DESIGN AND CONSTRUCTION OF RADIATION ALARM DEVICE

BY

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A thesis submitted to the postgraduate school of the Ahmadu Bello University, Zaria, IN PARTIAL FULFILMENT OF THE RECRUITMENT FOR THE AWARD OF MASTER OF SCIENCE (MSC) ELECTRICAL ENGINEERING.

CERTIFICATION

This thesis entitled “**Design and Construction of Radiation Alarm Device”** by Hamisu Abubakar Adamu meets the regulations governing the award of degree of master of science (Electronics and Telecommunications) of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literature presentation

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DECLARATION

This is to certify that I carried out the work reported in this thesis under the supervision of Professor B.G Bajoga and Dr. P.F.U Taylor. All sources of information as seen in this thesis are specifically acknowledged by means of references. I declare that no part of this thesis has been submitted elsewhere by me for the award of a degree.

______________________ _______________

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DEDICATION

This thesis is dedicated to my family.

ACKNOWLEDGEMENT

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ABSTRACT

There is a defined level of ionizing radiation (effective dose of 50mSv in any single year) that radiation workers are allowed to be exposed to, according to the International Committee on Radiation Protection (I.C.R.P) proposal which is duly adopted by International Atomic Energy Agency.

Gas detectors are commonly used for radiation monitoring because of their ease of operation. In principle, a gas detector can be operated as an Ionization chamber, a Proportional counter, or a Geiger- Mueller tube, depending on the level of high voltage bias supply it is subjected to. Geiger – Mueller detectors are preferred for radiation monitoring because of their ability to detect nearly all kinds of ionizing radiation and they provide a very strong signal that a pre-amplifier is not necessary.

This work has utilized the characteristics of G-M tubes to design and construct a Radiation alarm device capable of detecting unsafe radiation level in its vicinity. The device is intended for both indoor and outdoor use. This has therefore necessitated the use of a 9 volts alkaline battery for the device. Complementary Metal Oxide Semiconductor (CMOS) integrated circuit(IC) low power consumption and its ability to operate satisfactorily on a wide range of supply voltage made it a choice for this project. High efficiency performance of Switched Mode Power Supplies (SMPS) has been

harnessed to provide high voltage (HV) bias for the G-M tube. In order to further decrease the power consumption of the unit, the high voltage circuit was gated such that it operates for a very short period, and a buffer capacitor used to supply the tube continuously during the inactive period of the high voltage circuit.

The radiation alarm device developed is capable of alerting personnel once exposed to radiation dose of 27μSv/hour (Twenty seven microSeivert per hour) or higher. This threshold was found to be the maximum allowable radiation a personnel is allowed to be exposed to. Beside the cost advantage that the Radiation Alarm Device has over existing similar devices, it is also difficult to acquire ionizing radiation related instruments due to restrictions imposed on them globally. The cost of the device is put at about twenty seven thousand naira (N27,000), a price much less than the price for GM-90 Geiger Counter Radiation Detector, a product of Black cat system, whose price is three hundred and fifty dollars ($350).

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CHAPTER ONE

INTRODUCTION

1.1 Introduction

In accordance with national and international radiation regulatory laws, any organization that uses radiation sources must have radiation protection unit. One of the major roles of this unit is ensuring that all hazardous radiation areas are identified, demarcated, and a clear warning sign post put in place. But sometimes people get exposed to excess radiation in the course of their duty without their knowledge since one cannot sense radiation. The never-ending research in science and technology discovered not only the means of detecting radiation, but also that of measuring radiation dose equivalent and equate it with its biological effect in the human body.

Radiation is measured in doses: a dose is the quantity of energy absorbed by the exposed materials, usually expressed in ‘radiation absorbed dose’ or R.A.D. One R.A.D is equivalent to 0.01 joule/Kg. A quality factor needs to be introduced since R.A.D is not directly related to the biological damage caused. The mathematical product of R.A.D with this quality factor results in Rontgen-equivalentman (R.E.M) [1].

By definition,

$$1\,Seivert = 100\,R.E.M \text{ ------------------------------------- } (1.1)$$

The occupational exposure of any worker, according to the International Atomic Energy Agency (IAEA), shall be so controlled that the following maximum limits are not exceeded [4]:

(a) An effective dose of 20 mSv per year averaged over five consecutive years.
(b) An effective dose of 50 mSv in any single year.
(c) An equivalent dose to the lens of the eye of 150 mSv in a year.
(d) An equivalent dose to the extremities (hands and feet) or the skin of 500mSv in a year.

Consider an employee in a nuclear environment working forty (40) hours a week, forty six (46) weeks a year, then his maximum radiation exposure per hour shall be:

$$50mSv \big/ 46 \times 40 \approx 27 \mu Sv ---------------- (1.2)$$

1.2 Thesis Motivation

Since excess radiation can exist in the environment without one knowing, it is necessary for workers in radiation field to possess a portable device that alerts them once they find themselves exposed to excess radiation. This fact motivated the author, who is working in a Nuclear research Centre, to consider the design and construction of a portable electronic device capable of detecting unsafe level of radiation, according to the International Atomic Energy Agency (I.A.E.A) regulations. Except the Geiger-Mueller tube, all the components used for the construction of the device are off the shelf parts that are relatively cheap and readily available locally.

1.3 Literature Review

The word radiation was used, until about 1900, to describe electromagnetic waves. Around the turn of the 19th century, electrons, x-rays, and natural radioactivity were discovered and were also included under the umbrella of the term "radiation" [1]. The newly discovered radiation showed characteristics of particles, in contrast to the electromagnetic radiation, which was treated as a wave. In 1920s, DeBroglie developed his theory of the duality of matter, which was soon afterward proved correct by electron diffraction experiments. As a result, the distinction between particles and waves ceased to be important and the word radiation was used for the whole electromagnetic spectrum as well as to all the atomic and subatomic particles that have been discovered. One of the many ways in which different types of radiation are grouped together is in terms of ionizing and nonionizing radiation. Nonionizing radiation is electromagnetic radiation with wavelength (λ) of about 1 nanometer (nm) or longer. Ionizing radiation includes the rest of the electromagnetic spectrum (x-rays, $\lambda = 0.005$ to 1 nm) and gamma (γ) rays with wavelength shorter than that of x-rays. It also includes all the atomic and subatomic particles, such as electrons, positrons, protons, alphas, neutrons, and heavy ions. Nowadays the word radiation commonly refers to ionizing radiation.

In 1911 Johannes Wilhelm Geiger invented the first version of the Geiger counter, which could count the number of particles of ionizing radiation. In 1928 Geiger and Walther Mueller greatly improved the counter, and it was renamed the Geiger-Mueller counter [2]. The Geiger-Mueller (G-M) tube is contained within the Geiger-Mueller counter, which has the ability to detect nearly all kinds of ionizing radiation. The tube is filled with an inert gas, and contains positive and negative electrodes set up coaxially. When ionizing radiation is injected or introduced into the tube from the radioactive substance, the various ions move to their oppositely charged electrodes. As the ions pass through the tube they collide with the atoms of the gas, knocking off their electrons to create more ions. An avalanche takes effect, and more and more ions keep being created. As the tube becomes reactive, the ions are passed from the negative electrode to the positive electrode. The high voltage on the tube is discharged when the tube becomes full of ions, which results in a drop of the voltage to zero. This inverted pulse can be counted electronically, and the number of these pulses per second is regarded as measure of the amount of number of particles (radioactivity) that the substance is giving off.

1.4 Problem Definition and Methodology

The ability of Geiger-Mueller (G-M) tube to detect nearly all kinds of radiation makes it a choice for this project. The G-M detector like other radiation detectors, require high voltage bias supply for its operation. The problem initially encountered was how to realize a portable G-M based detector that can be suitable for both indoor and outdoor use. This gave rise to the development of an energy efficient circuit powered by a 9 volts alkaline battery.

The energy efficiency was realized by utilizing the high efficiency performance of Switched Mode Power Supplies (SMPS) to provide high voltage (HV) bias for the G-M tube. To further reduce the power consumption of the device, the supply to the high voltage circuit was controlled, and a buffer capacitor was used to supply the tube continuously during the inactive period of the high voltage circuit.

1.5 Thesis Outline

The thesis consists of six chapters. Chapter one has introduced regulatory statement concerning exposure of radiation workers to ionizing radiation. Chapter two explains modes of operation of radiation detectors with emphasis given to operation of Geiger – Mueller detectors. Chapter three discusses different methods of converting a low DC voltage into lower or higher DC voltage by employing switch mode techniques. Logic voltage level translation for CMOS/Transistor Transistor Logic (TTL) ICs logic is discussed in chapter four. Chapter five contains Design procedure and description of circuit operation of the Radiation Alarm device. Finally, chapter six contains Conclusion and Suggestion for further work.

CHAPTER TWO

GEIGER – MUELLER DETECTORS

2.1 Introduction

The function of a radiation detector is to produce a signal for every particle entering it. Every detector works by using some interactions of particles with matter. The three general modes of operation of radiation detectors are: Pulse mode, current mode, and mean square voltage mode (MSV, sometimes called Campbelling mode) [2].

In pulse mode operation, the measurement instrumentation is designed to record each individual quantum of radiation that interacts with detecting medium in the detector. At every high event rates, pulse mode operation becomes impractical or even impossible. The time between adjacent events may become too short to carry out an adequate analysis, or the current pulses from successive events may tend to overlap in time. Yet, most applications are better served by preserving information on the amplitude and timing of individual event that only pulse mode can produce.

In current mode, if the measuring device is assumed to have a fixed response time T, then the recorded signal from a sequence of events will be a time dependent current given by:

$$I(t) = \frac{1}{T}\int_{t=0}^{T} i(t)dt \text{------------------------}(2.1)$$

This time average of the individual current bursts serves as the basic signal that is recorded. If this mode of operation is employed when making measurements in mixed radiation environments where the charge produced by one type of radiation is much different from that produced by a second type, the measured current will linearly reflect the charges contributed by each type. In MSV mode, however, the derived signal is proportional to the square of the charge per event. This operational mode will therefore further give weight to the detector response in favour of the type of radiation giving the larger average charge per event. This mode is useful in enhancing the relative response to large amplitude events and finds widespread application in reactor instrumentation.

2.2 Radiation Detectors

Radiation detectors are broadly categorized into three; Solid-state, Gas, and Scintillation detectors. The signal at the output of most detectors is a voltage pulse. The ideal pulse type counter should satisfy the following requirements:

(a) Every particle entering the detector should produce a pulse at the exit of the counter, which is higher than the electronic noise level of the unit that accepts it.

(b) The duration of the pulse should be short, so that particles coming in one after the other in quick succession produce separate pulses.

(c) If energy of the particle is to be measured, the height of the pulse should have some known fixed relationship to the energy of the particle.

(d) If two or more particles deposit the same energy in the detector, the corresponding pulses should have the same height.

There is no detector that satisfies all these requirements [1]. In practice, the experimenter selects a detector that satisfies as many of these properties as possible to the highest degree possible and, depending on the objective of the measurement, applies appropriate corrections to the measured data.

2.2.1 Solid state Detectors

These are devices which work on the principle that they collect the charge generated by ionizing radiation in a solid. These detectors are made of semi-conductor material and are operated much like a solid state diode with a reverse bias. The applied high voltage generates a thick ‘depletion layer’ and any charge created by the radiation in this layer is collected at an electrode. The charge collected is proportional to the energy deposited in the detector and therefore these devices can also yield information about the energy of individual particles or photons of radiation [2].

2.2.2 Scintillation Detector

Scintillation detector measures radiation by detecting tiny flashes of light which radiation produces in certain materials. These light flashes, called scintillation, are converted to electrical pulses and, when fed into suitable electronics, can discriminate between different types of radiation and even between different energies of the same radiation [2]. The amount of light produced in scintillator is very small. It must be amplified before it can be recorded as a pulse or in any other way.

Scintillation detector always consists of two components which are optically coupled. The first is a scintillator. The second component is a Photomultiplier which converts the flashes of light into a pulse of electric current. The photomultiplier tube is energized by a high voltage supply.

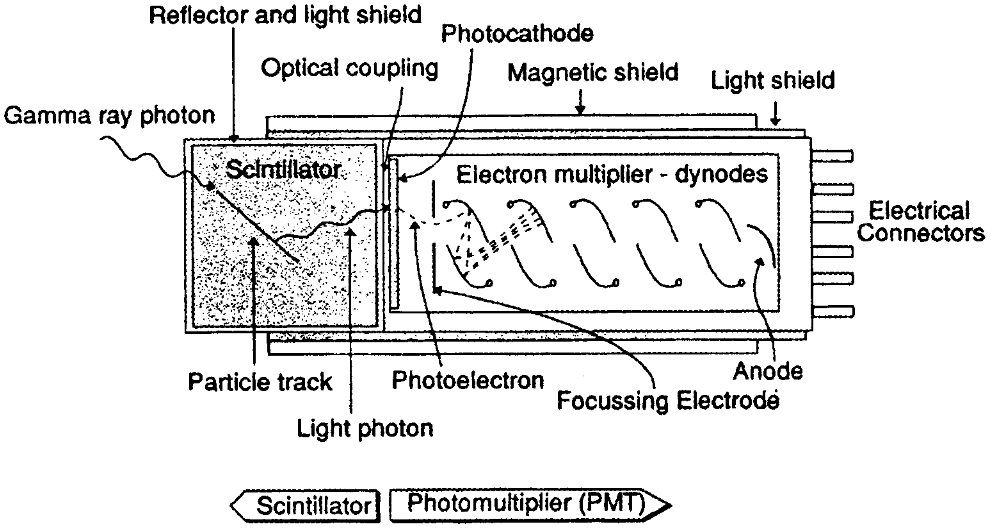


Figure 2.1: Scintillation Detector Schematic

2.2.3 Gas Detectors

Gas-filled detectors operate by utilizing the ionization produced by radiation as it passes through a gas. Typically, a gas-filled detector consists of two electrodes to which a certain electrical potential is applied. The space between the electrodes is filled with a gas. Ionizing radiation passing through the space between the electrodes dissipates part or all of its energy by generating electron-ion pairs. Both electrons and ions are charge carriers that move under the influence of electric field. The motion induces a current on the electrodes, which may be measured (current mode). Or, through appropriate electronics, the charge produced by the radiation may be transformed into a pulse, in which case particles are counted individually (pulse mode). The most popular of them is the Geiger-Mueller tube.

2.3 G-M Tube

The G-M tube is one of the oldest radiation detector types in existence, having been introduced by Geiger and Mueller in 1928 [2]. However, the simplicity, low cost, and ease of operation of this detector has led to its continued use to the present time. One additional advantage of the Geiger tube is its ability to detect all types of radiation, and this peculiar property it possesses makes it most suitable for radiation monitoring. Three concepts that govern the operation of Geiger-Mueller detectors are [1]:

(a) Ionization of gas

(b Charge movement and collection in gas

(c) Quenching

G-M tube basically consists of a pair of electrodes surrounded by a gas, specially selected for the ease with which it can be ionised. When radiation ionizes the gas, the tube produces a number of ion pairs, each consisting of an electron and a positive ion.

Figure 2.2: Basic Geiger-Mueller detector

Under the influence of electric field between the electrodes, the resulting motion of the positive ions and the electrons toward the negative and positive electrodes, respectively, constitutes an electrical current which is detected and recorded as a count. Thus, each particle or ray of radiation passing through the Geiger tube causes a short pulse of current to flow, the number of such pulses per unit time being a measure of the intensity of the radiation.

Under the influence of an electric field, electrons traveling to the anode acquire enough energy that their collision with gas molecules result in the formation of still other ion pairs. This process continues with the resulting formation of an avalanche of electrons and positive ions. The positive ions travel toward the cathode, also creating additional ion pairs on the way. Thus once initiated, ionization would cause the tube to discharge continuously in the absence of a quenching process. One way to quench a tube in order to restore it to its original quiescent state is to remove the electric field applied across its electrodes momentarily. This can be done electronically and is called external quenching. The duration of this voltage removal is one of the characteristics of the G-M tube, and is referred to as its dead time. Another method more commonly used today is internal quenching, accomplished by mixing small quantity of a polyatomic gas with the counter gas to absorb some of the energy of the electrons and positive ions after an ionization event. The net behaviour of a G-M tube during an ionizing event is the result of two opposing groups of factors; those tending to perpetuate discharge and those tending to limit discharge [1].

CHAPTER THREE

HIGH VOLTAGE POWER SUPPLY

3.1 Introduction

It is obvious that all kinds of radiation detectors require high voltage bias supply. Switch Mode Power Supplies (SMPS) are the current state of the art in high efficiency power supplies. SMPS owe their origins back to the days when valve or tube car radios needed the large high tension (HT) supply, for example 150V DC to be generated from an automobile power system of nominally 12V DC [5]. In those days the switched mode power supply took the form of a "vibrating reed" or vibrator which "chopped" up the 12V DC by electro-mechanical means and was then applied to a transformer, rectifier and filtering circuit to produce the much higher DC output. In principle only the electro-mechanical component has been replaced in favour of solid state electronics to produce a much more efficient, reliable and durable system.

the vibrator type power supply

Figure 3.1: Vibrator type HV power supply

SMPSs can be used to step-down or step-up a supply voltage. The term **switch mode converter** is used to describe a circuit which takes a DC input and provides a DC output of lower or higher voltage. Converters use a transformer and may provide input to output isolation. When discussing SMPS circuits, the different topologies are often referred to as 'Forward' or 'Flyback'. A Feed Forward converter circuit will supply energy to the load when the switching element (transistor) is switched on. A Flyback converter circuit transfers energy (from an inductor) to the load when the switching element (transistor) is switched off.

3.2 Forward Converter

In this circuit, the energy is stored in the inductor, L, as well as passed on to the load, during the ‘ON’ time of the switch. When the switch is switched ‘OFF’, L continues to supply the load until when the switch is closed back. The 'extra' winding of a forward converter's transformer ensures that at the start of a switch conduction, the net magnetization of the transformer core is zero. If there were no extra winding, then after a few cycles the transformer core would magnetically saturate, causing the primary current to rise excessively, so destroying the switch (i.e transistor) [6].

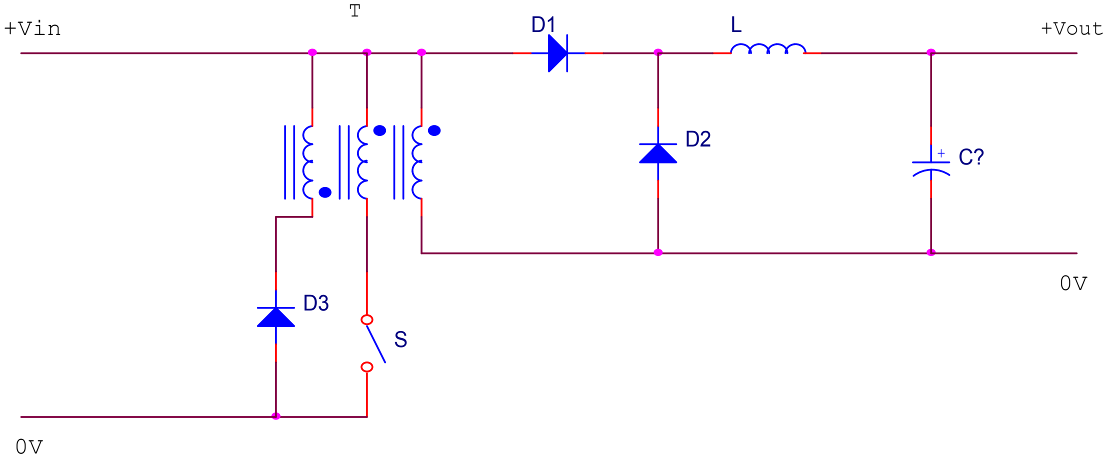


Figure 3.2: Forward Converter

The output voltage of a forward converter is equal to the average of the waveform applied to the LC filter and is given by:

$$V_{out} = V_{in} \times ({}^{n_2}\!/_{n_1}) \times (T_{on} \times f) ---------------------(3.1)$$

where:

n_2 = secondary turns on T1

n_1 = primary turns on T1

T_{on} = conduction time of switch

f = frequency of operation

3.3 Flyback Converter

In the Flyback converter circuit shown in figure 3.3, an external gate drive is employed to control the 'ON/OFF' times of a switching transistor, Q1. Its operation differs from previous circuit because of the polarity at the secondary of the transformer [7]. When Q1 is switched 'On', the top end of the transformer secondary goes negative, diode D1 is reverse biased, and the secondary is open circuited. Current flows from the input source and is stored I the primary winding. During the time Q1 is closed, C2 supplies the output current. When Q1 is switched 'Off', the primary is open circuited and the energy that had been stored in the primary winding is delivered via the secondary winding into the load and into capacitor C2 to replenish the charge it lost when Q1 was 'On' and C2 furnishing load current by itself.

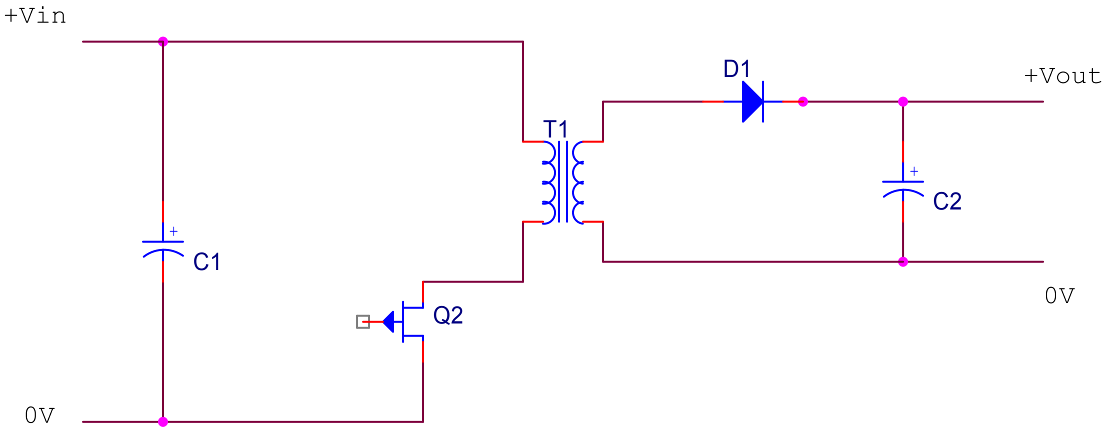


Figure 3.3: Flyback Converter

The output voltage for a flyback converter (trapezoidal current flow operation) may be calculated as follows:

$$V_{out} = V_{in} \times (n_2/n_1) \times \frac{T_{on} \times f}{1 - T_{on} \times f} \text{------------------------} (3.2)$$

where:

n_2 = secondary turns on T1

n_1 = primary turns on T1

T_{on} = conduction time of Q2

f = frequency of operation

3.4 Push pull Converter

The push pull converter belongs to the feed forward converter family. With reference to figure 3.4, when Q1 switches on, current flows through the 'upper' half of T1's primary and the magnetic field in T1 expands. The expanding magnetic field in T1 induces a voltage across T1 secondary, the polarity is such that D2 is forward biased and D1 reverse biased. D2 conducts and charges the output capacitor C2 via L1. L1 and C2 form an LC filter network.

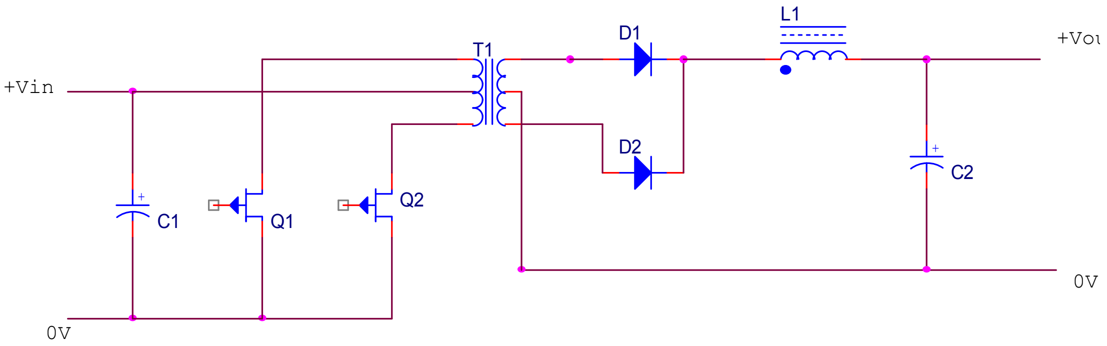


Figure 3.4: Push pull Converter

When Q1 turns off, the magnetic field in T1 collapses, and after a period of dead time (dependent on the duty cycle of the drive signal), Q2 conducts, current flows through the 'lower' half of T1's primary and the magnetic field in T1 expands. Now the direction of the magnetic flux is opposite to that produced when Q1 conducted. The expanding magnetic field induces a voltage across T1 secondary, the polarity is such that D1 is forward biased and D2 reverse biased. D1 conducts and charges the output capacitor C2 via L1. After a period of dead time, Q1 conducts and the cycle repeats.

There are two important considerations with the push pull converter [6]:

1. Both transistors must not conduct together, as this would effectively short circuit the supply. Which means that the conduction time of each transistor must not exceed half of the total period for one complete cycle, otherwise conduction will overlap.
2. The magnetic behaviour of the circuit must be uniform, otherwise the transformer may saturate, and this would cause destruction of Q1 and Q2. This requires that the individual conduction times of Q1 and Q2 be exactly equal and the two halves of the centre-tapped transformer primary be magnetically identical.

These criteria must be satisfied by the control and drive circuit as well as the transformer. The output voltage , V_{out} , equals the average of the waveform applied to the LC filter and is given by:

$$V_{out} = V_{in} \times (n_2/n_1) \times f \times (T_{on1} + T_{on2}) ------------------- (3.3)$$

where:

V_{out} = Average output voltage

V_{in} = Supply Voltage

n_2 = half of total number of secondary turns

n_1 = half of total number of primary turns

f = frequency of operation

T_{on1} = time period of Q1 conduction

T_{on2} = time period of Q2 conduction

3.5 Half Bridge Converter

The half bridge converter is similar to the push pull converter, but a centre tapped primary is not required. The reversal of the magnetic field is achieved by reversing the direction of the primary winding current flow. This type of converter is found in high power applications.

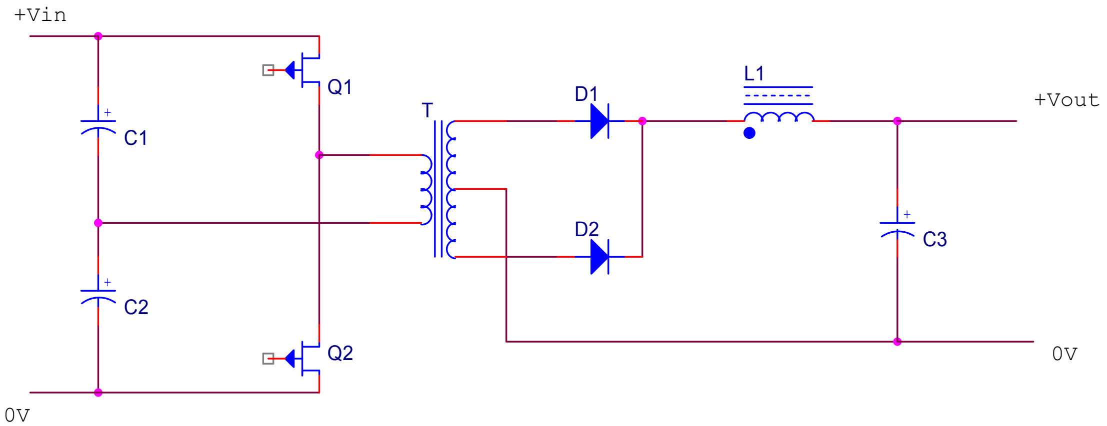


Figure 3.5: Half bridge Converter

For the half bridge converter, the output voltage Vout equals the average of the waveform applied to the LC filter.

$$V_{out} = \frac{1}{2} V_{in} \times \left({}^{n_2}\!/\!{}_{n_1} \right) \times f \times (T_{on1} + T_{on2}) ------------------ (3.4)$$

Where:

V_{out} = Output Voltage

V_{in} = Input Voltage

n_2 = half of total number of secondary turns

n_1 = primary turns

f = operating frequency

T_{on1} = Q1 conduction time

T_{on2} = Q2 conduction time

Note that $T_{on1} = T_{on2}$ and that Q1 and Q2 are never conducting at the same time.The control circuit of a half bridge converter is similar to that of a push-pull converter.

3.6 Full Bridge Converter

The full bridge converter is similar to the push pull converter, but a centre tapped primary is not required. The reversal of the magnetic field is achieved by reversing the direction of the primary winding current flow. This type of converter is found in high power applications.

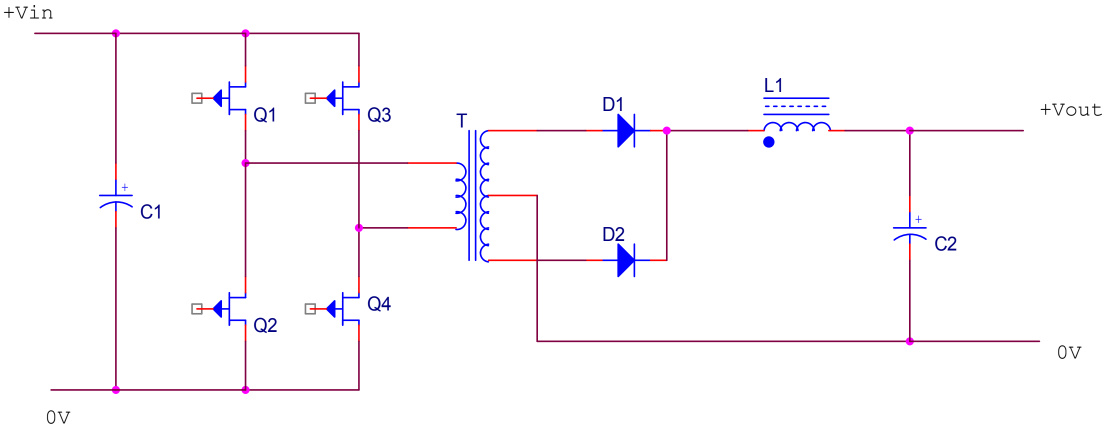


Figure 3.6: Full Bridge Converter

For the full bridge converter, the output voltage Vout equals the average of the waveform applied to the LC filter.

$$V_{out} = V_{in} \times (n_2 / n_1) \times f \times (T_{on1} + T_{on2}) -------------------(3.5)$$

Where:

V_{out} = Output Voltage

V_{in} = Input Voltage

n_2 = half of total number of secondary turns

n_1 = primary turns

f = operating frequency

T_{on1} = Q1 conduction time

T_{on2} = Q2 conduction time

Diagonal pairs of transistors will alternately conduct, thus achieving current reversal in the transformer primary. This can be illustrated as follows - with Q1 and Q4 conducting, current flow will be 'downwards' through the transformer primary, and with Q2 and Q3 conducting, current flow will be 'upwards' through the transformer primary.The control circuit operates in the same manner as for the push-pull converter and half-bridge converter, except that four transistors are being driven rather than two.

3.7 Voltage Multipliers

It is obvious that high voltage DC supply can be realized from battery by employing a step-up transformer in Converter circuit. One way of realizing a higher voltage is by connecting a voltage multiplier circuit to the secondary of the transformer. Voltage multiplier circuits such as voltage doublers, voltage quadruplers, etc are a special class of AC/DC converters. These circuits are required to obtain much higher DC voltage from an AC supply than is possible using conventional rectifier circuits [8]. The basic principle in such multipliers is to have a stack of capacitors in series and force equal voltage increments across each one.

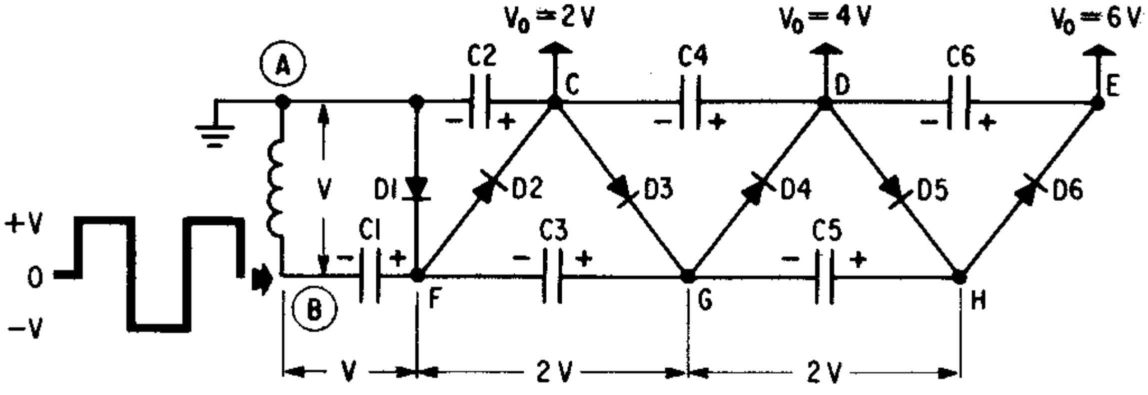


Figure 3.7: Voltage Multiplier (multiplication by even number)

Assume across transformer secondary, a square wave of ± V volts with respect to ground (figure 3.7). On the first half cycle when point B is negative relative to A, diode D1 charges C1 to a peak of ‘V’ in the polarity shown. On the next half cycle, B moves positive relative to A by an amount ‘V’, pushing the right –hand end of C1 up to ‘+2V’. C1 thus charges C2 up to ‘+2V’ via diode D2. On the third half cycle, B is again negative relative to A by ‘V’ and C1 again charges up to ‘+V’ with the polarity shown. Also on this half cycle, since D1 conducts, clamping to ground, the left-hand end of C3 is pulled down to ground. Now C2 charges C3 up to ‘+2V’ via diode D3. On the fourth half cycle, B moves up to ‘+V’, pushing the right-hand end of C1 up to ‘+2V’ to replenish the charge of ‘2V’ on C2. Also the right-hand end of C3 is pushed up to ‘+4V’. This puts a charge of ‘2V’ across C4 via diode D4. Now the right-hand end of C4 is at a potential of 4V above ground.

On the next half cycle, in a similar way, C4 charges C5 up to ‘2V’ via diode D5 and on the sixth half cycle, when B moves to ‘+V’, the right-hand end of C1 moves up to ‘+2V’ to replenish the charge on C2, the right-hand end of C3 moves up to ‘+4V’ to replenish the ‘+4V’ potential on C4. The right-hand end of C5 then charges the right-hand end of C6 up to ‘+6V’ via diode D6. Potentials of +2V, +4V, +6V are available at points C, D, and E respectively [7]. The maximum voltage any diode or capacitor is subjected to is '2V' volts. If voltage multiplication by an odd number is desired, point B is grounded as shown in figure 3.8.

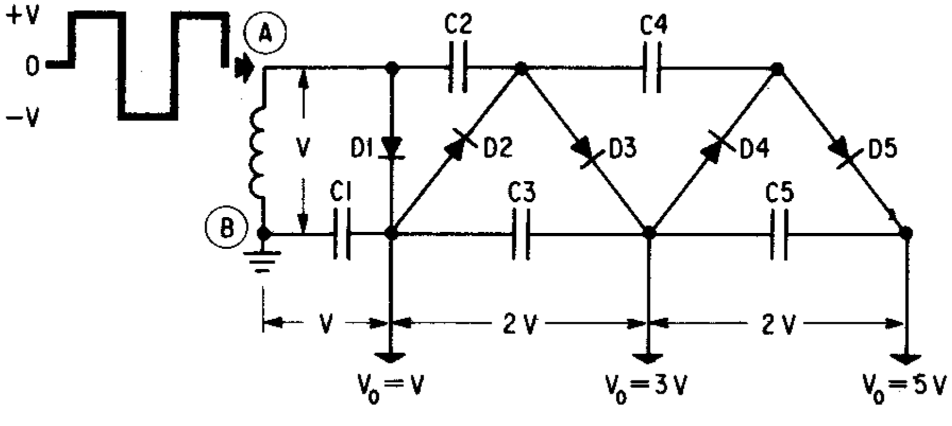


Figure 3.8: Voltage Multiplier (multiplication by odd number)

In a similar way, it can be shown that potentials at F, G, and H are respectively V, 3V, and 5V respectively.

CHAPTER FOUR

CMOS/TTL LOGIC VOLTAGE TRANSLATION

4.1 Introduction

The realization of logic operations began with vacuum tube and relay circuits. These were completely replaced by discrete transistor circuits, which in turn, have been completely replaced by integrated circuits (IC) devices [9]. There are a number of IC logic families. A logic family refers to a specific class of logic circuits that are manufactured using the same manufacturing techniques. Each logic family has its own basic electronic circuit upon which more complex circuits and functions are developed. The electronic components employed in the construction of the basic circuit are usually used to name the logic family. The most commonly used logic families are the Transistor-Transistor Logic (TTL) and the Complementary Metal Oxide Semiconductor (CMOS) logic.

4.2 CMOS Vs TTL

Since it appears that any gate possible to construct using TTL technology can be duplicated in CMOS, why do these two "families" of logic design still coexist? The answer is that both TTL and CMOS have their own unique advantages [10]. First and foremost on the list of comparisons between TTL and CMOS is the issue of power consumption. In this measure of performance, CMOS is the unchallenged victor. Because the complementary P- and N-channel MOSFET pairs of a CMOS gate circuit are (ideally) never conducting at the same time, there is little or no current drawn by the circuit from the V_{dd} power supply except for what current is necessary to source current to a load. TTL, on the other hand, cannot function without some current drawn at all times, due to the biasing requirements of the bipolar transistors from which it is made. There is a caveat to this advantage, though. While the power dissipation of a TTL gate remains rather constant regardless of its operating state(s), a CMOS gate dissipates more power as the frequency of its input signal(s) rises. If a CMOS gate is operated in a static (unchanging) condition, it dissipates zero power (ideally).

However, CMOS gate circuits draw transient current during every output state switch from "low" to "high" and vice-versa. So, the more often a CMOS gate switches modes, the more often it will draw current from the V_{dd} supply, hence greater power dissipation at greater frequencies. A CMOS gate also draws much less current from a driving gate output than a

TTL gate because MOSFETs are voltage-controlled, not current-controlled, devices. This means that one gate can drive many more CMOS inputs than TTL inputs. The measure of how many gate inputs a single gate output can drive is called fanout.

Another advantage that CMOS gate designs enjoy over TTL is a much wider allowable range of power supply voltages. Whereas TTL gates are restricted to power supply (V_{cc}) voltages between 4.75 and 5.25 volts, CMOS gates are typically able to operate on any voltage between 3 and 18 volts [11].The reason behind this disparity in power supply voltages is the respective bias requirements of MOSFET versus bipolar junction transistors. MOSFETs are controlled exclusively by gate voltage (with respect to substrate), whereas BJTs are current-controlled devices. TTL gate circuit resistances are precisely calculated for proper bias currents assuming a 5 volt regulated power supply. Any significant variations in that power supply voltage will result in the transistor bias currents being incorrect, which then results in unreliable (unpredictable) operation.

The only effect that variations in power supply voltage have on a CMOS gate is the voltage definition of a "high" (1) state. For a CMOS gate operating at 15 volts of power supply voltage (V_{dd}), an input signal must be close to 15 volts in order to be considered "high" (1). The voltage threshold for a "low" (0) signal remains the same: near 0 volts. One decided disadvantage of CMOS is slow speed, as compared to TTL. The input capacitances of a CMOS gate are much, much greater than that of a comparable TTL gate -- owing to the use of MOSFETs rather than BJTs -- and so a CMOS gate will be slower to respond to a signal transition (low-to-high or visa-versa) than a TTL gate, all other factors being equal.

Logic gate circuits are designed to input and output only two types of signals: "high" (1) and "low" (0), as represented by a variable voltage: full power supply voltage for a "high" state and zero voltage for a "low" state. In a perfect world, all logic circuit signals would exist at these extreme voltage limits, and never deviate from them (i.e., less than full voltage for a "high," or more than zero voltage for a "low"). However, in reality, logic signal voltage levels rarely attain these perfect limits due to stray voltage drops in the transistor circuitry, and so we must understand the signal level limitations of gate circuits as they try to interpret signal voltages lying somewhere between full supply voltage and zero.

4.3 TTL Signal Levels

TTL gates operate on a nominal power supply voltage of 5 volts, +/- 0.25 volts. Ideally, a TTL "high" signal would be 5.00 volts exactly, and a

TTL "low" signal 0.00 volts exactly. However, real TTL gate circuits cannot output such perfect voltage levels, and are designed to accept "high" and "low" signals deviating substantially from these ideal values. "Acceptable" input signal voltages range from 0 volts to 0.8 volts for a "low" logic state, and 2 volts to 5 volts for a "high" logic state. "Acceptable" output signal voltages range from 0 volts to 0.5 volts for a "low" logic state, and 2.7 volts to 5 volts for a "high" logic state.

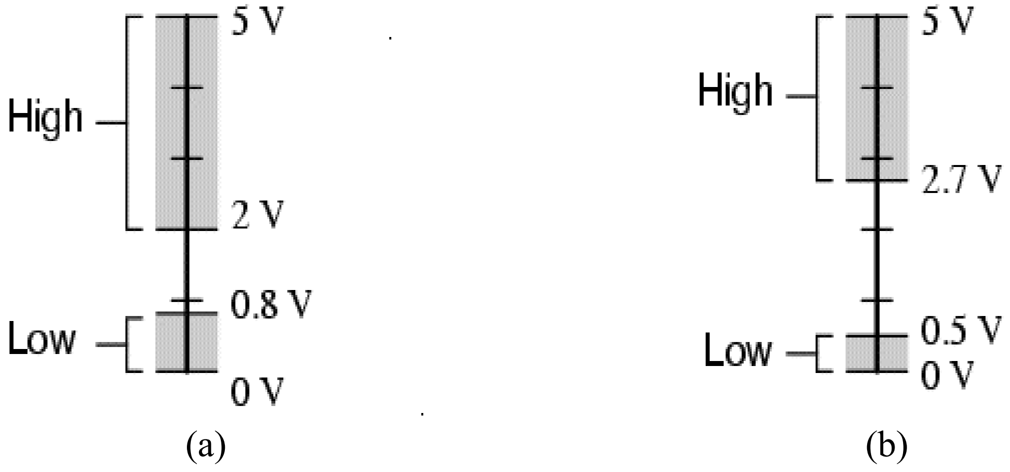
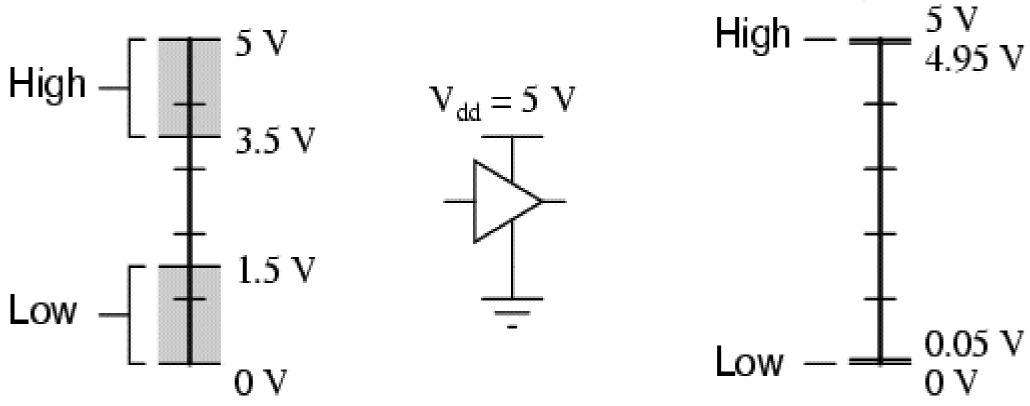


Figure 4.1: Acceptable TTL gate signal levels: (a) input, (b) output

If a voltage signal ranging between 0.8 volts and 2 volts were to be sent into the input of a TTL gate, there would be no certain response from the gate. Such a signal would be considered uncertain, and no logic gate manufacturer would guarantee how their gate circuit would interpret such a signal. As can be seen, the tolerable ranges for output signal levels are narrower than for input signal levels, to ensure that any TTL gate outputting a digital signal into the input of another TTL gate will transmit voltages acceptable to the receiving gate. The difference between the tolerable output and input ranges is called the noise margin of the gate, and is one of the important factors always considered when selecting a logic gate for a particular application. Simply, noise margin is the peak amount of spurious or "noise" voltage that may be superimposed on a weak gate output voltage signal before the receiving gate might interpret it wrongly.

4.4 CMOS Signal Levels

For a CMOS gate operating at a power supply voltage of 5 volts, the acceptable signal voltages range from 0 volts to 1.5 volts (0 to 30%V_{dd}) for a "low" logic state, and 3.5 volts to 5 volts for a "high" logic state (i.e. 70%V_{dd} to V_{dd}) [11]. Acceptable output signal voltages range from 0 volts to 0.05 volts (0 to 5%V_{dd}) for a "low" logic state, and 4.95 volts to 5 volts for a "high" logic state (i.e. 95%V_{dd} to V_{dd}).



(a) (b)

Figure 4.2: Acceptable CMOS gate signal levels for 5V supply: (a) input, (b) output

It is obvious from figure 4.2 that CMOS gate circuits have far greater noise margins than TTL: 1.45 volts for CMOS low-level and high-level margins, versus a maximum of 0.7 volts for TTL. CMOS noise margins widen even further with higher operating voltages. Unlike TTL, which is restricted to a power supply voltage of 5 volts, CMOS may be powered by voltages as high as 18 volts (a characteristic that makes CMOS logic particularly suitable for operation directly from batteries).

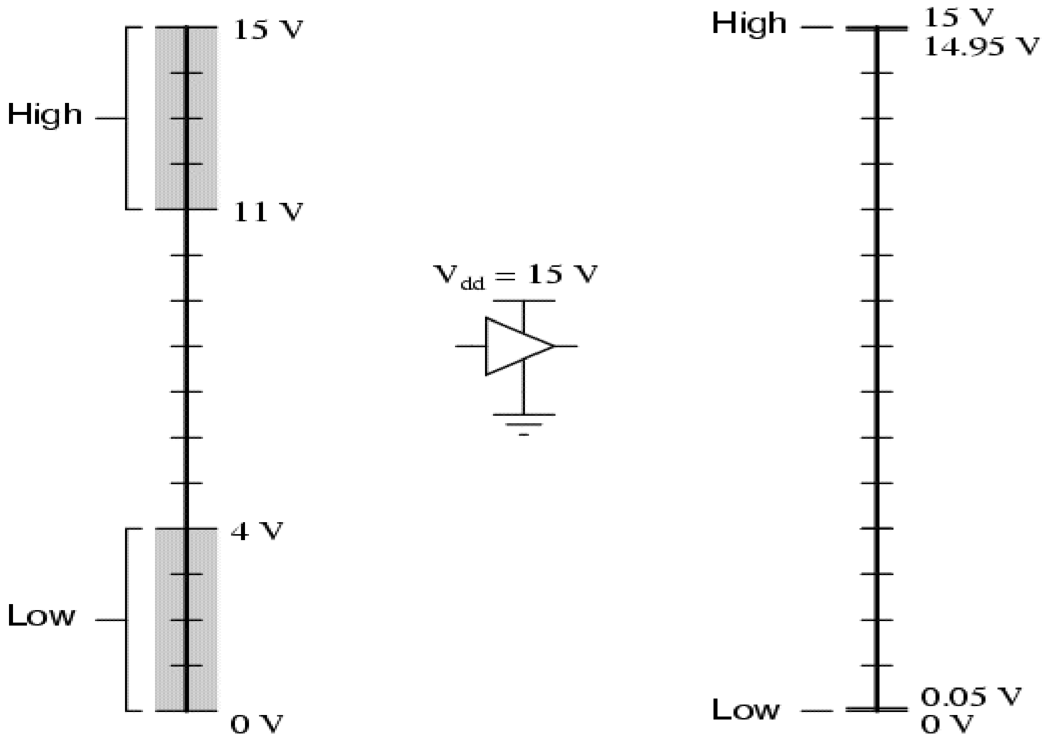


Figure 4.3: Acceptable CMOS gate signal levels for 15V supply: (a) input, (b) output

4.5 Voltage Translation

The differing voltage level requirements of TTL and CMOS technology present problems when the two types of gates are used in the same system [11]. Although operating CMOS gates on the same 5.00 volt power supply voltage required by the TTL gates is no problem, TTL output voltage levels will not be compatible with CMOS input voltage requirements.

4.5.1 TTL to CMOS

Take for instance a TTL NAND gate outputting a signal into the input of a CMOS inverter gate. Both gates are powered by the same 5.00 volt supply (V_{cc}). If the TTL gate outputs a "low" signal (guaranteed to be between 0 volts and 0.5 volts), it will be properly interpreted by the CMOS gate's input as a "low" (expecting a voltage between 0 volts and 1.5 volts). However, if the TTL gate outputs a "high" signal (guaranteed to be between 5 volts and 2.7 volts), it might not be properly interpreted by the CMOS gate's input as a "high" (expecting a voltage between 5 volts and 3.5 volts). CMOS inputs are sensitive to voltages generated by electrostatic sources, and may even be activated into “high” or “low” states by spurious voltage sources across if left floating [10]. Therefore if CMOS gate input is being driven by a TTL gate it is inadvisable to allow the input to float under any circumstances, because TTL’s output floats when it goes high. By connecting a pull-up resistor as shown in figure 4.4, the TTL gate’s “high” signal voltage level is augmented and at the same time preventing the CMOS input from floating [11].

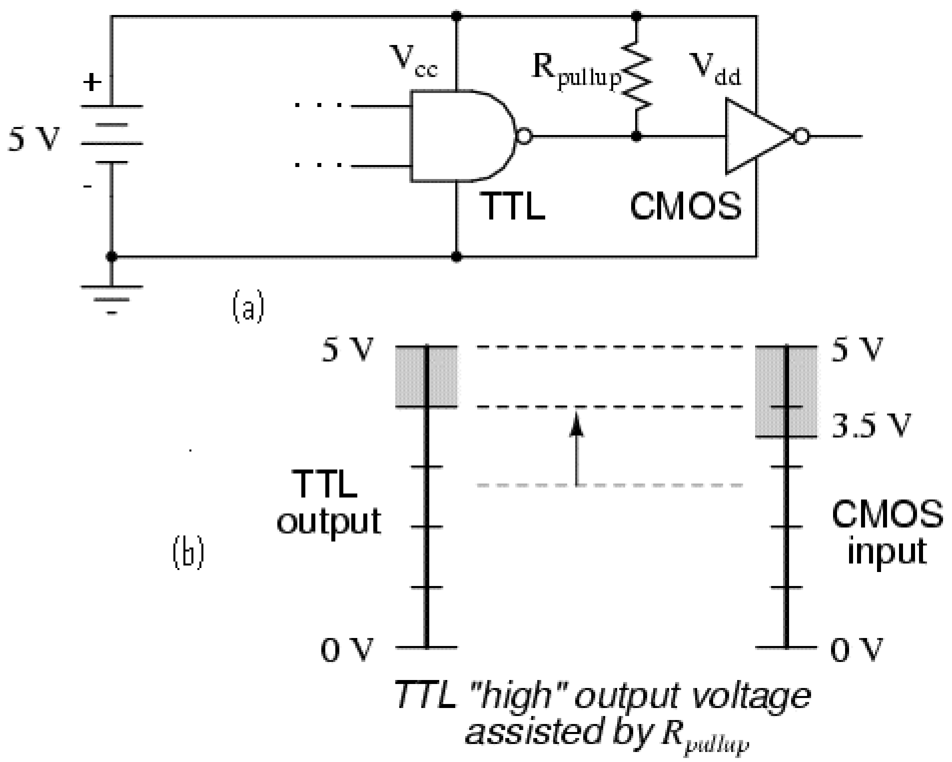


Figure 4.4: TTL/CMOS logic translation: (a) circuit (b) TTL "high" output augmented

Something more than this, though, is required to interface a TTL output with a CMOS input, if the receiving CMOS gate is powered by a greater power supply voltage, say 10 volts. There will be no problem with the CMOS gate interpreting the TTL gate's "low" output, of course, but a "high" signal from the TTL gate is another matter entirely. The guaranteed output voltage range of 2.7 volts to 5 volts from the TTL gate output is nowhere near the CMOS gate's acceptable range of 7 volts to 10 volts for a "high" signal. Connecting a pull-up resistor to the 10 volt V_{dd} supply rail will raise the TTL gate's "high" output voltage to the full power supply voltage supplying the CMOS gate.

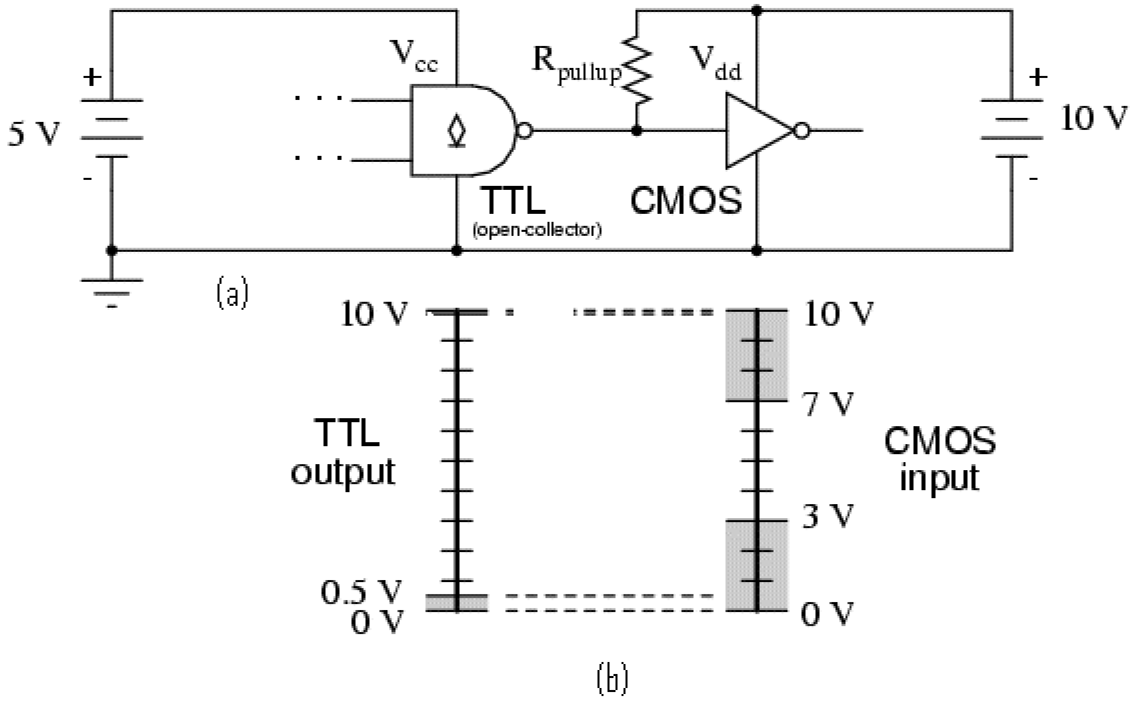


Figure 4.5: TTL/CMOS logic translation for uneven supply: (a) circuit (b) TTL "high" output augmented

4.5.2 CMOS to TTL

Due to the excellent output voltage characteristics of CMOS gates, there is typically no problem connecting a CMOS output to a TTL input provided both gates are powered from 5 volts supply. The only significant issue is the current loading presented by the TTL inputs, since the CMOS output must sink current for each of the TTL inputs while in the "low" state. Of course, Fan-out requirements still have to be observed. Increased current sinking/sourcing capability of CMOS is obtained by simply connecting input terminals of gates as shown in figure 4.6 [11]. Also, CMOS buffers can sink current sufficient to drive five standard TTL inputs.

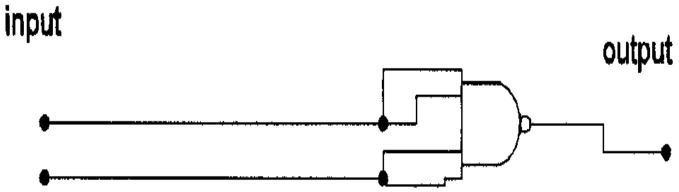


Figure 4.6: 4-input NAND gate connected as 2-input gate for increased drive capability

When the CMOS gate in question is powered by a voltage source in excess of 5 volts (V_{cc}), though, a problem will result. The "high" output state of the CMOS gate, being greater than 5 volts, will exceed the TTL gate's acceptable input limits for a "high" signal. A solution to this problem is to create an "open-collector" inverter circuit using a discrete NPN transistor, and use it to interface the two gates together (figure 4.7).

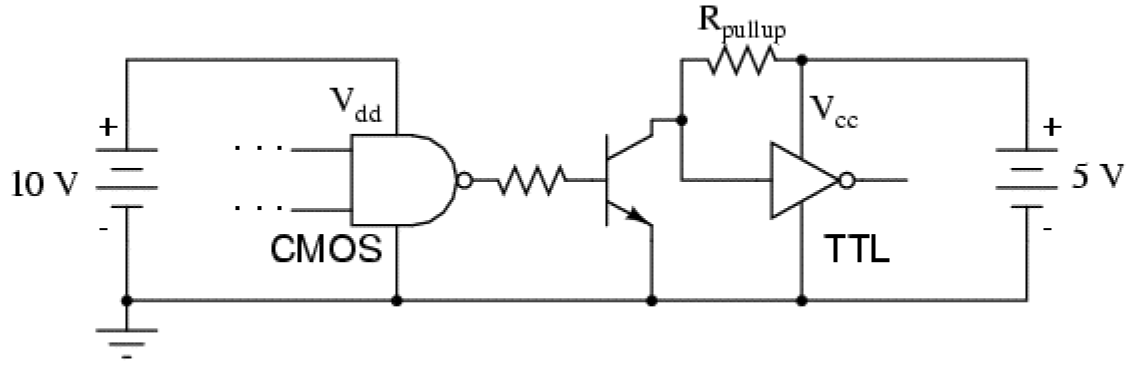


Figure 4.7: CMOS/TTL logic translation for uneven voltage supply

Another possibility of down level conversion of CMOS/TTL interfacing is by the use of a resistor voltage divider, provided the CMOS gate output has the drive capability [3].

CHAPTER FIVE

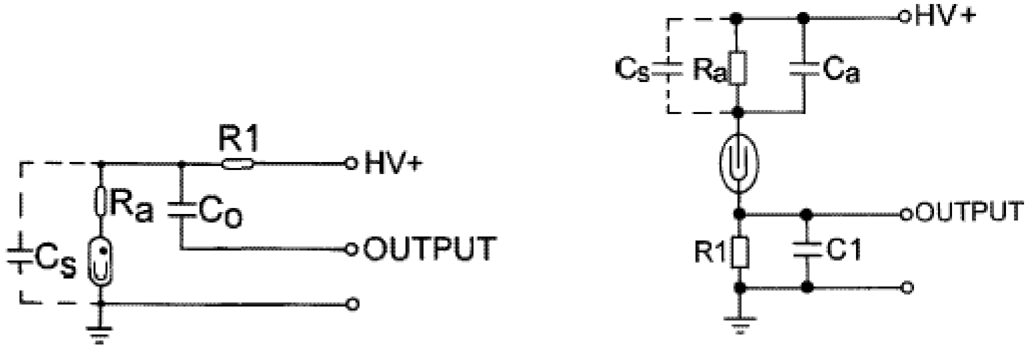
CIRCUIT DESIGN AND OPERATION

5.1 Introduction

As earlier highlighted, three concepts that govern the operation of Geiger –Mueller detectors are: Ionization of gas, Charge movement and collection in gas, and Quenching. Ionization is caused by radiation entering the GM tube, and the quenching process is internally executed (since the tube selected for this work has internal quenching capability). What this work is concerned with is the charge movement and collection in gases, and how this collected charge could be translated into useful information. The Radiation alarm circuit is a mobile device, intended to be used for both indoor and outdoor monitoring, and it is therefore powered from a 9V alkaline battery. The design therefore focused on realization of an energy efficient device, so that battery replacement with be minimal. Measurements were taking using Tektronix digital storage oscilloscope, and the resulting graphs printed via a laser printer. In case of high voltage measurements, the readings were taking via a 1:10 differential probe.

5.2 Design Procedure

The GM tube used is a Thin wall type, whose specifications are as given in appendix A. Output from the tube can be collected either from its anode or its cathode [12], as shown in figure 5.1.



(a) (b)

Figure 5.1: GM tube circuit connections: (a) anode output, (b) cathode output

The Radiation alarm circuit can be broadly divided into three sections:

(a) High voltage supply

(b) Power consumption control circuit, and

(c) Radiation translation section

5.2.1 High Voltage Supply

The high voltage supply takes the form of push pull converter discussed in section 3.4. The switching transistors here are bipolar transistors whose bases are driven by an oscillator with alternate outputs. If selection is made such that R1 is equal to or greater than 10R2, the relaxation oscillator in figure 5.2 will produce a square wave of 50% duty cycle [11], whose frequency of oscillation is given by:

$$f = 1/1.4R_2C_1 \text{-------------------------} (5.1)$$

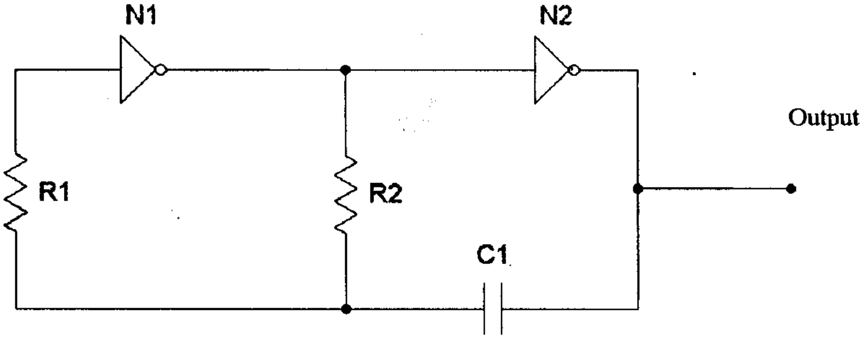


Figure 5.2: Relaxation oscillator

The circuit can be gated if inverter N1 is replaced with a two input NAND gate. Figure 5.3 shows a gated oscillator with alternate outputs needed to drive the converter’s switching transistors.

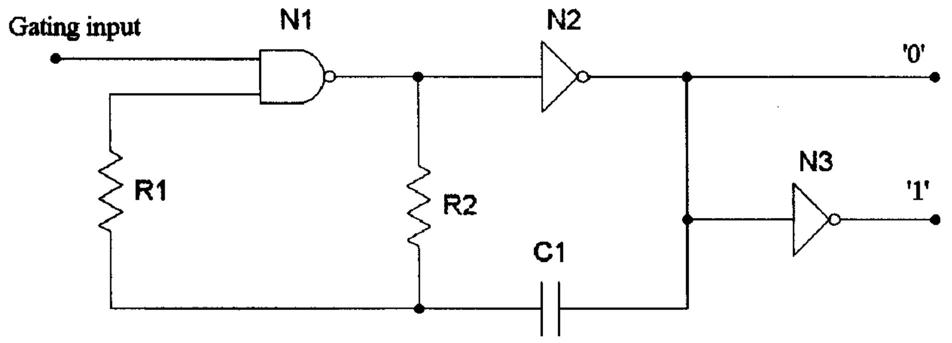


Figure 5.3: Gated relaxation oscillator

The frequency of oscillation of the circuit, given R2 =220kΩ, and C1 = 1uF is 3.3 Kilohertz. The DC/AC up-converter circuit is shown in figure 5.4.

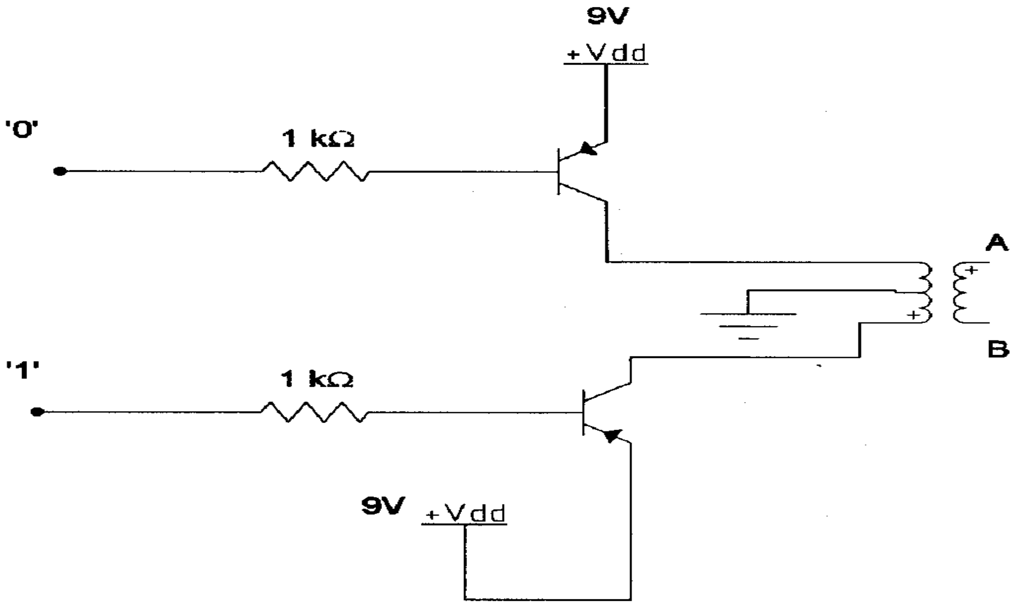


Figure 5.4: DC/AC up-converter

From equation 3.3, the voltage at the transformer's secondary is:

$\mathrm{V_{AB}} = 9 \times ({}^{n2}\!/_{n1}) \times f \times (T_{on1} + T_{on2})$

But ${}^{n2}\!/_{n1} = 10$, and $(T_{on1} + T_{on2}) = f$;

Therefore, $\mathrm{V_{AB}} = 90\mathrm{V_{p\text{-}p}}$

A voltage multiplier, using the principle of multipliers discussed in section 3.6, converts the $90\mathrm{V_{p\text{-}p}}$ into a high DC voltage as shown in figure 5.5 (2). The cursor positions indicated a measurement of 44.8 volts (delta value on the graph). The displacement of the graph showed a value of 8 volts. The peak voltage across the tube will be 520 volts (i.e $(44.8+8)\times 10$).

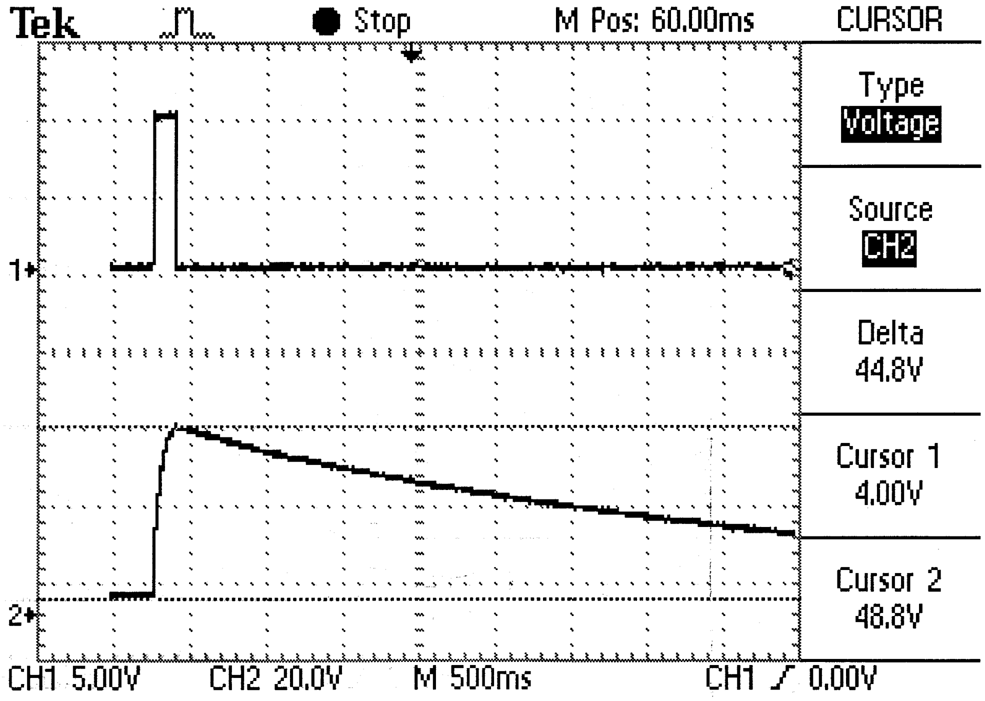


Figure 5.5: (2) High voltage supply to G-M tube

5.2.2 Power Consumption Control

The Radiation alarm device is powered by a 9V alkaline battery. Therefore a means of preserving the battery and make its replacement minimal is necessary. This is realized by introducing a relaxation oscillator to control the loading effect of the high voltage power supply. The oscillator is like the one in figure 5.2, with R2 and C1 values given as 10Mega ohm and 1micofarad respectively. The frequency of oscillation of this oscillator will be:

$$f = 1/1.4R_2C_1 = {}^{1}\!/_{14}\,Hz ----------------------- (5.2)$$

The pulse width of the square wave = 14/2 seconds = 7 seconds. This indicates that in every fourteen seconds, the high voltage circuit will operate for a period of seven seconds only, thereby reducing the power consumption of the HV circuit by 50%. The pulse width was further reduced by moving the switching threshold of the inverters [11]. This is achieved by the introduction of resistor R3 and diode D1, to provide a shorter discharging path for capacitor C1 (figure 5.6). A pulse width of 160ms was realized, from the transformed oscillator, at nearly the same frequency as shown in figure 5.7 and figure 5.8.

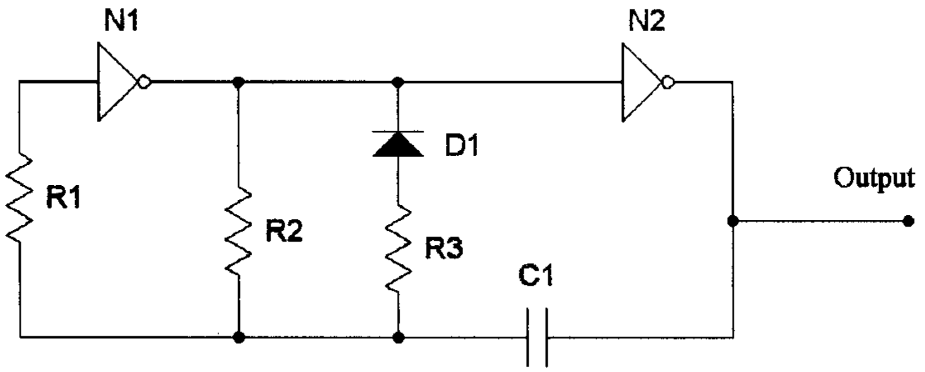
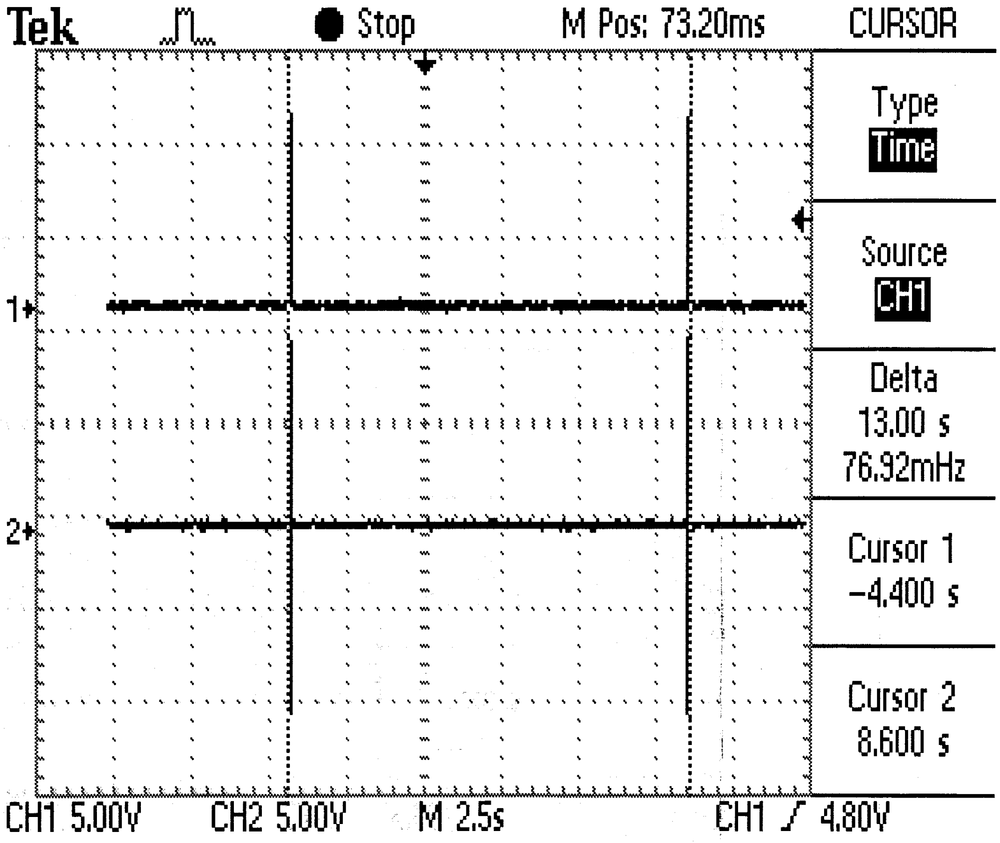


Figure 5.6: Transformed Relaxation oscillator



M Pos: 73.20ms

CURSOR

Type Time

Source CH1

Delta 13.00 s 76.92mHz

Cursor 1 -4.400 s

Cursor 2 8.600 s

CH1 5.00V CH2 5.00V M 2.5s CH1 ⁄ 4.80V

Figure 5.7: Period for transformed oscillator output; (1) Pulses from transformed oscillator; (2) Supply across transformer primary windings

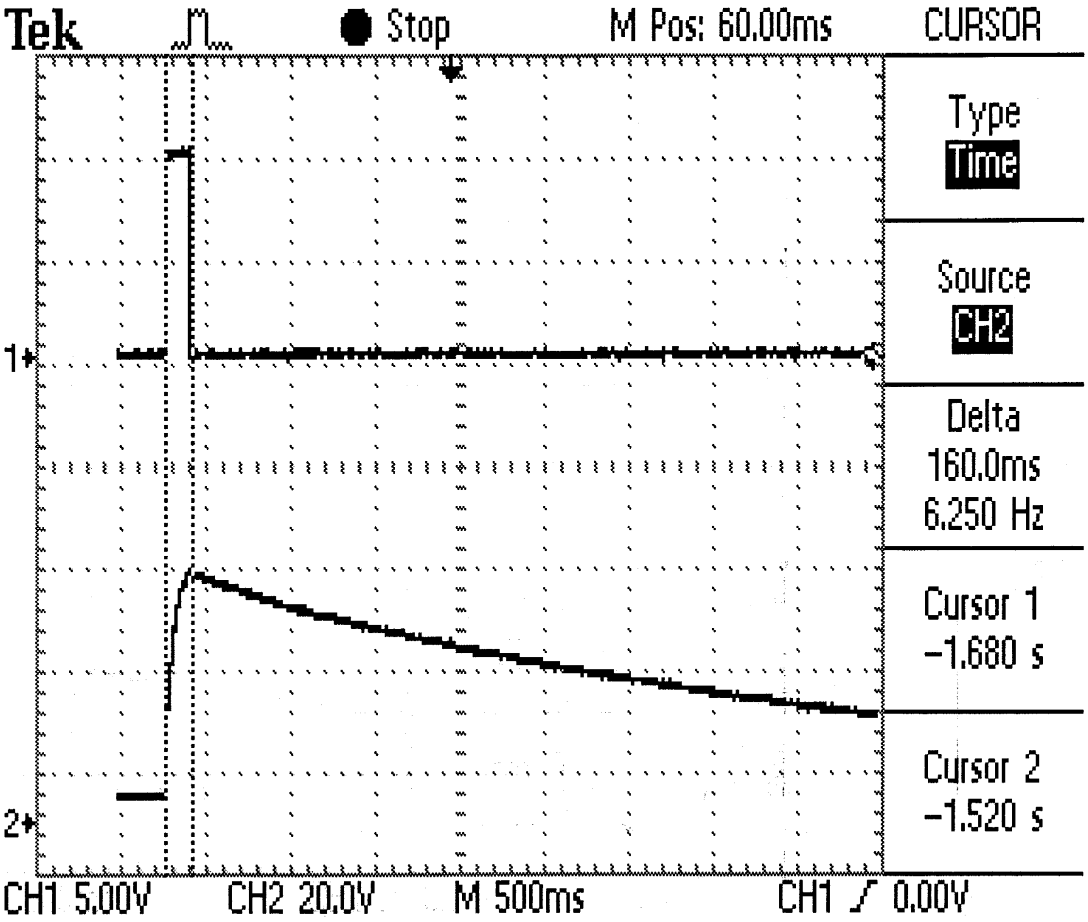


Figure 5.8: HV transient across GM tube; (1) Pulse from transformed oscillator output; (b) Voltage across G-M tube

As shown in figure 5.8, the high voltage circuit loads the device supply for only 160 milliseconds in every 13 seconds (approximately 1.2% loading). The transient nature of the high voltage supply is the effect of a buffer capacitor introduced to continuously supply the G-M tube, during the inactive period of the high voltage circuit. The high voltage was measured via a differential probe of multiplying factor equal to 10. Thus the peak voltage supplied to the tube is approximately 500 volts, as reflected in figure 5.5 (2).

5.2.3 Radiation Translation

The Radiation translation section collects pulses from G-M tube, count same for a specified period of time, and give an audible alarm once the count rate exceeds a preset threshold (indicating that an unsafe level of radiation is being detected). The unit comprises of a Basic stamp II (BS2) module, a buzzer, and associated components.

The Basic stamp II is a PIC-microcontroller based unit designed for projects that require an embedded system with some level of intelligence. It comes with a BASIC interpreter chip, internal memory (RAM and EEPROM), and sixteen (16) general input/output pins of TTL level (0 – 5 volts). It is programmed via an RS232 (serial) interface, and its pin assignment and how it interfaces with PC is contained in appendix B.

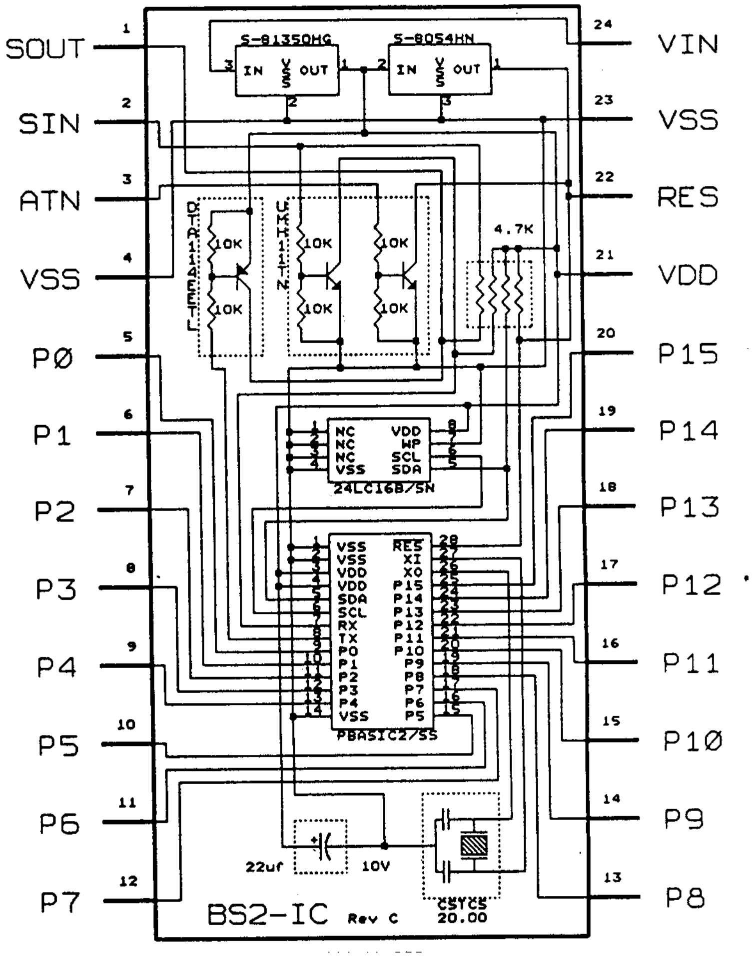


Figure 5.9: Basic stamp II schematic

The BS2 runs on a 20MHz clock speed (20nS instruction cycle) and is programmed with a simplified, but customized form of the BASIC programming language, called PBASIC. The PBASIC command reference is shown in appendix C, and the following commands (COUNT, PULSOUT, GOTO, etc) shall be discussed.

(a) COUNT

Syntax: **COUNT** Pin, Period, Variable

The **COUNT** instruction makes the Pin an input, then for the specified period of time, counts cycles on that pin and stores the total in a variable. **COUNT** on BS2 can respond to transactions (pulse width) as small as 4.6µs from a square wave of up to 120 KHz. The unit of Period is ‘ms’ and it ranges between 1ms to 65.535 seconds.

(b) **PULSOUT**

Syntax: **PULSOUT** Pin, Period

PULSOUT sets Pin to output mode, inverts the state of that pin; wait for the specified Period; then converts the state of the pin again; returning the bit to its original state. In other words, it generates a pulse, of duration specified by Period, on a pin dictated by Pin. The unit of Period is 10µs, and maximum pulse width is 655.35ms.

(c) **IF … THEN**

Syntax: **IF** Condition **THEN** Address

IF … THEN is PBASIC's decision maker. It tests a condition and, if that condition is true, goes to a point in the program specified by an address label. The comparison operators available are: Equal (=), Not Equal (<>), Greater Than (>), Less Than (<), Greater Than or Equal To (>=), and Less Than or Equal To (<=). Also available are the following conditional logic operations: NOT, AND, OR, and XOR.

(d) **LOW**

Syntax: **LOW** Pin

The **LOW** command sets the specified pin to "0" (a 0 volt level) and then sets its mode to output.

(e) **GOTO**

Syntax: **GOTO** Address

The **GOTO** command makes the BS2 execute the code that starts at the specified Address location. The BS2 reads PBASIC code from left to right/ top to bottom. The **GOTO** command forces the BS2 to jump to another section of code. A common use for **GOTO** is to create endless loops; programs that repeat a group of instructions over and over.

The Radiation alarm circuit was calibrated using ATOMEX AT1121 dose rate meter, Cobalt 60 source, and ORTEC 755 Counter; experiment setup is as shown in figure 5.10.

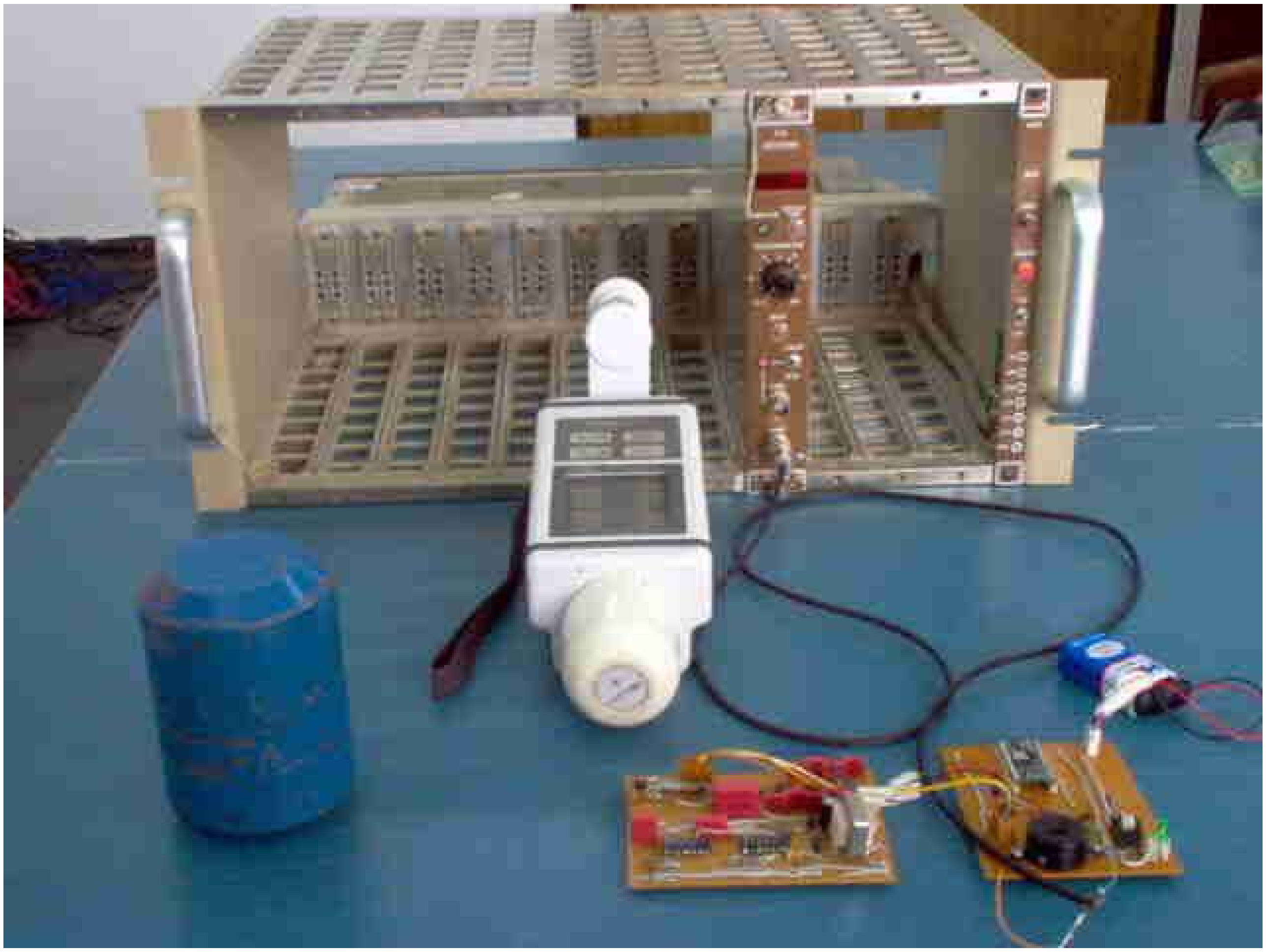


Figure 5.10: Photograph of experiment setup for Circuit calibration

The pulse count recorded for 27μSv/hour radiation (being the maximum allowable radiation level a radiation worker is allowed to be exposed to) was found to be 241 (259±7%) counts per minute. This result was averaged from a total number of thirteen readings collected as shown in table 1, Dose meter readout is as shown in figure 5.11. The error margin of the dose rate meter is ±7%.

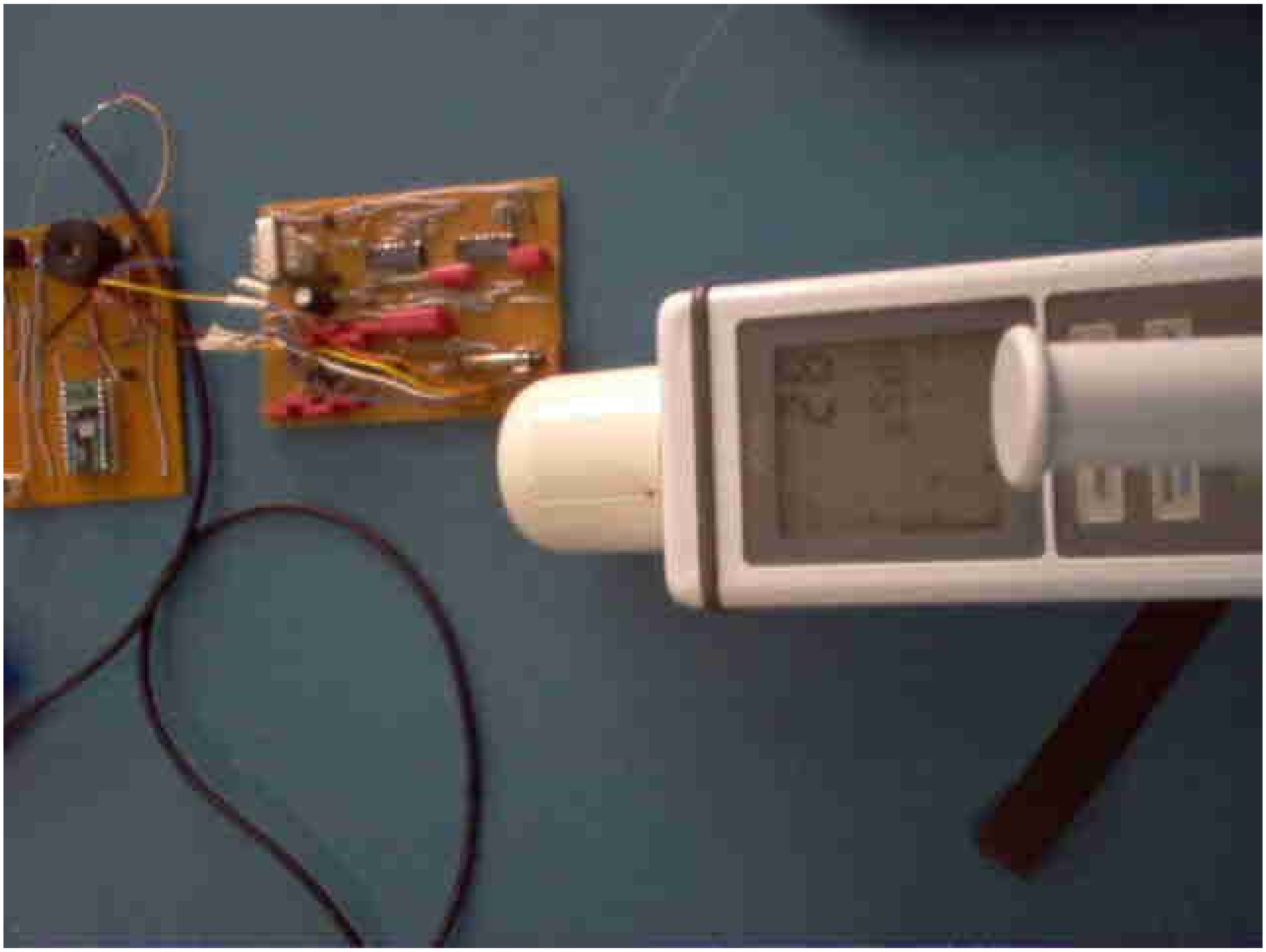


Figure 5.11: Photograph of Dose meter readout

Serial Number	Count/minute for 27µSv/hour dose
1	277
2	266
3	270
4	244
5	263
6	258
7	264
8	260
9	261
10	238
11	241
12	264
13	257
Total	**3,363**

Table 5.1: Count rate for 27µSv/hour dose rate recorded for one minute interval

The BS2 was programmed to continuously monitor pulses from G-M tube once the Radiation alarm device is powered on. The unit remains silent until a radiation level of 27µSv/hour or higher is detected, during which an audible alarm is triggered to alert the personnel carrying the device.

The following program was written and stored in the BS2 EEPROM:

```
Pulses        VAR        Word
Loop:
        COUNT 0, 60000, Pulse
        IF Pulse < 240 THEN Loop
        PULSOUT 7, 50000
        GOTO Loop
```

The program performs the following functions:

1. A variable, named Pulses, is defined and directed to be stored, as a word, in a location of the module's working memory
2. A loop commences, and pulses that arrive the module input, pin 0, are counted for a period of one minute (60000ms) and stored as a word.

3. The result stored in step 2 is compared with a preset threshold of 240 and a logical decision is considered.
4. If the count obtained is found to be less than 240, the loop restarts.
5. If the count is found to be greater than 240, a pulse of 500ms (10µs x 50000) is output on pin 7
6. The loop restarts and the operation is repeated. This process continues once the BS2 is powered on.

5.3 Circuit Operation

The complete circuit of the Radiation Alarm circuit is shown in figure 5.10. Every 13 seconds, the power consumption regulating oscillator produces a pulse of 160ms duration. Only then the oscillator that drives the bases of transistors Q1 and Q2 starts running. The transistors alternatingly switch transformer T1 primary windings to a 9V DC supply, producing an AC voltage at the secondary winding of the transformer.

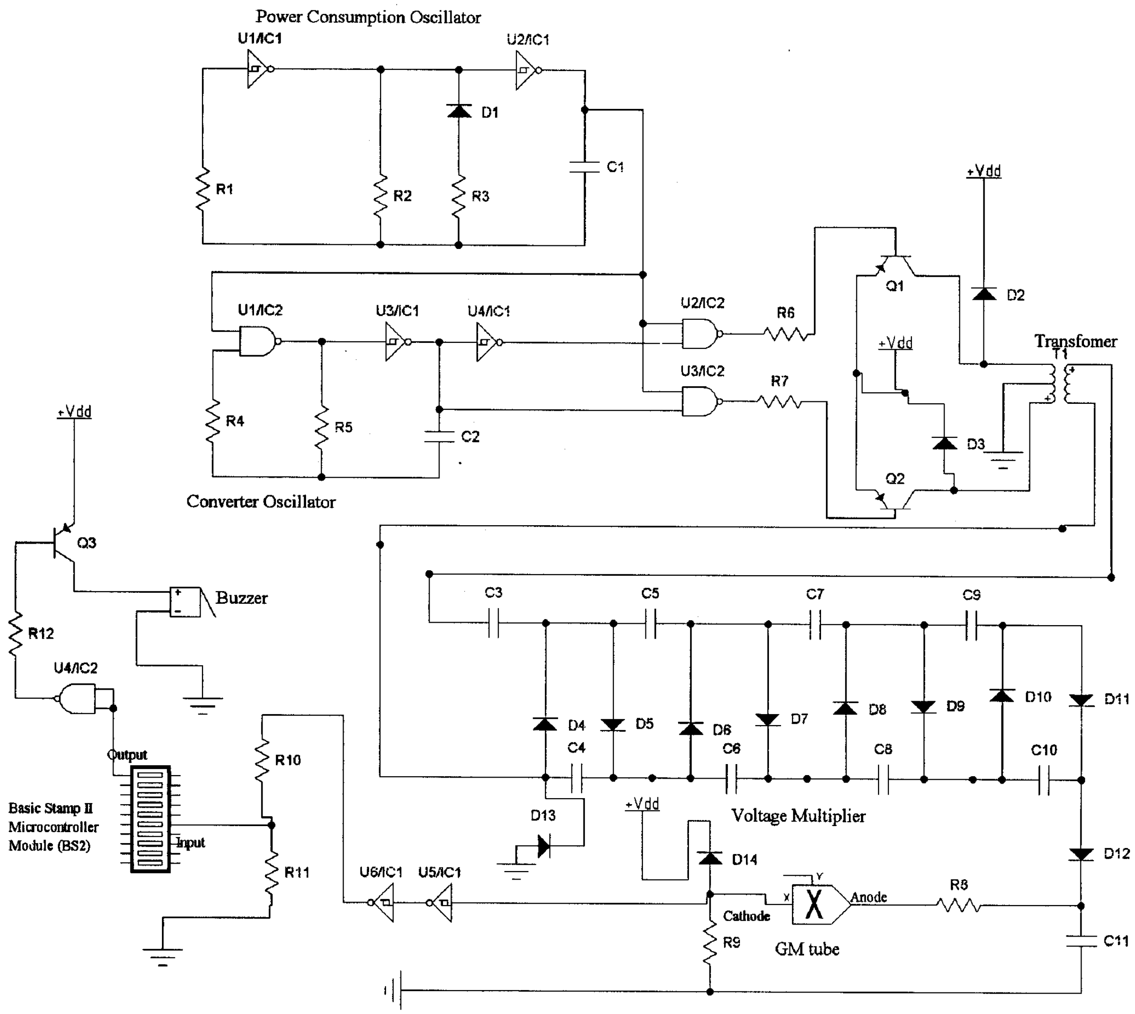


Figure 5.12: Circuit diagram for Radiation alarm device

A voltage multiplier converts this voltage to a very high DC voltage, of about 500 volts, which biases the G-M tube. The high voltage supply exists momentarily, only for 160ms. To power the tube continuously, a buffer capacitor, C11, is used. Radio-active particles that reach the G-M tube cause current peaks on R9. Because the width of pulses from the tube are uneven, inverters U5/IC1 and U6/IC1 are used to shape them into acceptable pulse width for the BS2 (as shown in figure 5.11). The cursor positions indicate a pulse of 44 microseconds width.

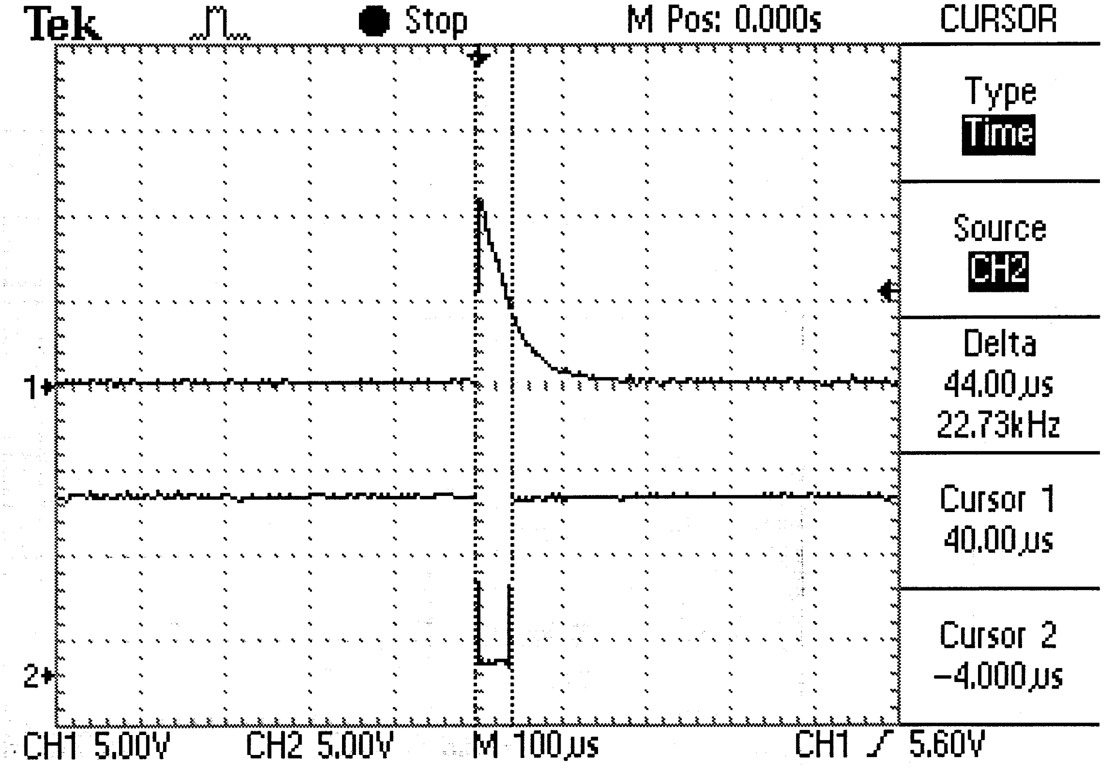


Figure 5.13: G-M tube output pulse; (1) original pulse, (2) shaped pulse

The BS2 continuously processes pulses from the G-M tube, according to the resident program on it, and triggers a buzzer once an unsafe radiation level is detected by the tube. NAND gate U4/IC2 has its inputs paralleled to accommodate the TTL logic it is connected to. Diodes D2 and D3 smoothen glitches resulting from transistors Q1 and Q2 switching events. They also clamp the supply to transformer T1 primaries to 9 volts. Diode D4 clamps pulses from G-M tube to maximum amplitude of 9 volts.

The Radiation alarm circuit is not sensitive to low level radiation. However, this limitation does not affect the function which the circuit is intended for, i.e monitoring a radiation intensive environment. Figure 5.14 shows the Radiation Alarm Device.

Figure 5.14: Radiation Alarm Device

5.4: List of Components

(a) Resistors

R1	100 MΩ
R2, R8	10 MΩ
R3, R6, R7, R12	100 KΩ
R4	1 MΩ
R5, R9,	220 KΩ
R10, R11	6.7 KΩ

(b) Capacitors

C1	1 μF
C2	1 nF
C3 to c10	33 nF
C11	33nF/ 1000 volts, electrolytic

(c) Diodes

D1, D2, D3, D14	1N 918
D4 to D13	1N4007

(d) Transistors

Q1, Q2, Q3	BC 559

(e) Integrated Circuits

IC1	CMOS Hex inverter Schmitt Trigger
IC2	CMOS Quad 2-input NAND Schmitt Trigger

(f) Miscellaneous

Basic Stamp II module

Buzzer

Centre-tap mini Transformer

LN 713 Thin-wall G-M tube

Light emitting diode

Double pole, double throw mini switch

CHAPTER SIX

CONCLUSION

6.1 Conclusion

The Radiation Alarm Device monitors its vicinity continuously and triggers an audible alarm to alert the personnel carrying it, once it detects an unsafe radiation level, as defined by the International Atomic Energy Agency (I.A.E.A). The word radiation was used, until 1900, to describe electromagnetic waves [1], but nowadays the word radiation commonly refers to ionizing radiation. The heart of the device circuit is a Geiger-Mueller tube. G-M tube basically consists of a pair of electrodes surrounded by a gas specially selected for the ease with which it can be ionized. Three concepts that govern G-M operation are: Ionization of gas, Charge movement and collection in gas, and Quenching of excessive discharge in gas.

Each particle or ray of radiation passing through the Geiger tube ionizes the gas into electrons and positive ions. Electric field across the tube influences motion of the electrons and ion pairs toward positive and negative electrodes, respectively, causing a short pulse of current to flow. This pulse is recorded as a count by Basic Stamp II (BS2) microcontroller module. The BS2 is a PIC-microcontroller based unit which comes with 16 input/output pins and a set of built-in commands for mathematical and I/O operations. The BS2 outputs a pulse of 500 milliseconds duration to drive a buzzer, once the pulse count rate for a period of one minute interval exceeds the preset threshold specified in the BS2 program; 240 counts/minute in this case, indicating a 27μSv/hour radiation dose.

Because the Radiation alarm device was intended for both indoor and outdoor use, it was designed and powered from a 9 volts alkaline battery. To make battery replacement minimal, the device was designed to be energy efficient. This was achieved by harnessing the efficiency of switch mode power supplies (SMPS) and utilization of low power consumption of CMOS ICs, as well as the use of a buffer capacitor to provide the high voltage requirement of the unit for most of the time.

The performance and characterization of the prototype Radiation Alarm Device has been found to be very satisfactory and confirmed to meet all the design specifications. It is also established to be very cost-effective and offer the possibility for future commercialization.

6.2: Recommendations for Further Work

As earlier indicated, the Radiation Alarm Device can not detect a very low radiation, although it satisfies its intended purpose of detecting high radiation dose. This is because the G-M tube is not continuously biased within its recommended operating voltage of 450V – 650V. To remedy this limitation, the power consumption regulating oscillator should be removed so that the high voltage supply oscillator will run freely, and the unit be powered from a regulated power supply. Once the operating voltage requirement is satisfied, the G-M tube sensitivity curve will conform with that shown in appendix A. By properly programming the BS2 module and interfacing it with a Liquid crystal display, the improved circuit can be used as a Dose rate meter. A Dose rate meter is a device used to measure and display radiation dose in areas prone to radiation activities.

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APPENDIX A : LND 713 G-M DETECTOR SPECIFICATIONS

GENERAL SPECIFICATIONS

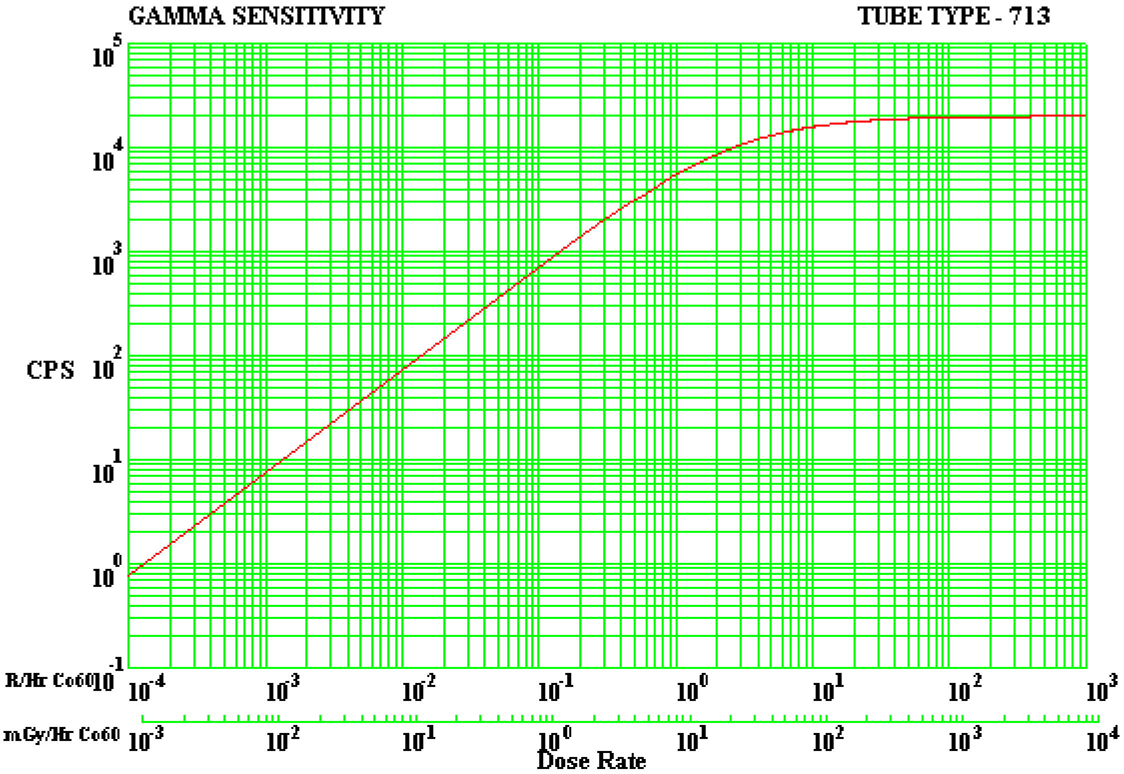
Gas Filling	**Ne +Halogen**
Cathode Material	**446 Stainless Steel**
Maximum Length (inch/mm)	**1.85 / 47.0**
Effective Length (inch/mm)	**1.10 / 27.9**
Maximum Diameter (inch/mm)	**0.36 / 9.3**
Effective Diameter (inch/mm)	**0.306 / 7.77**
Connector	**Pin**
Operating Temperature Range ^{0}C	**-40 to +75**

WALL SPECIFICATIONS

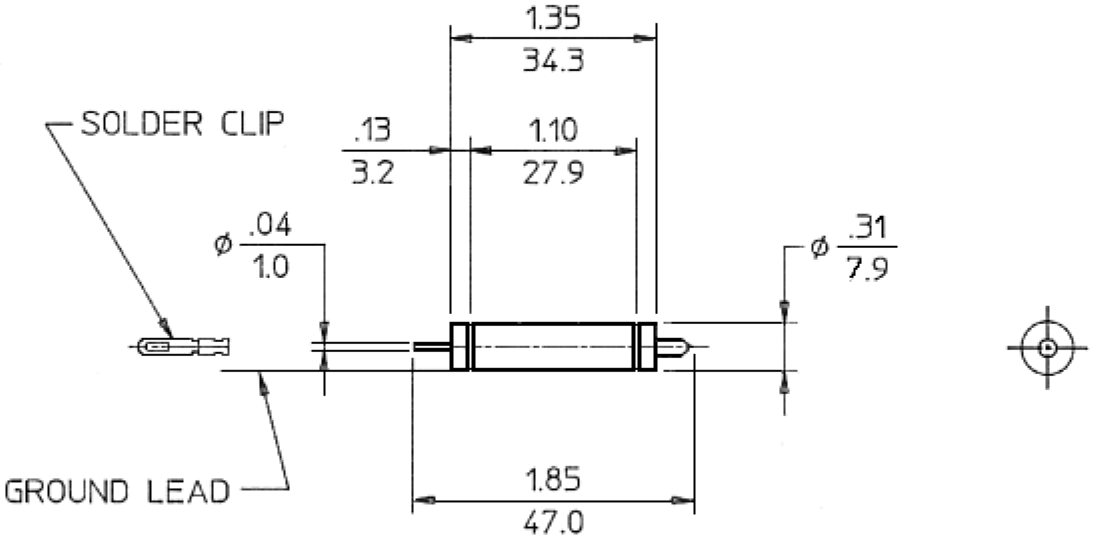
Areal Density (mg/cm^2)	**30**
Thickness (inch/mm)	**0.002 / 0.05**

ELECTRICAL SPECIFICATIONS

Minimum Anode Resistor (meg ohm)	**2.2**
Recommended Anode Resistor (meg ohm)	**4.7**
Recommended Operating Voltage (volts)	**500**
Operating Voltage Range (volts)	**450 - 650**
Maximum Plateau Slope (%/100 volts)	**8**
Minimum Dead Time (micro sec)	**45**
Gamma Sensitivity Co^{60} (cps/mR/hr)	**7.5**
Maximum Background Sheilded 50mmPb + 3mmAl (cpm)	**4**
Tube Capacitance (pf)	**3**
Weight (grams)	

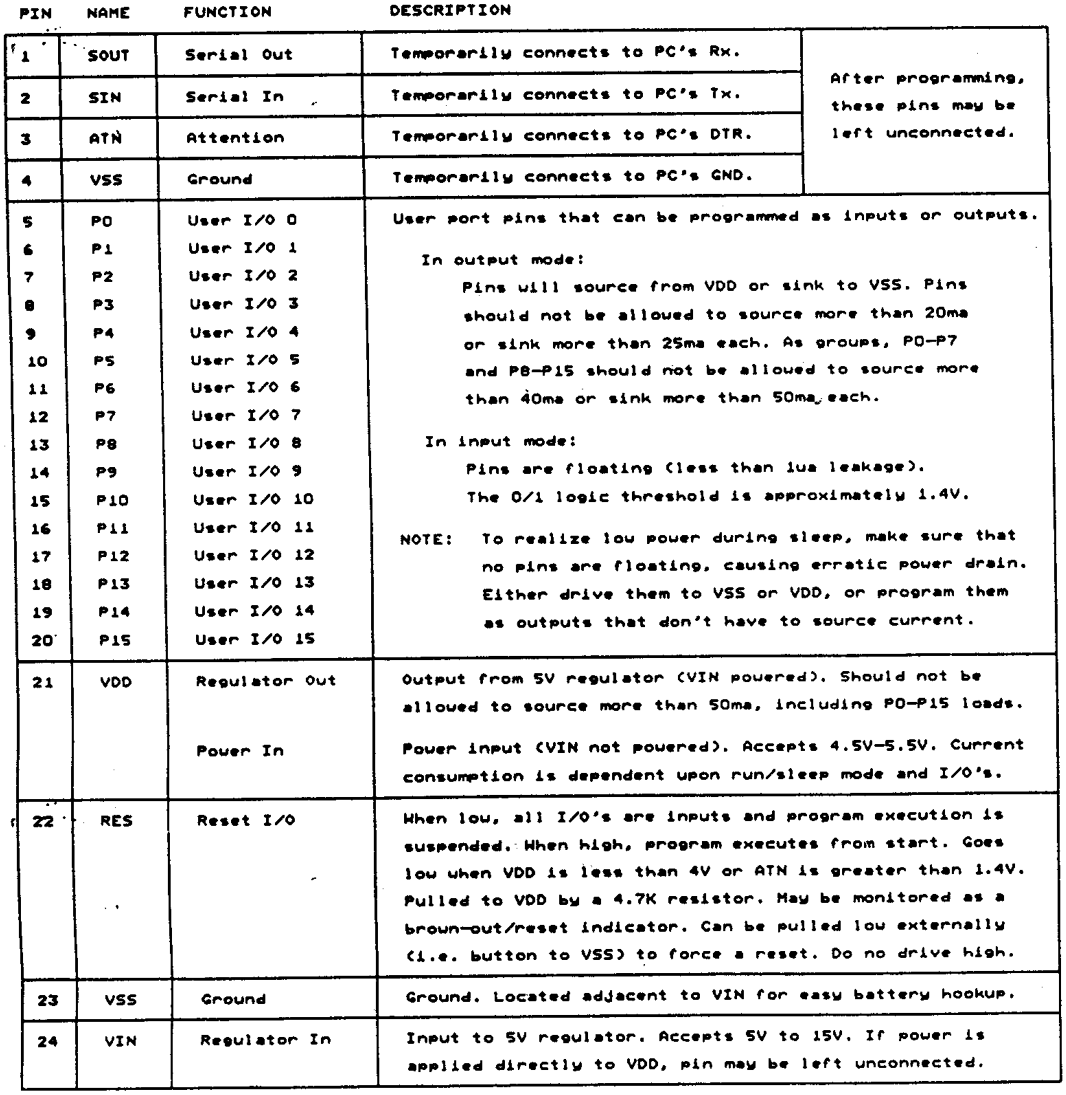


Gamma sensitivity curve for LN 713 thin wall G-M Detector

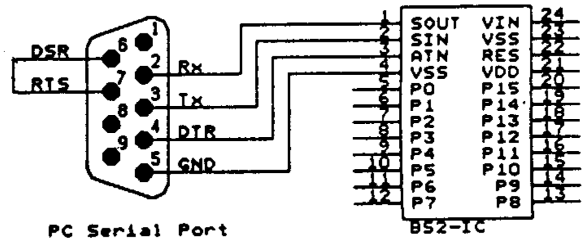


LN 713 Thin wall Detector drawing

APPEDIX B: BASIC STAMP II PIN ASSIGNMENT



PIN	NAME	FUNCTION	DESCRIPTION	
1	SOUT	Serial Out	Temporarily connects to PC's Rx.	After programming, these pins may be left unconnected.
2	SIN	Serial In	Temporarily connects to PC's Tx.	
3	ATN	Attention	Temporarily connects to PC's DTR.	
4	VSS	Ground	Temporarily connects to PC's GND.	
5	P0	User I/O 0	User port pins that can be programmed as inputs or outputs. In output mode: Pins will source from VDD or sink to VSS. Pins should not be allowed to source more than 20ma or sink more than 25ma each. As groups, P0-P7 and P8-P15 should not be allowed to source more than 40ma or sink more than 50ma each. In input mode: Pins are floating (less than 1ua leakage). The 0/1 logic threshold is approximately 1.4V. NOTE: To realize low power during sleep, make sure that no pins are floating, causing erratic power drain. Either drive them to VSS or VDD, or program them as outputs that don't have to source current.	
6	P1	User I/O 1		
7	P2	User I/O 2		
8	P3	User I/O 3		
9	P4	User I/O 4		
10	P5	User I/O 5		
11	P6	User I/O 6		
12	P7	User I/O 7		
13	P8	User I/O 8		
14	P9	User I/O 9		
15	P10	User I/O 10		
16	P11	User I/O 11		
17	P12	User I/O 12		
18	P13	User I/O 13		
19	P14	User I/O 14		
20	P15	User I/O 15		
21	VDD	Regulator Out	Output from 5V regulator (VIN powered). Should not be allowed to source more than 50ma, including P0-P15 loads.	
		Power In	Power input (VIN not powered). Accepts 4.5V-5.5V. Current consumption is dependent upon run/sleep mode and I/O's.	
22	RES	Reset I/O	When low, all I/O's are inputs and program execution is suspended. When high, program executes from start. Goes low when VDD is less than 4V or ATN is greater than 1.4V. Pulled to VDD by a 4.7K resistor. May be monitored as a brown-out/reset indicator. Can be pulled low externally (i.e. button to VSS) to force a reset. Do no drive high.	
23	VSS	Ground	Ground. Located adjacent to VIN for easy battery hookup.	
24	VIN	Regulator In	Input to 5V regulator. Accepts 5V to 15V. If power is applied directly to VDD, pin may be left unconnected.	



APPENDIX C: PBASIC COMMAND REFERENCE

• AUXIO	**AUXIO**
• BRANCH	**BRANCH** *Offset,[Address1, Address2, ...AddressN]* *
• BUTTON	**BUTTON** *Pin, DownState, Delay, Rate, Workspace, TargetState, Address*
• COUNT	**COUNT** *Pin, Period, Variable*
• DATA	*{Symbol}* **DATA** *DataItem {, DataItem, ...}*
• DEBUG	**DEBUG** *OutputData {, OutputData}*
• DTMFOUT	**DTMFOUT** *Pin, {OnTime, OffTime,} [Tone {, Tone, ...}]*
• EEPROM	**EEPROM** *{Location,} (DataItem {, DataItem, ...})*
• END	**END**
• FOR...NEXT	**FOR** *Counter = StartValue TO EndValue {STEP StepValue}* ... **NEXT**
• FREQOUT	**FREQOUT** *Pin, Period, Freq1 {, Freq2}*
• GET	**GET** *Location, Variable*
• GOSUB	**GOSUB** *Address*
• GOTO	**GOTO** *Address*
• HIGH	**HIGH** *Pin*
• I2CIN	**I2CIN** *Pin, SlaveID, Address {\LowAddress}, [InputData]*
• I2COUT	**I2COUT** *Pin, SlaveID, Address {\LowAddress}, [OutputData]*
• IF...THEN	**IF** *Condition* **THEN** *Address*
• INPUT	**INPUT** *Pin*
• IOTERM	**IOTERM** *Port*
• LCDCMD	**LCDCMD** *Pin, Command*
• LCDIN	**LCDIN** *Pin, Command, [InputData]*
• LCDOUT	**LCDOUT** *Pin, Command, [OutputData]*
• LOOKDOWN	**LOOKDOWN** *Target, {ComparisonOp} [Value0, Value1, ...ValueN], Variabl*
• LOOKUP	**LOOKUP** *Index, [Value0, Value1, ...ValueN], Variable* *
• LOW	**LOW** *Pin*
• MAINIO	**MAINIO**
• NAP	**NAP** *Period*

• OUTPUT	**OUTPUT** *Pin*
• OWIN	**OWIN** *Pin, Mode, [InputData]*
• OWOUT	**OWOUT** *Pin, Mode, [OutputData]*
• PAUSE	**PAUSE** *Period*
• POLLIN	**POLLIN** *Pin, State*
• POLLMODE	**POLLMODE** *Mode*
• POLLOUT	**POLLOUT** *Pin, State*
• POLLRUN	**POLLRUN** *ProgramSlot*
• POLLWAIT	**POLLWAIT** *Period*
• POT	**POT** *Pin, Scale, Variable*
• PULSIN	**PULSIN** *Pin, State, Variable*
• PULSOUT	**PULSOUT** *Pin, Period*
• PUT	**PUT** *Location, Value*
• PWM	**PWM** *Pin, Duty, Cycles*
• RANDOM	**RANDOM** *Variable*
• RCTIME	**RCTIME** *Pin, State, Variable*
• READ	**READ** *Location, Variable*
• RETURN	**RETURN**
• REVERSE	**REVERSE** *Pin*
• RUN	**RUN** *ProgramSlot*
• SERIN	**SERIN** *Rpin {\Fpin}, Baudmode, {Plabel,} {Timeout, Tlabel,} [InputData]*
• SEROUT	**SEROUT** *Tpin {\Fpin}, Baudmode, {Pace,} {Timeout, Tlabel,} [OutputData*
• SHIFTIN	**SHIFTIN** *Dpin, Cpin, Mode, [Variable {\Bits} {, Variable {\Bits}...}]*
• SHIFTOUT	**SHIFTOUT** *Dpin, Cpin, Mode, [OutputData {\Bits} {, OutputData {\Bits}...*
• SLEEP	**SLEEP** *Period*
• SOUND	**SOUND** *Pin, (Note, Period {, Note, Period...})*
• STOP	**STOP**
• STORE	**STORE** *ProgramSlot*
• TOGGLE	**TOGGLE** *Pin*
• WRITE	**WRITE** *Location, DataItem*
• XOUT	**XOUT** *Mpin, Zpin, [House\Command { \Cycles} {, House\Command { \Cycl*