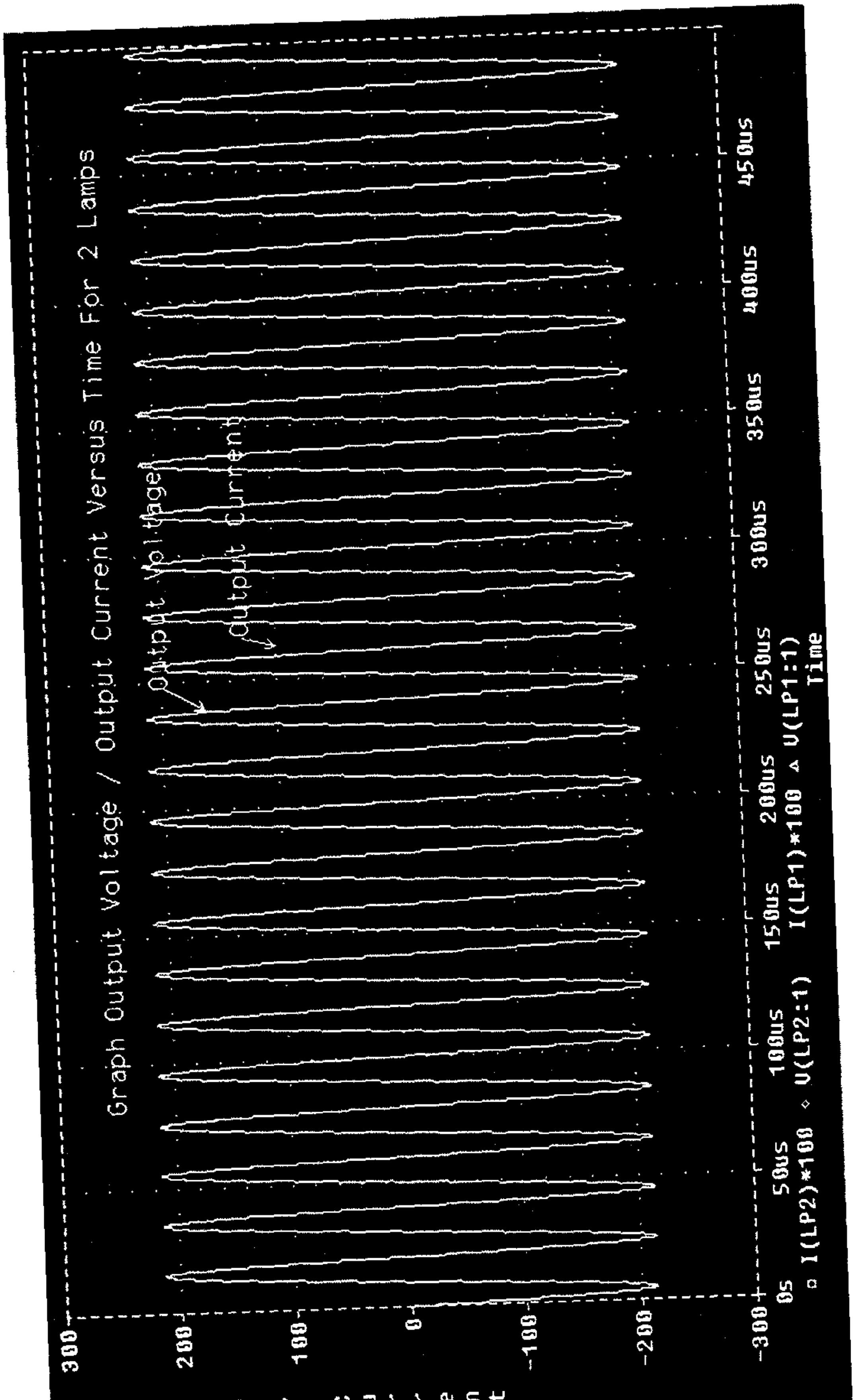

Figure 18: Graph of Output Voltage and Output Current Versus Time For 2 Lamps

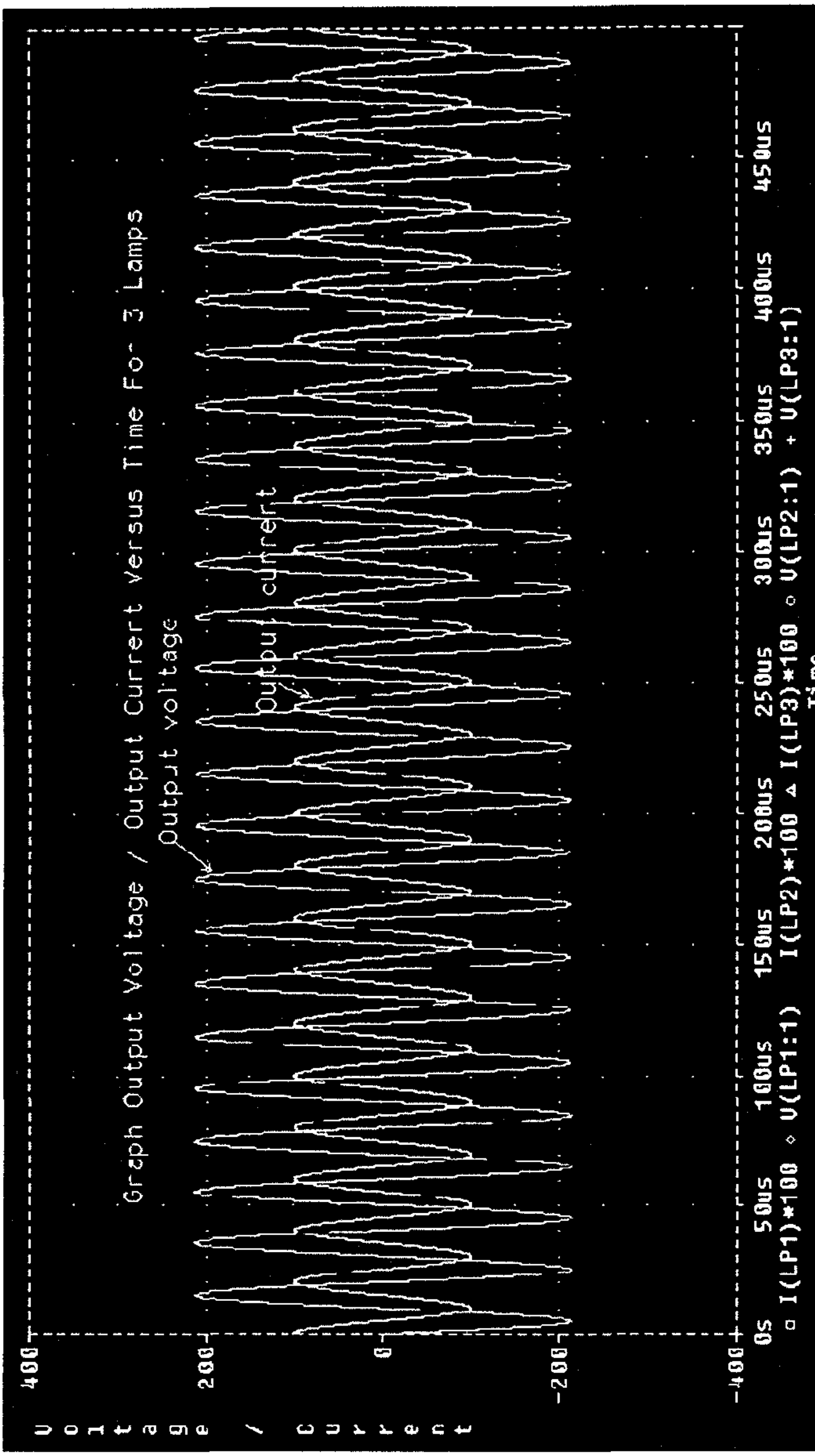

Figure 19: Graph of Output Voltage and Output Current Versus Time For 3 Lamps

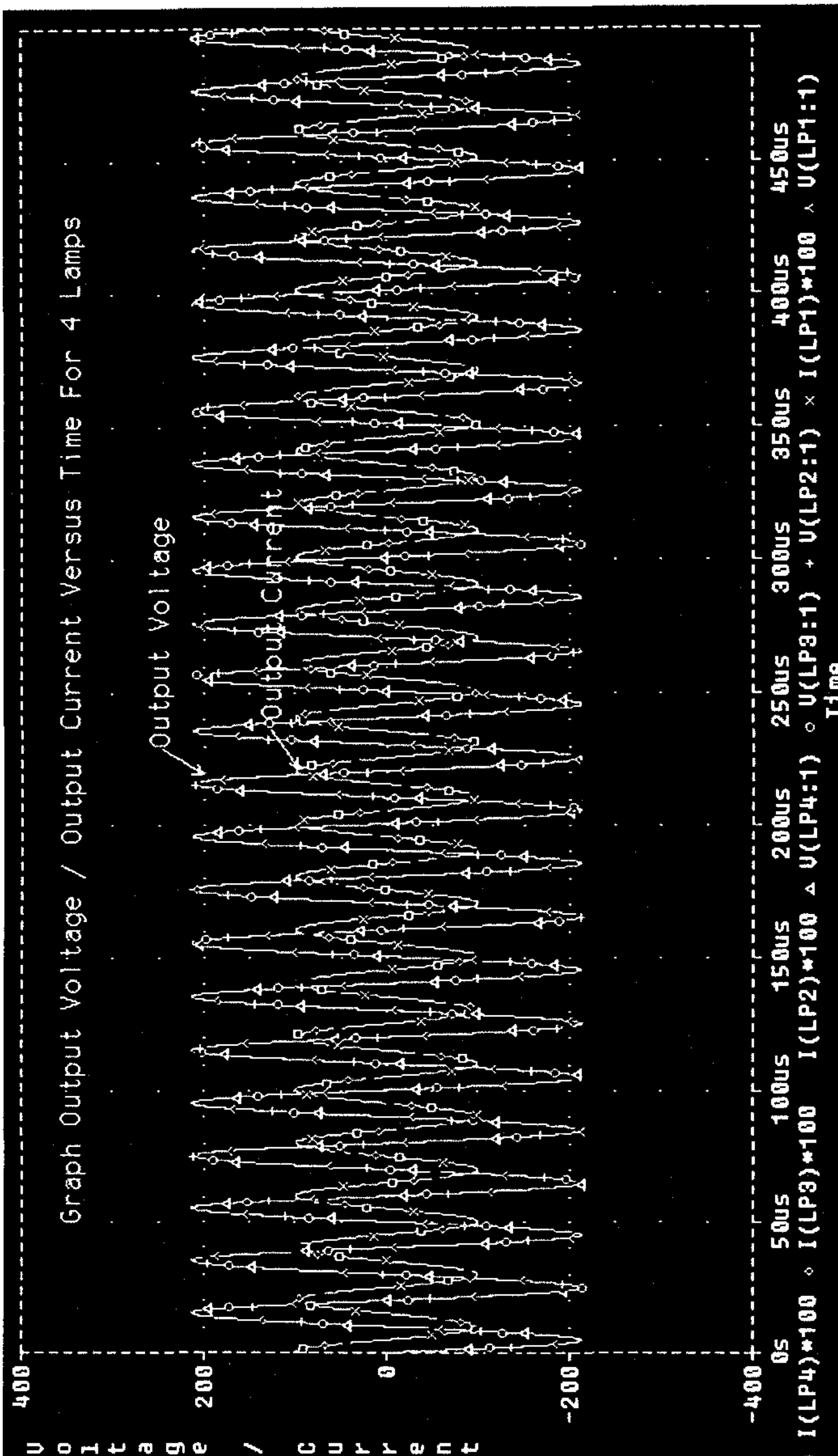

Figure 20: Graph of Output Voltage and Output Current Versus Time For 4 Lamps

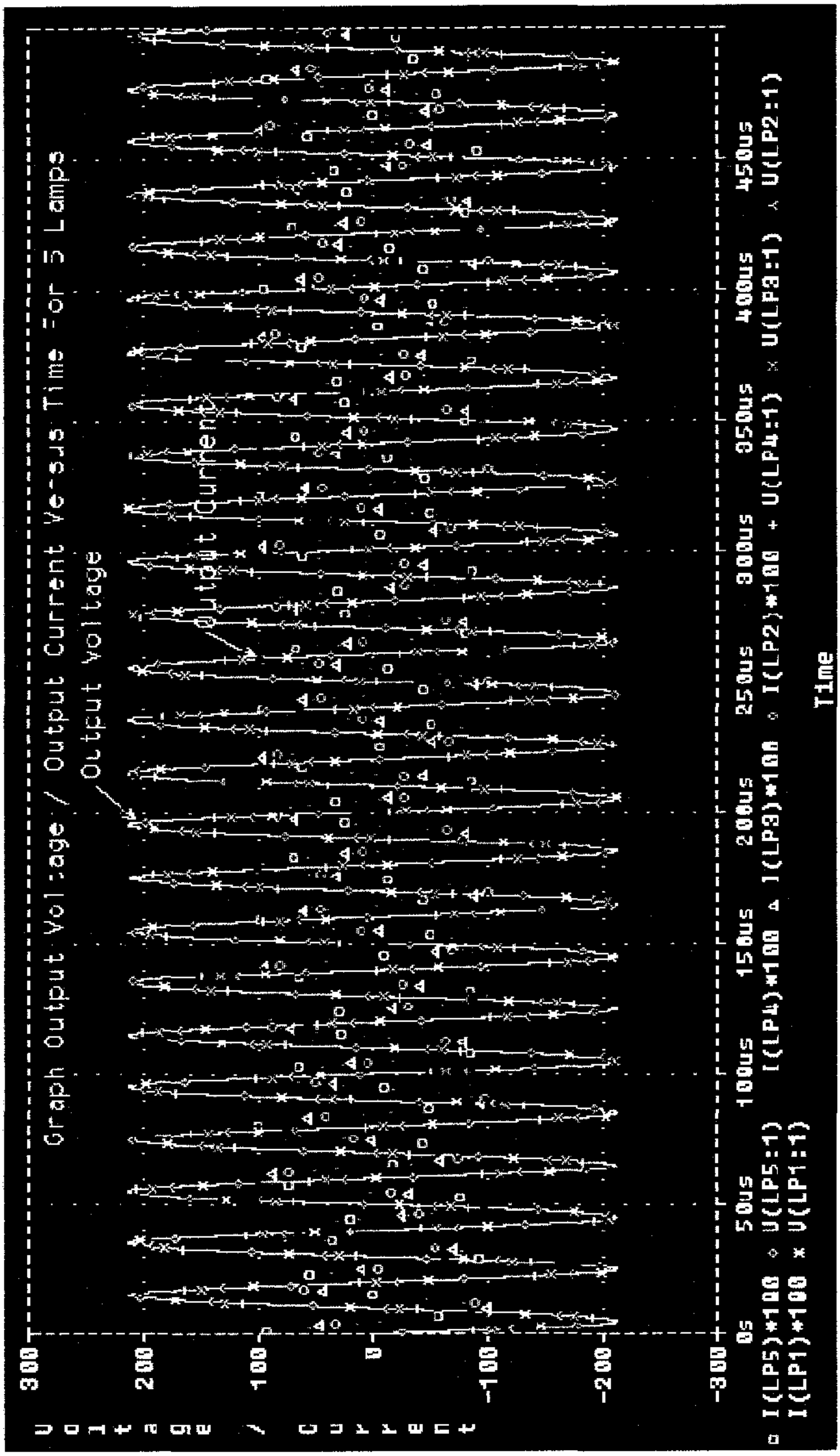

Figure 21: Graph of Output Voltage and Output Current Versus Time For 5 Lamps

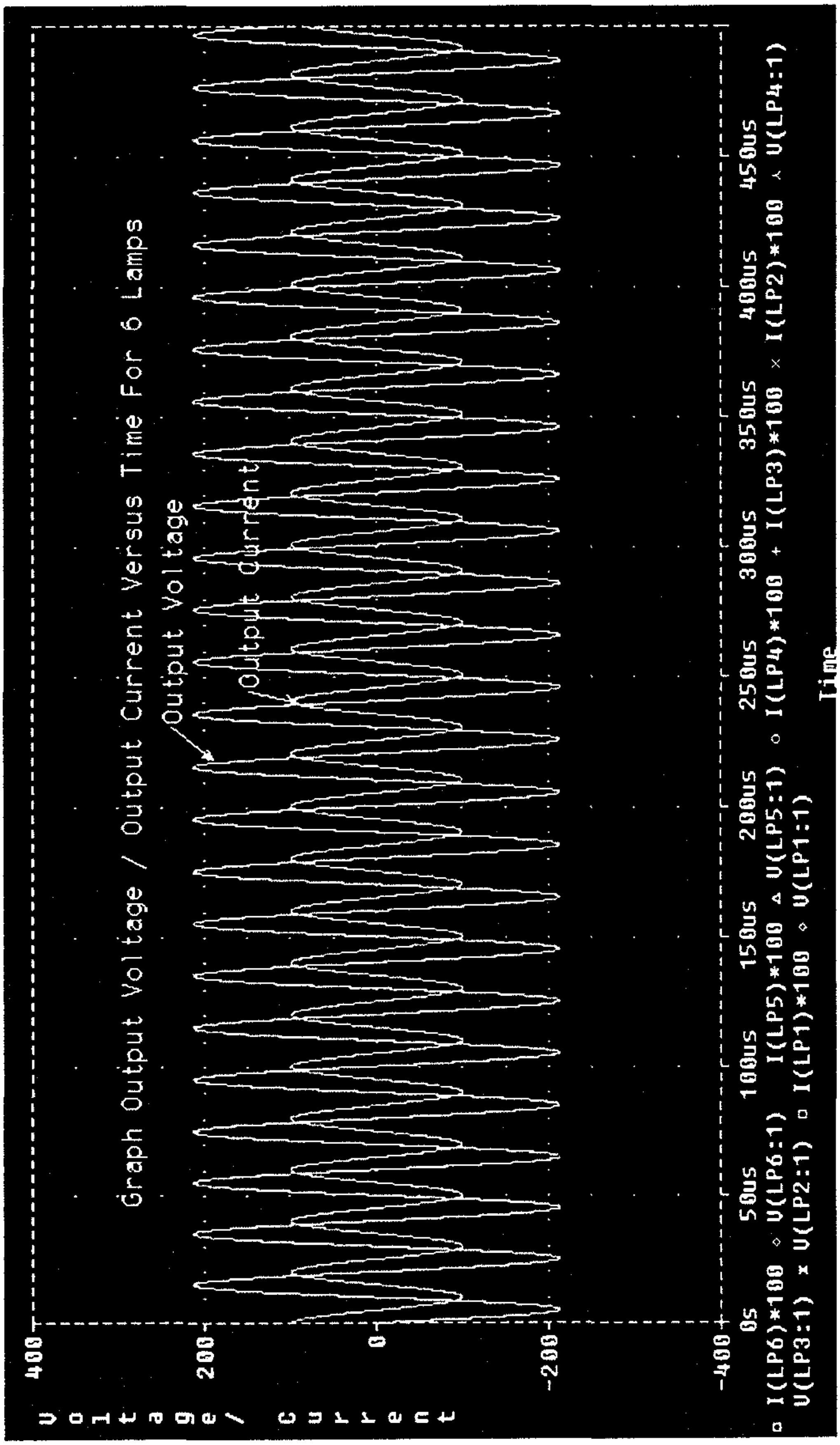

Figure 22: Graph of Output Voltage and Output Current Versus Time For 6 Lamps

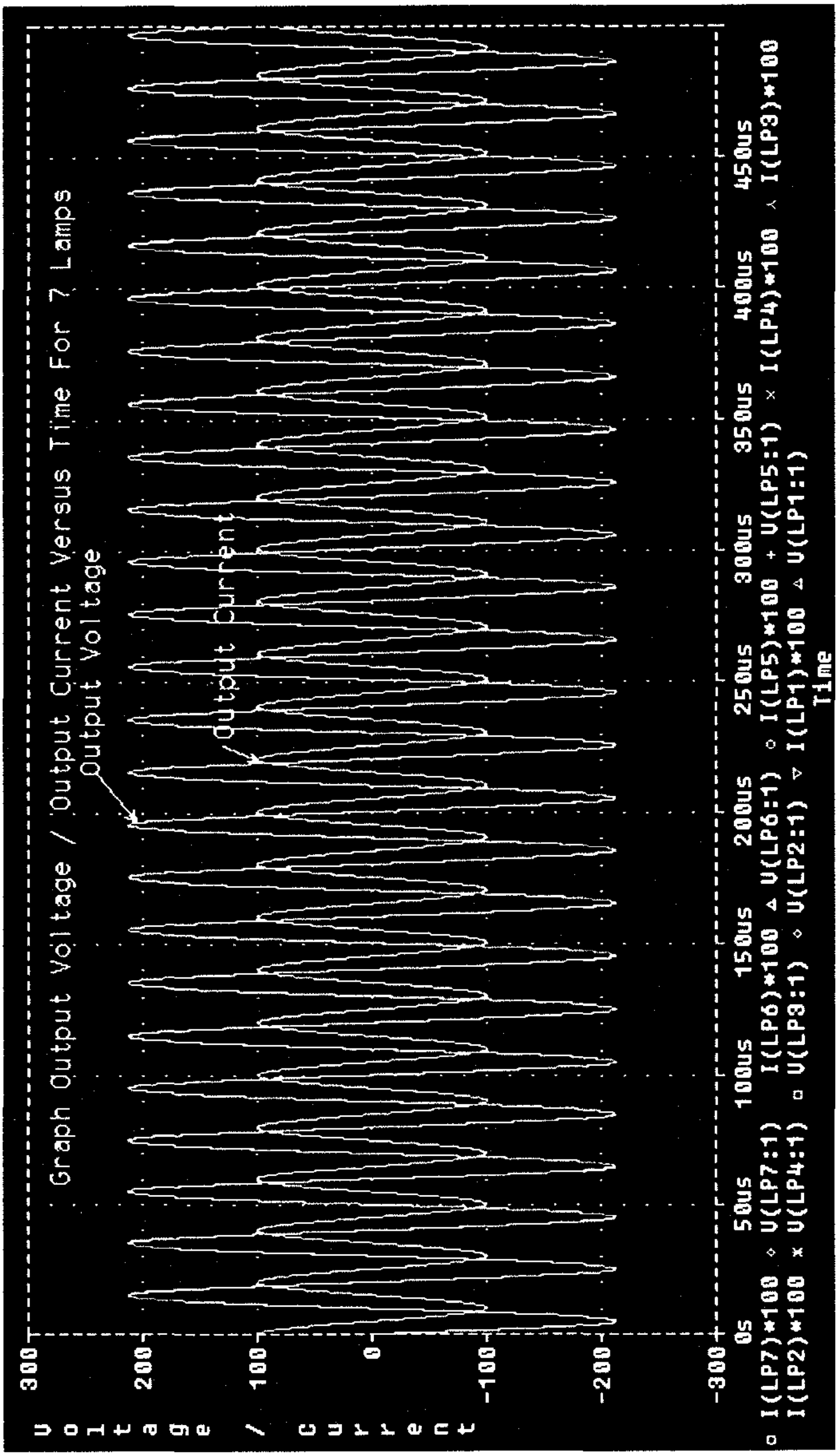

Figure 23: Graph of Output Voltage and Output Current Versus Time For 7 Lamps

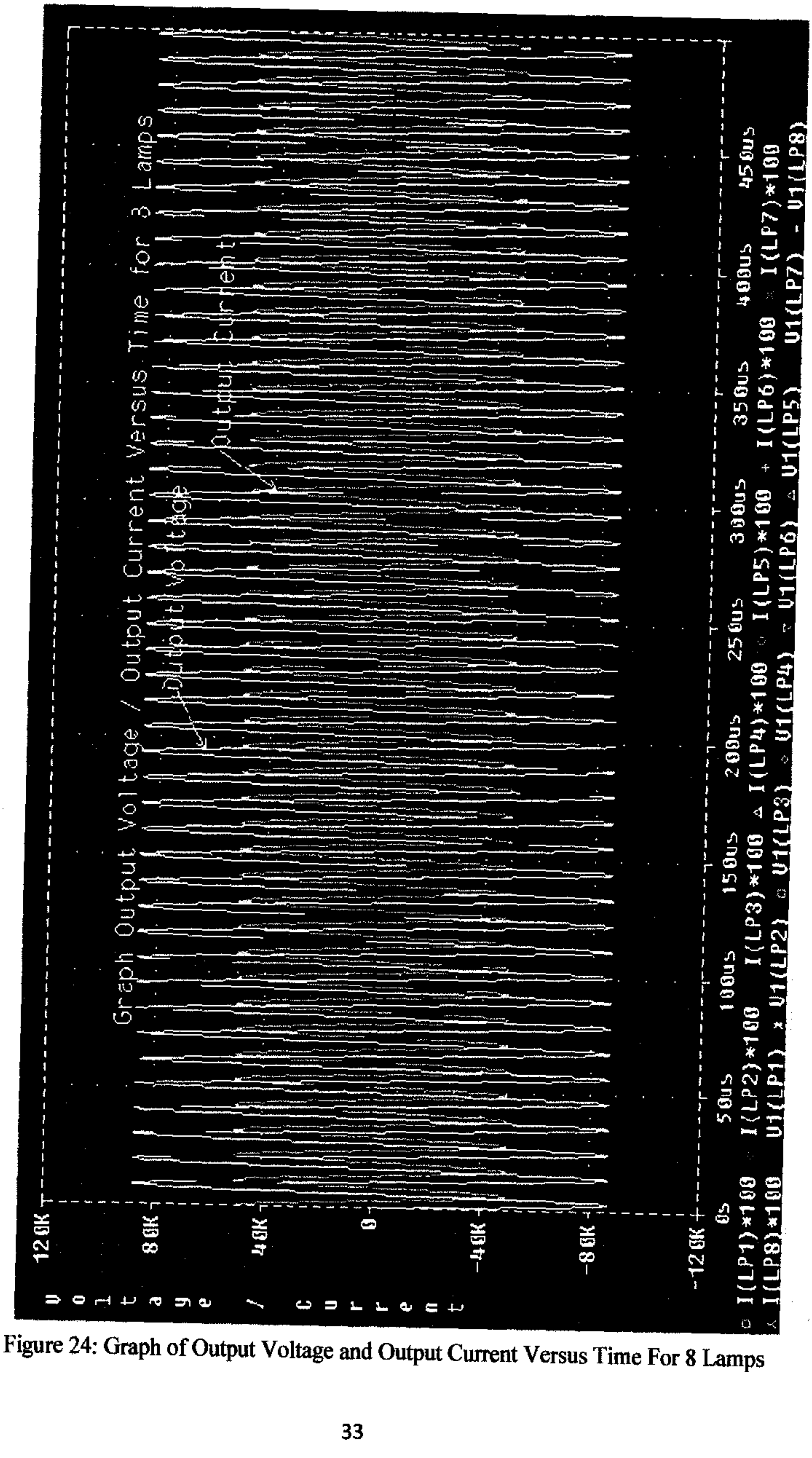

Figure 24: Graph of Output Voltage and Output Current Versus Time For 8 Lamps

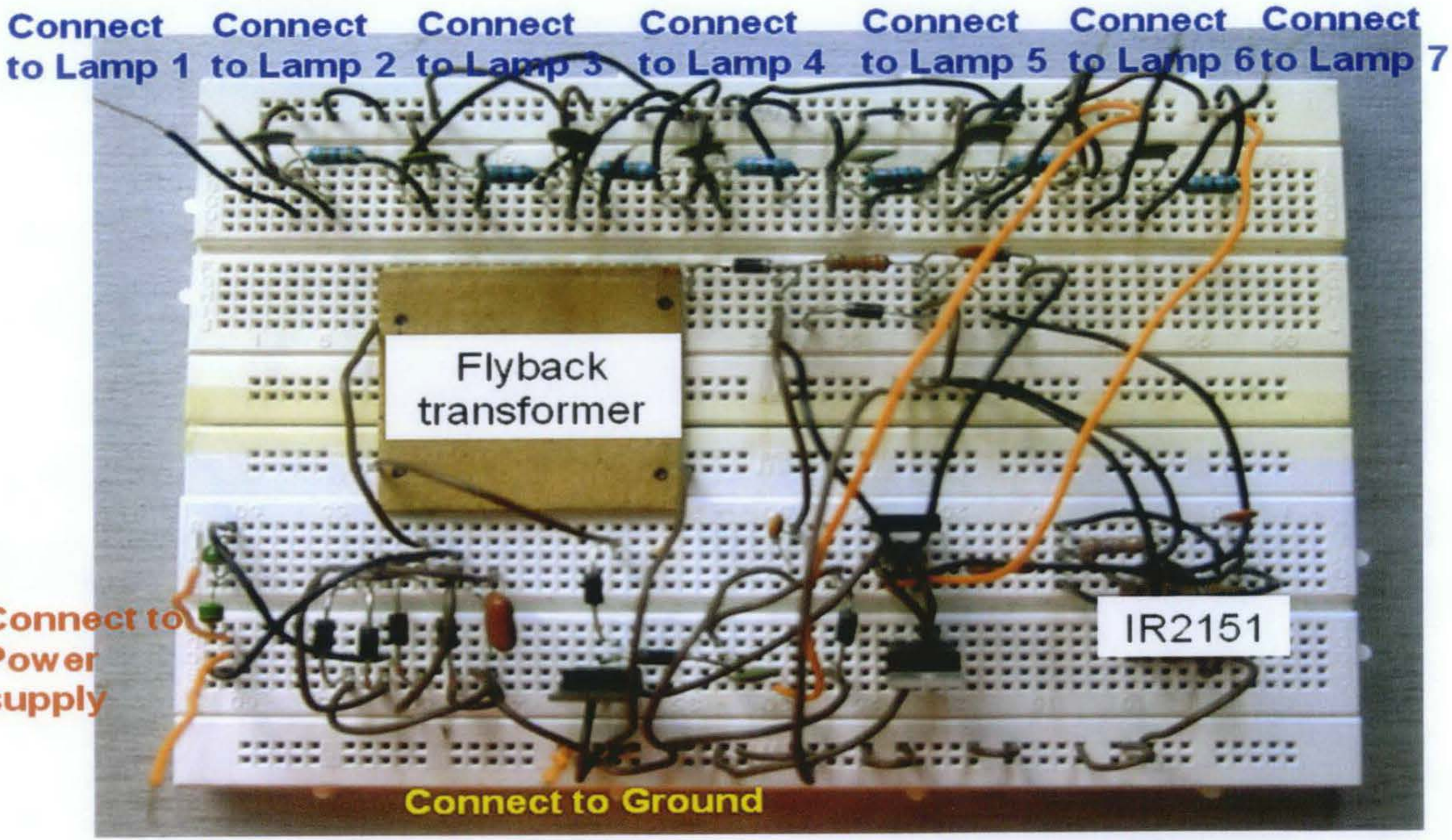

Figure 25: Prototype of proposed electronic ballast

4.2 Cost Calculations

Table 4 shows the estimated cost of the electronic ballast circuit based on the survey on the internet and from the electronic store. The total cost estimation of the circuit is RM129.95 without the price of flyback transformer (author still could not find its price). This price can be considered cheap because this electronic ballast can supply up to 7 lamps.

Table 4: The estimation cost of the electronic ballast circuit

Components	Value/ Details	Quantity	Price each (RM)	Total price (RM)
Resistor, R1	10	1	0.40	0.40
Resistor, R2	10	1	0.40	0.40
Resistor, R3	220k	1	0.40	0.40
Inductor, Ls	150m	1	2.00	2.00
Inductor, (LP1 –LP7)	680u	7	0.60	4.20
Capacitor, C3 & C4	0.01u	2	0.20	0.40
Capacitor, C2	10u	1	0.20	0.20
Capacitor, Cs	50n	1	0.20	0.20
Capacitor, C1	220u	1	0.20	0.20
Capacitor, (CP1 – CP7)	0.015u	7	0.20	1.40
MOSFET, M1	IRF740	1	5.00	5.00
MOSFET, M2	IRF740	1	5.00	5.00
MOSFET, M3	IRF740	1	5.00	5.00
Diode(D1 - D9)	IN4007	9	0.15	1.35
IRF2151		1	103.80	103.80
			Total	129.95

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Ballast is an important device for fluorescent lamp operation. There are two types of ballast: electromagnetic ballast and electronic ballast. Even though the electronic ballast is far more sufficient than electromagnetic ballast it has high purchase cost and can only connect to one or two lamps.

After some research on alternatives to build electronic ballast, it was found that the combination of flyback converter and self-oscillating can produce electronic ballast which meets this project's requirement. A suitable lamp arrangement was considered for the electronic ballast to operate multiple lamps.

The combination of all the circuits has been simulated in Pspice and the results obtained were able to meet this project's requirement. The electronic ballast can operate with multiple lamps (up to 7 lamps) and its initial cost is cheaper (RM129.95 without the price of flyback transformer). The efficiency of electronic ballast is calculated and the results show that the efficiency is low (33.33%).

All the electronic components needed in order to build electronic ballast circuit were bought and a prototype of the electronic ballast is ready to be built. However, the prototype of electronic ballast is not working due to the absent of flyback transformer and IR2151.

5.2 Recommendation

For future work, it is recommended that the price of flyback transformer be determined, so that the total purchase price of designated electronic ballast's cost can be calculated. The flyback transformer and IR2151 need to be order earlier so that prototype of electronic ballast can be built and tested. Since the efficiency of electronic ballast is low (33.33%), the further modification need to be done. The electronic ballast can operate to eight lamps by adding a choke.

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APPENDICES

LIFE CYCLE COST CALCULATION - ELECTROMAGNETIC AND ELECTRONIC BALLAST

Assumptions :-

1) Life cycle cost based on 20 years in service for 2 x 36W indoor fluorescent light fitting inside an office building.
2) Energy (electricity), component and manpower cost remains the same for the next 20 years.
3) Light fitting is on for 10 hours per day.
4) Energy cost is RM0.15 per kWh.

Item	Description	Electromagnetic Ballast	Electronic Ballast
1	Capital (Installation) Cost		
1.1	Price per light fitting	RM120.00	RM170.00
1.2	Manpower x 1 man-hr @RM16/man-hr	RM16	RM16
	Sub-Total (1)	RM136.00	RM186.00
2	Maintenance Cost		
2.1	Lamp and starter replacement (once every two years)	(1 man-hr x RM16 + material cost) x (20/2) = (RM16 + RM30) x (20/2) = RM460.00	NA
2.2	Lamp replacement (once every three years)	NA	(1 man-hr x RM16 + material cost) x (20/3) = (RM16 + RM25) x (20/3) = RM273.33
2.3	Ballast replacement (once every twelve years)	NA	(1 man-hr x RM16 + material cost) x (20/12) = (RM16 + RM70) x (20/12) = RM143.33
2.4	Ballast replacement (once every fifteen years)	(1 man-hr x RM16 + material cost) x (20/15) = (RM16 + RM20) x (20/15) = RM48.00	NA
	Sub-Total (2)	RM508.00	RM416.66
3	Operational Cost		
3.1	Energy cost @ RM0.15/kWh	(power consumption in kW x 10hrs x RM0.15) x (365 x 20) = (0.072 x 10 x RM0.15) x (365 x 20) = RM788.40	(power consumption in kW x 10hrs x RM0.15) x (365 x 20) = (0.050 x 10 x RM0.15) x (365 x 20) = RM547.50
	Sub-Total (3)	RM788.40	RM547.50
	Grand Total (1 + 2 + 3)	*RM1,432.40*	*RM1,150.16*

GANTT CHART OF PROJECT

No	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	Understanding the electronic ballast circuit	■	■	■	■												S						
2	Suitable equation and calculation for the circuit					■			M								T						
3	Submission of Progress Report 1				■				I								U						
4	Seminar 1 (compulsory)							■	D								D						
5	Submission of Progress Report 2									■							Y						
6	Submission of Draft Report								S					■									
7	Submission of Final Report Soft Cover								E							■	W						
8	Submission of Technical Report								M							■	E						
9	Get the electronics components (Buy/Laboratory)						■		R								E						
10	Build prototype							■	E	■							K						
11	Experiment the prototype								A		■	■	■										
12	Meeting with supervisor		■	■	■	■	■	■	K	■	■	■	■	■	■	■	■	■	■	■	■	■	■
13	Submission of Final Report Hard Cover																	Final	Exam				■
14	Oral Presentation																	Final	Exam		■		

OUTPUT SIMULATION OF PSPICE

```
**** 04/17/108 14:28:36 ******** NT Evaluation PSpice (July 1997) ***********
 * E:\My Notes\Final Sem Final Sem\Fyp2\pspice\resultdgnlampmodelflyback.sch

 ****     CIRCUIT DESCRIPTION  ************************************

* Schematics Version 8.0 - July 1997
* Thu Apr 17 14:28:21 2008

** Analysis setup **
.tran 1ms 30ms
.OP

* From [SCHEMATICS NETLIST] section of msim.ini:
.lib nom.lib
.inc "Triac_st.OLB "

**** INCLUDING Triac_st.OLB ****

**** RESUMING resultdgnlampmodelflyback.cir ****
.stmlib "Triac_st.OLB "

.INC "resultdgnlampmodelflyback.net"

**** INCLUDING resultdgnlampmodelflyback.net ****
* Schematics Netlist *

R_R4       $N_0002 $N_0001  220k
D_D106       $N_0003 $N_0004 D1N4002
D_D107       $N_0005 $N_0003 D1N4002
C_C5       0 $N_0002  10n IC=1V
```

```
D_D109       0 $N_0005 D1N4002
K_TX8        L1_TX8 L2_TX8 0.5
L1_TX8       $N_0006 $N_0004 2m
L2_TX8       $N_0007 0 4.5m
D_D108       $N_0007 $N_0001 D1N4002
R_R24        $N_0009 $N_0008  10
R_R26        $N_0010 $N_0008  10
C_C85        0 $N_0001  220u
C_C103       $N_0005 0  10u
C_C105       0 $N_0009  10n
D_D110       $N_0002 0 D1N4002
V_V11        $N_0008 0
+PULSE 10V 20V 1.2us 80ns 40ns 1.26us 2.58us
D_D69        $N_0011 $N_0006 D1N4002
D_D74        0 $N_0011 D1N4002
D_D75        0 $N_0012 D1N4002
D_D76        $N_0012 $N_0006 D1N4002
M_M2         $N_0001 $N_0010 0 0 IRF150
M_M3         0 $N_0010 0 0 IRF150
M_M1         $N_0003 $N_0010 0 0 IRF150
V_Vin        $N_0013 $N_0011
+SIN 0 220 50 0 0 0
C_CP6        $N_0014 0  10n IC=1V
C_CP1        $N_0015 0  10n IC=1V
C_CP2        0 $N_0016  10n IC=1V
C_CP3        0 $N_0017  10n IC=1V
C_CP4        0 $N_0018  10n IC=1V
C_CP5        0 $N_0019  10n IC=1V
C_CP7        $N_0020 0  10n IC=1V
C_C109       0 $N_0006  1n
L_L46        $N_0013 $N_0012  150mH IC=2A
L_LP6        $N_0014 0  500uH IC=1A
```

```
L_LP1      $N_0015 0  500uH IC=1A
L_LP2      $N_0016 0  500uH IC=1A
L_LP3      $N_0017 0  500uH IC=1A
L_LP4      $N_0018 0  500uH IC=1A
L_LP5      $N_0019 0  500uH IC=1A
L_LP7      $N_0020 0  500uH IC=1A

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* Schematics Aliases *

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D_D106      D106(1=$N_0003 2=$N_0004 )
D_D107      D107(1=$N_0005 2=$N_0003 )
C_C5        C5(1=0 2=$N_0002 )
D_D109      D109(1=0 2=$N_0005 )
K_TX8       TX8()
L1_TX8      TX8(1=$N_0006 2=$N_0004 )
L2_TX8      TX8(3=$N_0007 4=0 )
D_D108      D108(1=$N_0007 2=$N_0001 )
R_R24       R24(1=$N_0009 2=$N_0008 )
R_R26       R26(1=$N_0010 2=$N_0008 )
C_C85       C85(1=0 2=$N_0001 )
C_C103      C103(1=$N_0005 2=0 )
C_C105      C105(1=0 2=$N_0009 )
D_D110      D110(1=$N_0002 2=0 )
V_V11       V11(+=$N_0008 -=0 )
D_D69       D69(1=$N_0011 2=$N_0006 )
D_D74       D74(1=0 2=$N_0011 )
```

```
D_D75        D75(1=0 2=$N_0012 )
D_D76        D76(1=$N_0012 2=$N_0006 )
M_M2         M2(d=$N_0001 g=$N_0010 s=0 s=0 )
M_M3         M3(d=0 g=$N_0010 s=0 s=0 )
M_M1         M1(d=$N_0003 g=$N_0010 s=0 s=0 )
V_Vin        Vin(+=$N_0013 -=$N_0011 )
C_CP6        CP6(1=$N_0014 2=0 )
C_CP1        CP1(1=$N_0015 2=0 )
C_CP2        CP2(1=0 2=$N_0016 )
C_CP3        CP3(1=0 2=$N_0017 )
C_CP4        CP4(1=0 2=$N_0018 )
C_CP5        CP5(1=0 2=$N_0019 )
C_CP7        CP7(1=$N_0020 2=0 )
C_C109       C109(1=0 2=$N_0006 )
L_L46        L46(1=$N_0013 2=$N_0012 )
L_LP6        LP6(1=$N_0014 2=0 )
L_LP1        LP1(1=$N_0015 2=0 )
L_LP2        LP2(1=$N_0016 2=0 )
L_LP3        LP3(1=$N_0017 2=0 )
L_LP4        LP4(1=$N_0018 2=0 )
L_LP5        LP5(1=$N_0019 2=0 )
L_LP7        LP7(1=$N_0020 2=0 )
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.END

**** 04/17/108 14:28:36 ******** NT Evaluation PSpice (July 1997) **********

 * E:\My Notes\Final Sem Final Sem\Fyp2\pspice\resultdgnlampmodelflyback.sch
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      N  1.984
    ISR  100.000000E-12
    IKF  94.81
     BV  100.1
    IBV  10
     RS  .03389
     TT  4.761000E-06
    CJO  51.170000E-12
     VJ  .3905
      M  .2762

**** 04/17/108 14:28:36 ******** NT Evaluation PSpice (July 1997) *********
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****    MOSFET MODEL PARAMETERS ******************************

  IRF150
        NMOS
  LEVEL    3
      L  2.000000E-06
      W  .3
    VTO  2.831
     KP  20.530000E-06
  GAMMA    0
    PHI  .6
     RD  1.031000E-03
     RS  1.624000E-03
     RG  13.89
    RDS  444.400000E+03
```

IS 194.000000E-18

JS 0

PB .8

PBSW .8

CBD 3.229000E-09

CJ 0

CJSW 0

TT 288.000000E-09

CGSO 9.027000E-09

CGDO 1.679000E-09

TOX 100.000000E-09

XJ 0

DELTA 0

ETA 0

KAPPA 1.000000E-12

DIOMOD 1

VFB 0

U0 0

TEMP 0

VDD 0

XPART 0

**** 04/17/108 14:28:36 ******** NT Evaluation PSpice (July 1997) ******

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($N_0003) 698.7E-12 ($N_0004) 99.1130

($N_0005) 349.4E-12 ($N_0006) 99.1130

($N_0007) 0.0000 ($N_0008) 10.0000

($N_0009) 10.0000 ($N_0010) 10.0000

($N_0011) -.9614 ($N_0012) 100.0700

($N_0013) -.9614 ($N_0014) .9980

($N_0015) .9980 ($N_0016) -1.0020

($N_0017) -1.0020 ($N_0018) -1.0020
($N_0019) -1.0020 ($N_0020) .9980

VOLTAGE SOURCE CURRENTS
NAME CURRENT

V_V11 2.220E-16
V_Vin -2.000E+00

TOTAL POWER DISSIPATION -2.22E-15 WATTS

**** 04/17/108 14:28:36 ******** NT Evaluation PSpice (July 1997) ********
* E:\My Notes\Final Sem Final Sem\Fyp2\pspice\resultdgnlampmodelflyback.sch

**** OPERATING POINT INFORMATION TEMPERATURE = 27.000
DEG C **

**** DIODES

NAME	D_D106	D_D107	D_D109	D_D108	D_D110
MODEL	D1N4002	D1N4002	D1N4002	D1N4002	D1N4002
ID	-1.46E-08	-9.67E-17	-9.67E-17	6.04E-14	-1.43E-08
VD	-9.91E+01	-3.49E-10	-3.49E-10	2.18E-07	-1.00E+00
REQ	2.00E+12	3.61E+06	3.61E+06	3.61E+06	9.08E+10
CAP	1.11E-11	5.25E-11	5.25E-11	5.25E-11	3.60E-11

NAME	D_D69	D_D74	D_D75	D_D76
MODEL	D1N4002	D1N4002	D1N4002	D1N4002
ID	-1.00E+00	1.00E+00	-1.00E+00	1.00E+00
VD	-1.00E+02	9.61E-01	-1.00E+02	9.61E-01
REQ	2.59E-02	5.16E-02	2.59E-02	5.16E-02
CAP	1.84E-04	9.23E-05	1.84E-04	9.23E-05

**** MOSFETS

NAME	M_M2	M_M3	M_M1
MODEL	IRF150	IRF150	IRF150
ID	-4.55E-06	0.00E+00	1.46E-08
VGS	1.00E+01	1.00E+01	1.00E+01
VDS	-2.18E-07	0.00E+00	6.99E-10
VBS	0.00E+00	0.00E+00	0.00E+00
VTH	2.83E+00	2.83E+00	2.83E+00
VDSAT	7.17E+00	7.17E+00	7.17E+00
GM	6.34E-07	0.00E+00	2.03E-09
GDS	2.21E+01	2.21E+01	2.21E+01
GMB	0.00E+00	0.00E+00	0.00E+00
CBD	3.23E-09	3.23E-09	3.23E-09
CBS	2.90E-19	2.90E-19	2.90E-19
CGSOV	2.71E-09	2.71E-09	2.71E-09

CGDOV	5.04E-10	5.04E-10	5.04E-10
CGBOV	0.00E+00	0.00E+00	0.00E+00
CGS	1.04E-10	1.04E-10	1.04E-10
CGD	1.04E-10	1.04E-10	1.04E-10
CGB	0.00E+00	0.00E+00	0.00E+00

**** 04/17/108 14:28:36 ******** NT Evaluation PSpice (July 1997) *********

* E:\My Notes\Final Sem Final Sem\Fyp2\pspice\resultdgnlampmodelflyback.sch

**** INITIAL TRANSIENT SOLUTION TEMPERATURE = 27.000 DEG
C **

NODE VOLTAGE NODE VOLTAGE NODE VOLTAGE NODE
VOLTAGE

($N_0001)-218.0E-09 ($N_0002) -1.0000

($N_0003) 698.7E-12 ($N_0004) 99.1130

($N_0005) 349.4E-12 ($N_0006) 99.1130

($N_0007) 0.0000 ($N_0008) 10.0000

($N_0009) 10.0000 ($N_0010) 10.0000

($N_0011) -.9614 ($N_0012) 100.0700

($N_0013) -.9614 ($N_0014) .9980

($N_0015) .9980 ($N_0016) -1.0020

($N_0017) -1.0020 ($N_0018) -1.0020

($N_0019) -1.0020 ($N_0020) .9980

VOLTAGE SOURCE CURRENTS

NAME	CURRENT
V_V11	2.220E-16
V_Vin	-2.000E+00

TOTAL POWER DISSIPATION -2.22E-15 WATTS

JOB CONCLUDED

TOTAL JOB TIME 177.72