Gamma Perforating Large Tool (GPLT)

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List of Abbreviations

API	American Petroleum Institute.
CCL	Casing Collar Locator.
CHIP	Cased Hole Interface Panel.
CPI	Correction Prevention Improvements.
GPLT	Gamma Perforation Large Tool.
LDO	Low drop out
LVR	linear voltage regulator
NGRT	Natural Gamma Ray Tube.
PM	Preventive Maintenance.
PSI	Pound per Square Inch.
RMPC	Rack Mounted Portable Computer
RSO	Read Surface Out.
WSP	Wireline Shooting Panel.

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Candidates,

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Abstract

This project is interested in wireline logging, wireline logging can be defined as the systematic recording of data, versus depth or time, in wells being drilled or produced to obtain various characteristics of down hole formation, our project is to build logging tool up to International standard, we will build a testing a pre-production prototype of Gamma ray/ Casing Collar Locator (CCL) perforating tool.

This tool is very important for petroleum industry. This tool consists of three circuits. It is used for gamma ray detection in a drilled oil & gas well. Also to locate the collars in these wells to help in perforating process to produce oil & gas from these wells and to help on determination depth of the well. In brief explanation,

After drilling a well, casings are put inside this well to keep it from collapsing. The point that connect two successive casings is called a collar. after casings is put inside the well, the tool is moved inside the casings to measure gamma ray level and locate collars positions. The measurements are taken from a truck on the surface that is connected with the tool through a cable.

From these measurements, it is known that the well has oil, gas, or water. After determining the important positions inside the well another part of the tool is used to perforate the well in this positions to produce oil, gas or water which is in the well, it is called perforating tool.

The aim of this project is to Mimic tool by mimic its circuit to know how it works and how measurements are done by the electronic circuit then design totally new circuits that do the same job and our aim to build the first tool of this kind in Egypt and the middle east.

We used all the available tools and Resources to reach our goal. We finished all the circuits of this tool (Firing - CCL – Gamma Ray – High voltage) as a Mimic for the Original Tool and New design for our new tool and we reached the Printed Circuit Board (PCB) Level for both the Mimic Circuits and New Designed Circuits.

Chapter 1: Introduction

In this chapter we will focus on introduction to petroleum industry which is the field related and very important to understand the idea of the project and to know the project importance so this chapter will focus on delivering a good knowledge and information about the petroleum industry which serve the project idea.

Petroleum refers to crude oil and natural gas or simply oil and gas. These are mixtures of hydrocarbons which are molecules, in various shapes and sizes, of hydrogen and carbon atoms found in the small, connected pore spaces of some underground rock formations. These petroleum reservoirs are generally thousands of feet below the surface. Crude oil and natural gas are believed to be the remains of plants and animals, mostly small marine life, that lived many millions of years ago. Reserves are classified as proved, probable, or possible, depending on the likelihood that the estimated volumes can be economically produced.

Drilling into the crust of the earth makes it possible for us to lower instruments into the boreholes and carry out in situ measurements in order to gain information on the physical properties of the rock formation surrounding the well, as well as the temperature and pressure within the well. This family of measurements recorded along the well is commonly called well logs or wireline logs to distinguish them from various other drilling logs. This is a very heterogeneous group of measurements that have the only thing in common that they are carried out within a well.

Well logging in geothermal wells has been highly focused on temperature, pressure and spinner logs but the purpose of this paper is to look at wireline logs that informs on the geological formations intersected by the well and the fractures dissecting the formations. Application of these logs is still relatively limited in geothermal exploration in most countries, except in Iceland where we have since 1976 used oil well logging techniques for a systematic investigation of the geothermal wells. A logging truck is stationed at the drill site and one or two logging engineers are standby to carry out logging operations. As the drilling proceeds several logs are done in the well. The logs most relevant for the drilling operations are temperature, caliper and CBL logs and gyro surveys, but several geological wireline logs are also done to study the rock formations of the well and with pressure, the permeability (or transmissivity) of the well is determined through pressure transient tests. Organic materials of plant or animal origin accumulate in the lowest places, usually in the crevices, low-lying land, sea bed, coral reefs, etc., and are gradually buried under the surface of Earth. Thus, huge amounts of organic matter are trapped layer after layer in the earth's crust and rock. Rocks that bear these organic layers are called sedimentary rocks. Several kilometers below the earth's surface, organic sediments are decayed biologically to a mass, known as kerogen, which has a very high mass of organic-to-inorganic ratio favorable for conversion to hydrocarbon. The temperature of Earth increases with depth (geothermal gradient) at the rate of approximately 30°C per kilometer. Thus, at a depth of 4–5 km, called kitchen by geologists, temperatures of 120°C–150°C exist where kerogen is converted to hydrocarbon oil under very high pressure of rocks and soil. But this conversion takes millions of years (geological time period) to complete. Methane is also formed thermos genetically (i.e., thermal conversion of kerogen) along with biogenic methane already present before the formation of crude oil. Migration of oil with gas occurs within the accumulate in the pores of the sedimentary rocky layer as shown in Figure 1.1.

to high temperature and pressure over millions of years. From the source rock, oil and gas then migrate to areas or traps that have a structure favorable for storing oil and gas.

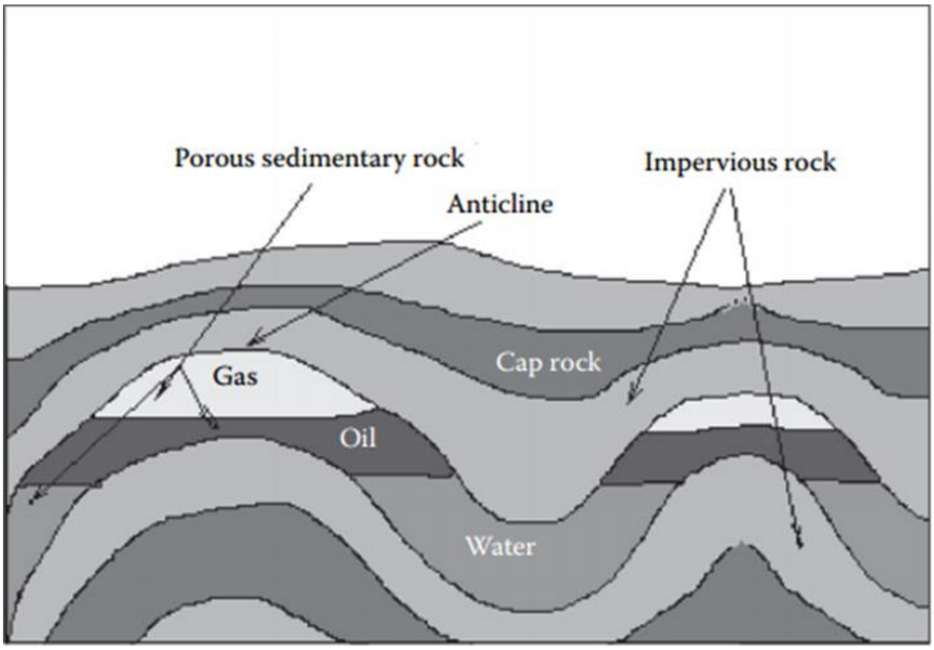


Figure 1-1 A typical anticline oil and gas reservoir [1]

Traps are usually anticline or domed or faulted areas having oil and gas trapped in a porous rocky area covered by impermeable rock (seal or cap rocks) layers that do not allow further migration or escape to another area. Such an area that traps oil and gas is known as a reservoir or basin. [1].

Petroleum engineering requires a good knowledge of many other related disciplines, such as geophysics, petroleum geology, formation evaluation (well logging) which is the major concept related to the project and which is we will focus on it now.

1.1 Wire Line Logging

Well logging, also known as borehole logging is the practice of making a detailed record (a well log) of the geologic formations penetrated by a borehole. The log may be based either on visual inspection of samples brought to the surface (geological logs) or on physical measurements made by instruments lowered into the well (geophysical logs). Some types of geophysical well logs can be done during any phase of a well's history: drilling, completing, producing, or abandoning.

Well logging is a highly advanced technique where complex electronics and sensors are placed inside a logging probe which is lowered on a wireline into a well to carry out measurements continuously or at discrete depth intervals as the probe is moved down or up the well. The objective of the logging can be for example,

- To study the well, its geometry and completion.
- To study the rock formation and fractures intersected by the borehole.
- To determine the reservoir temperature and fluid pressures.
- To locate feed points connecting the well to the geothermal reservoir.

The geological wireline logs discussed are the electrical resistivity log of normal configuration, neutron-neutron porosity log and the natural gamma ray log. These logs give valuable information on the lithological section of the wells, the boundaries and thicknesses of the rock units and complement the drill cutting analysis.

The oil and gas industry uses wire line logging to obtain a continuous record of a formation's rock properties. Wire line logging can be defined as being "The acquisition and analysis of geophysical data performed as a function of well bore depth, together with the provision of related services. The measurements are made referenced to "TAH" -True Along Hole depth- these and the associated analysis can then be used to infer further properties, such as hydrocarbon saturation and formation pressure, and to make further drilling and production decisions.

Figure 1.2 shows a log from "New York Gas and Oil Stowell-Kolb" which measure the natural gamma ray in the well which is the same as one function of our analog electronic tool functions is to measure the natural gamma ray in "API" American Petroleum Institute, which is the standard unit of natural gamma ray and this curve with depth, shows the gamma ray in different depths and another curve showing the density of the fluid in the formation.

The geological wireline logs are usually run “open hole” for each cased section of the well and when the production part of the well is completed and final depth is reached. The standard logging suit consists of:

- Temperature log to locate feed zones and feed points and to evaluate the heating up rate (heat recovery) of the well after circulation is stopped.
- Caliper log to locate washout zones and to estimate the volume of cement necessary to fill up the annulus between the casing and the formation.

- Resistivity logs (normal 16” and 64”), neutron logs (porosity), and natural gamma ray logs to evaluate the geological formations.

Wire line logging is divided into two types Open hole logging and Cased hole logging which is related to our project and we will be interested on it. In the following section, we will be talking about 2 types briefly with some details for cased hole logging.

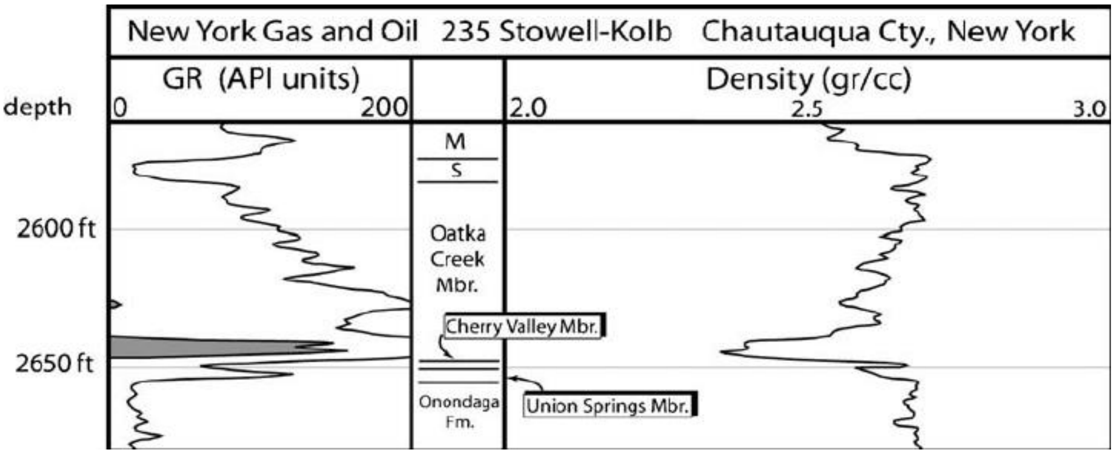


Figure 1-2 a log of the natural gamma ray and density of formation versus depth [2]

1.1.1 Cased Hole Logging

Cased-hole logging involves retrieving logging measurements through the well casing, or the metal piping that is inserted into the well during completion operations. Both gamma ray and neutron porosity logs can be run through the casing of a well, and better ideas of thermal decay and interval transit time can be achieved through porosity, hydrocarbon saturation and product ability measurements.

Cased-hole formation evaluation logs are playing a major role in efforts to increase recovery from existing reservoirs. While the logs available today are significant improvements over those of just a few years ago, care must still be exercised for successful applications. Application limitations remain, although some of these are being addressed by ongoing research. Cased-hole logs are playing a major role in locating and Evaluating such bypassed hydrocarbon zones. In view of this role, a review of the common technology, applications, limitations, and possible future developments in cased-hole logging is appropriate. Cased-hole logs for looking behind pipe are used in a broad spectrum of applications, although these applications use range from cement evaluation to monitor EOR processes, for the purpose of this discussion our focus will be on recompletions, and specifically the location and evaluation of bypassed oil or gas zones. [2]

One of the most important cased hole logs is gamma ray logs which our tool measures the natural gamma ray counts and this help us in the location of the perforation to produce the oil or gas economically and that will be explained in the next chapters. Gamma ray logs include both conventional tools that measure total natural gamma ray count rates and newer spectral gamma ray tools, which measure the individual contributions of potassium, uranium, and thorium to the energy spectrum of natural gamma rays. These tools are predominantly lithology indicators and, as such, are useful in depth control, correlation, and lithology evaluation (especially shale). They also detect the buildup of radioactive scale, which in certain cases can indicate zones of prolonged water movement, such as perforations, watered-out zones, or channels behind pipe.

Cased-hole neutron logs are also of two primary types: the older conventional neutron log that measures capture gamma ray count rates with a single detector and the newer dual detector, compensated neutron log that presents a log trace scaled in porosity units.

These logs are good porosity, gas, and lithology indicators. With proper calibration, quantitative estimates of porosity and semi quantitative estimates of gas saturation can be obtained, provided that shale effects are properly accounted for. Because of their gas response, they are widely used in monitoring gas/liquid contacts. [3]There are other cased hole logging tools is very important for well formation like Pulsed neutron capture (PNC) logs are the primary tools used in detecting oil behind pipe. First commercially available in the mid 1960's, they measure the macroscopic thermal neutron capture cross section, macroscopic thermal neutron captures cross section, using a pulsed neutron source. Present-day tools can be run through tubing as small as 2 inch. [5.08 cm]. Because the chlorine present in salt water has a large thermal neutron capture cross section, these logs can distinguish high-salinity formation water from hydrocarbons, and hence can yield quantitative estimates of water saturation if properly calibrated. They also respond to gas saturation and porosity, but their applications can be severely limited by low brine salinity, low porosity, or shales.

Pulsed neutron spectral (PNS) or induced gamma ray spectra 110gs are also commonly known as carbon/oxygen (C/O) or gamma ray spectroscopy logs. [4]These logs, which were first commercially available in the mid-1970's,5-8 measure the energy spectra of gamma rays from both inelastic neutron scattering and thermal neutron capture to obtain estimates of the relative concentrations of particular elements present in the formation. Various ratios of these elemental components (such as the C/O ratio) can be used to evaluate oil saturation, lithology, and even' brine salinity; also, count rate or component yield ratios can be used to estimate porosity. The advantage of these tools is their ability to estimate oil saturation independent of brine salinity; however, low porosity, complex lithology, and measurement statistics can limit this application.

There are some cased hole logging tools, they are not important in the field of the project so we will mention it only without explanation, these tools and services are as follows

- Mechanical Services (Completion).
- Pipe Recovery and Inspection.
- Cement Evaluation (CBL)
- Production Logging (Completion Evaluation, TEMP, PRES, FLOW)
- Production Logging (Reservoir Monitoring, Completion Evaluation).

- CH Formation Evaluation.

Current economic conditions are providing an opportunity and challenge to increase recovery from existing reservoirs, an activity in which cased-hole logs are playing a major role. The cased-hole logs available today are a significant improvement over the tools available just a few years ago, with enhancements in processing, measurement precision, and borehole corrections. Knowledge of tool limitations and integrated use of all available well data, however, remain essential elements of any cased-hole log application. Cased hole logs are used effectively in a wide variety of conditions, although situations still remain in which current logs are not sufficiently diagnostic. Cased-hole logging technology continues to advance, with favorable prospects for improving interpretation and extending the range of application for these tools.

1.1.2 Open Hole Logging

Open-hole logging refers to logging operations that are performed on a well before the wellbore has been cased and cemented. In other words, the logging is done through the bare rock sides of the formation. This Is the most common type of logging method because the measurements are not obstructed and it's done during or after the well has been drilled?

In order to get the optimum decision for the formation of the wellbore and to make sure about all the properties and the characteristics of the formation, correlation between the open hole logs and cased hole logs is made to get the right decision. There are some service and open hole tools will be written below without description as our project is mainly interested in the cased hole logging. The open hole services are as follows

- Resistivity HRI, DLLT and MSFL.
- Natural Gamma Radiation NGRT.
- Neutron Porosity DSNT.
- Bulk Density.
- Borehole Diameter FACT, Caliper.

The Logic is that once we know the Resistivity, Porosity and thickness of the Formation Rocks, we can estimate how much OIL it contains.

Significant advances have been made in cased-hole logging instrumentation over the last 10 years, resulting in many improvements in tool designs and measurement capabilities. These improvements are reflected in the logging data provided to the user, as summarized in Table 3 and discussed below. Dramatic changes have resulted from the introduction of well site computers for data acquisition and processing. As in open hole logging, the impact of these computers has been substantial, providing faster

Logging operations, simultaneous acquisition of larger data volumes, improved real-time quality control, and quality field tapes for the customer. Well site processing and interpretation of certain logs are also available, although the user is advised to be wary of quick well site interpretations, which may be incomplete.

From the above explanation about the wire line logging and explaining its types and their importance and effect on the petroleum industry, it seems it is very important about the petroleum industry, so we have to know explicitly what is we know from wire line logging, we will divide what we know into two sections, which is what we know during exploration and during production. They will be discussed below.

1.2 During Exploration

In this phase we know from wire line logging that

- Are oil or gas present?
- If there are where?
- Quantity?

This is important factor as the process of drilling a wellbore is very costly so if there are a few quantities so there is no need for drilling and starting the process of drilling and production.

- Can it be produced economically?

1.3 During Production

In this phase we know from wire line logging that

- Why is the well not producing?
- How much of the oil present can be produced?
- Is there some enhancement to get the optimum production from the oil or gas?

This is important factor as the process of drilling a wellbore is very costly so if there are a few quantities so there is no need for drilling and starting the process of drilling and production.

- Can it be produced economically?

There are some geological Wireline logs applied now days and they played a very important rule and service for the petroleum industry like the resistivity, gamma ray which is our tool objective, and neutron-neutron logs.

The knowledge on the geological sections in geothermal wells is primarily obtained by studies of drill cuttings. The cuttings are formed at the well bottom and then flushed to the surface with the circulating fluid. The analyses of the drill cuttings must therefore take into account the time it takes to bring them to the surface and also the unavoidable different travel time for cuttings of different size and mixing of the cuttings as they are flushed to the surface.

The permeability of the geothermal reservoirs is dominated by fracture permeability. Studies of permeable fractures are therefore very important in geothermal exploration. Several logging tools have been developed for fracture imaging. The tool that we use in Iceland is the borehole tele viewer. We have used it in several wells during the past years and gained very valuable information for defining the inclination and direction of fractures intersected by the wells, knowledge very valuable for future targeting of wells.

Now, after explaining and discussing the importance of the wire line logging and showing its types and the usage of each type of wire line logging. There is some concept in petroleum industry must be explicitly known and understood to be able to understand the project idea and its importance like petroleum geology.

1.4 Petroleum Geology

Geology is the Science that deals with the origin, history and physical structure of the earth as revealed in rocks it's essential to the petroleum industry because most petroleum is found within rocks.

Petroleum geologist have 2 jobs:

- Finding & scanning for petroleum accumulation.
- Evaluation of this location to determine whether it has enough petroleum to be commercially produced.

Geologist used to assume that the continents lay where they are now. Most Geologist today think that the crust is an assemblage of huge plates that fit together like a jigsaw puzzle. Along time these pieces of the earth's crust moved & changed shape. They Collide or pull away from each other (according to plate Tectonics Theory)

Geologist describe 3 basic structure that may occur when rocks deform or change shape due to tectonic movements which will be described in the next section.

- **Warps**

Wraps occur when broad areas of the crust rise or drop without fracturing. The rock strata in these areas appear to be horizontal but, on closer inspection are actually slightly tilted.

- **Folds**

They are rock strata that have been crumpled and buckled into wavelike structures. The most common structure in mountain chains. The up warps or arches are called Anticline. The down warps are called syncline.

- **Faults**

When rocks near the surface break, the fracture is called a fault. The two halves may move apart a few millimeters or many meters in relation to each other. Faults are classified according to their movement direction into

  - Vertical Faults → Normal & Reverse
  - Horizontal Faults → Over thrust & lateral

Combination of Horizontal & Vertical could happen as in growth faults. Faults are important to petroleum geologists because they affect the location of oil and gas. Sometimes Garbsen & Horsts could be produced.

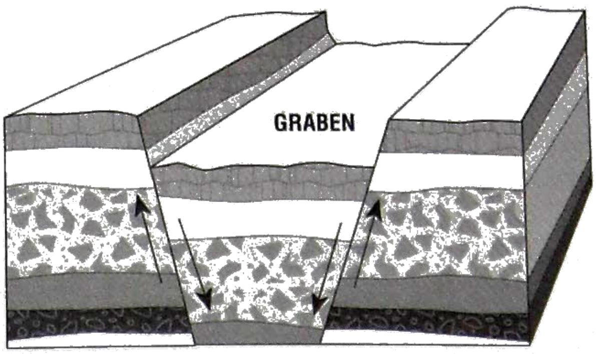


Figure 1-3 growth fault

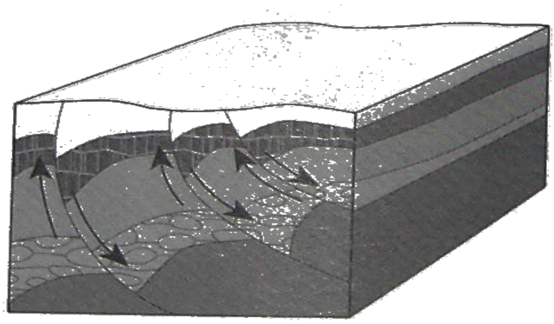


Figure 1-4 another shape for Garbsen

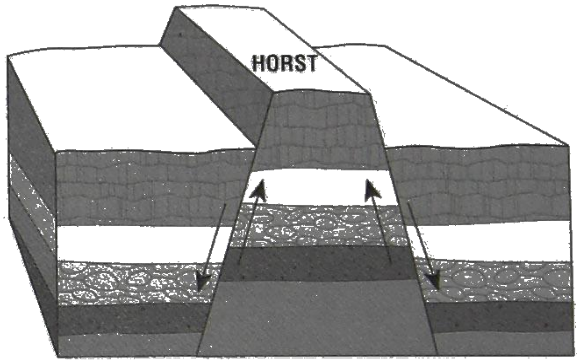


Figure 1-5 shape of Horst in earth's crust

Geologists group the rocks of the earth’s crust into 3 types according to how they were formed

- **Igneous Rocks**

  Deep in the earth’s crust temperature is high enough to melt rock into Magma can erupt to the surface as lava or it may force its way into other solid rocks underground. When it cools it solidifies forming Igneous Rocks. Igneous represents 65% of Earth’s crust. It consists of two groups

  - Intrusive (Plutonic) Granite
  - Extrusive (Volcanic) Basalt

Igneous Rocks are usually crystalline and non-porous. Not interesting from Petroleum point of view.

- **Sedimentary rocks**

  Are Rocks formed from sediments? A sediment can consist of eroded particles of older rocks that wash downhill to lakes or to the oceans. It may consist of minerals that precipitate out of water Minerals in water cement those deposits together into sedimentary rocks

  Examples: Limestone, Sandstone & clay

  Sedimentary rocks are the most interesting to petroleum geologists because most Oil & gas accumulation occurs in them. It is varying greatly in appearance and composition. Sedimentary rocks represent 8% of crust (today), Cover 75% of land surface, Porous (space between grains) and Accumulates Petroleum.

- **Metamorphic Rocks**

  It's either Igneous or sedimentary that have been buried deep in the earth where they were subjected to high Temperature & pressure. During this process original rock undergoes physical & chemical changes

  Example: Limestone → Marble.

This the introduction to petroleum industry from the project point of view, we discussed only what serves the project idea and to simply understand the project. The Coverage of the Chapters, the material in this thesis can be decomposed into 4 chapters after the introduction chapter, first the system level of the electronic analog logging tool, second we will start to talking about one of the circuit of the tool which is the biggest one and the main circuit in the tool which is the Gamma ray circuit, third we will focus on another circuit in our logging tool which is the Firing circuit, in chapter five we will talk about the last circuit in the tool which is the Casing Collar Locator (CCL) circuit and finally in the last chapter we will talk about the Printed Circuit Board layout and show the layout of each circuit of the tool. In each chapter of the circuits we put explanation, simulation results and PCB layout for each circuit.

Chapter 2: System Level of the GPLT tool

In this chapter we will focus on the system level of our analog electronic tool, the circuits that the tool decomposed from, Explanation of each part in the tool and the objective of each circuit in the tool and the operating voltage of each circuit.

The Gamma Perforating Large Tool (GPLT) consists of three circuits which are

- Gamma Ray circuit.
- Firing circuit.
- Casing Collar Locator (CCL).

GPLT allows the user to correlate with Gamma ray and perforate in the same run. Multiple configurations available for Perforating, Mechanical services and Coring. GPLT has some specification and restriction on it such as its outer diameter is (3 1/8) inch so it is large tool and it has maximum pressure of (20K psi) and maximum temperature rating of (350 Deg. F). The circuits that the GPLT consisting of are discussed briefly their functions and the usage of it in the tool then we will discuss a big picture about the tool circuits and the connections between them. The circuits will be discussed below

2.1 Gamma Ray Circuit

Gamma rays are electromagnetic waves, not particles. They have no mass and no charge. Gamma rays have a high penetration capability. It takes a thick sheet of metal such as lead or concrete to reduce their energy significantly. Gamma rays do not directly ionize other atoms, although, they may cause atoms to emit other particles which will then cause ionization. We don't find pure gamma sources - gamma rays are emitted alongside alpha or beta particles. Strictly speaking, gamma emission isn't 'radioactive decay' because it doesn't change the state of the nucleus, it just carries away some energy.

The gamma ray circuit function is to sense and measure the natural gamma ray emissions from radioactive formations of the wellbore. By the use of sensing and measuring the natural gamma ray we can know the optimum location which has higher gamma ray which exists mostly in the shale which is one of the rock type for perforation. Since many gamma rays can pass through steel casing, the log can be run in both open and cased holes. In related applications, induced gamma rays are measured (i.e., pulsed neutron logging), but these are not discussed in this section. Gamma Ray Recorded in counts per second which calibrated to "API Units" American Petroleum Institute which is 1/200th of the calibrated, standard response [5]

In some order wells it is possible to obtain a higher gamma ray reading across open perforations due to the deposition of water soluble NORM from the formation during production. The gamma ray curve on a new well should be slightly reduced from that of the open hole log due to the shielding effect of the cement sheath and casing. An old well may have a radioactive scale built up on the casing rendering the gamma ray unusable for correlation and it is recommended to run a neutron as well.

Gamma ray logs are used for three main purposes are as follow:

- Correlation.
- Evaluation of the shale content of a formation.
- Mineral analysis.

Now, talking about the method which is we can detect the gamma ray signal from the earth is an important matter to show in this section, there are two popular methods for detecting the gamma ray signal which are Geiger-Muller (G-M Detectors) and Crystal Scintillator Detectors, we will be explained in some details the Crystal Scintillator Detectors because this method of detecting the gamma ray is used in GPLT tool then briefly show the advantages and disadvantages of the two methods.

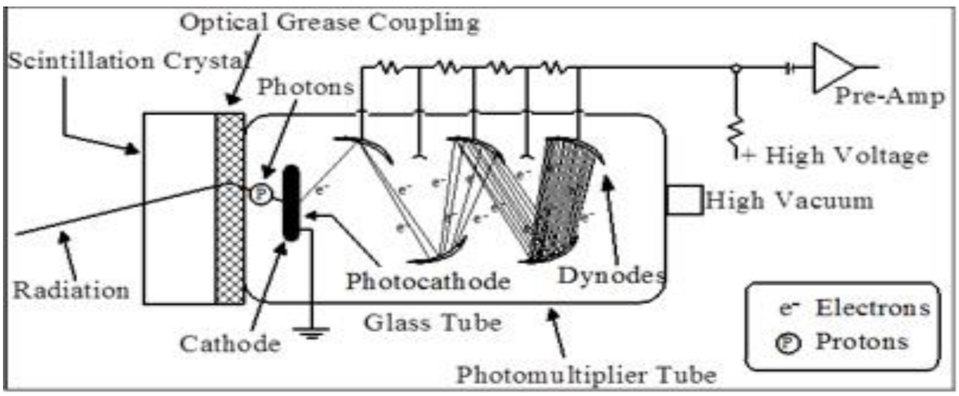


Figure 2-1 Scintillation Detectors

The scintillation detector as shown in figure 2.1 is divided into three sections which are

- Crystal Scintillator.
- Photomultiplier Tube (PMT).
- Pre-Amp board.

A popular method for the detection of gamma rays involves the use of crystal scintillators. The general description of a scintillator is a material that emits low-energy (usually in the visible range) photons when struck by a high energy charged particle. When used as a gamma ray detector, the scintillator does not directly detect the gamma rays. Instead, the gamma rays produce charged particles in the scintillator crystal which interact with the crystal and emit photons. These lower energy photons are subsequently collected by photomultiplier tubes (PMTs), then this photon collects with cathode which convert these photons to electrons so there is a current flow but due to that the electrons is low so we have to increase the number of electrons so for that reason they used high voltages which is the dynodes in figure 2.1. As a result, from the huge voltage difference between the dynodes and the ground the current will be increased.

The light pulse is incident upon the Dynodes in the PMT to eject Electrons and the Electrons are accelerated through each dynode by increasing the high voltage at each stage there by achieving the signal strength which is sufficient for detection purposes.

There are some advantages and disadvantages for the two methods of the gamma ray detection which are Geiger Muller Detectors and Crystal Scintillator Detectors. They are mentioned in the following section

- **Geiger-Muller Detectors**
  - Very sensitive to GR detection.
  - Cannot be used for differentiation of gamma energy level
  - Short Plateau.

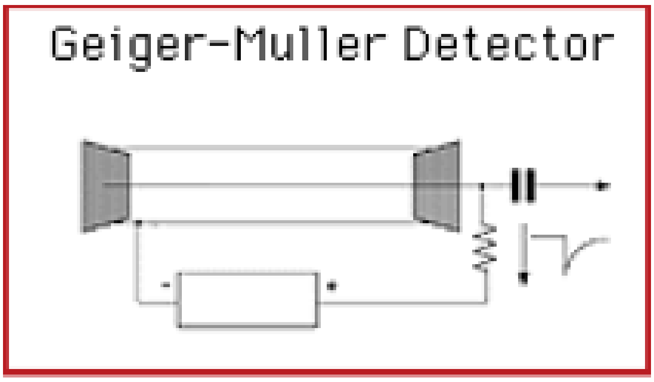


Figure 2-2 Geiger- Muller Detector

- **Scintillation Detectors**
  - Longer plateau.
  - Can record higher gamma ray count rates.
  - The dead time is lower.
  - Counts almost every gamma ray that reaches the crystal.
  - Much more reliable at high temperature.
    (As opposed to about a 6% efficiency rate by G-M detector).

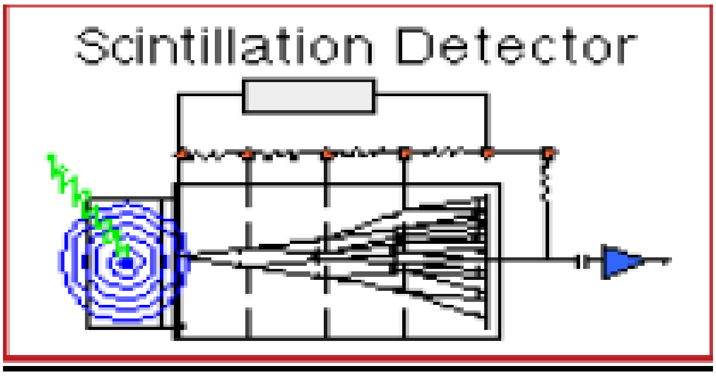


Figure 2-3 Scintillation Detector

One of the problems of gamma ray logging is the choice of a standard calibration system since all logging companies use counters of different sizes that are encased in steel housings that vary in transparency to gamma rays. On very old logs, the scale might be quoted in ~ l g m of radium per ton of formation. For many reasons this was found to be an unsatisfactory method of calibration, so a standard was devised by the American Petroleum Institute (API).A test pit at the University of Houston contains the "artificial shale. A cylinder, which is 24 ft. long and 4 fi in diameter, contains a central 8footseaion consisting of cement mixed with 13ppm uranium, 24ppm thorium and 4% potassium. Above and below are 8foot sections of neat Portland cement, and all 3 layers are cased with 5.5-inch J-55 casing. The API standard defines200API units as the difference in radio activity between the neat cement and the radio actively doped cement any logging service company may place its tool in this pit to make a calibration.

Field calibration is performed using a portable jig or blanket that contains a radioactive source, usually a small amount of Ra or Th. The source produces a known increase in radioactivity over the background count rate. This increase is equivalent to a known number of API units.

The components, blocks and the method that used for sensing and measuring the natural gamma ray in counts per second unit and calibrated it to the standard unit of the gamma ray which is "API" will be explained and discussed with details in chapter three.

2.2 Firing Circuit

There is a firing protection circuit in the GPLT, to protect the gun below it from firing when the tool is powered up. To fire a gun on a positive current, the voltage must be increased to approximately 155 volts plus the voltage required to fire the detonator.

Firing circuit is a commitment to safety, reliability and efficiency, which are the most important aspects of a successful perforating operation. It is providing a comprehensive range of the perforating tools and system build with safety and reliability in mind.

Firing circuit is a circuit has two main sections. First section is a voltage regulator circuit which used to maintain constant output voltage, however changes that happen to input voltage. This section output is input to Gamma Ray circuit. Second section is perforation supply circuit, which is used to supply perforation gun with required voltage for perforation. Also firing circuit must isolate Voltage regulator section from Perforation section. Perforation detonator can be positive detonator which mean that it is activated by using positive voltage or negative detonator which is activated by using negative voltage.in our tool perforation is done through negative detonator

The firing protection circuit is considered like a switch between the logging circuit which is the gamma ray and the perforation circuit. The components, blocks and the method that used for obtaining the goal of the firing protection circuit will be explained and discussed with details and with the schematics of the circuit in chapter four.

2.3 Casing Collar Locator (CCL) Circuit

Casing Collar Locator section used the concept of faraday 'theory which is made up of induction coil, magnetic steel and amplifier. The induction coil is located between the four magnetic steels. When the tool meets the casing collar while it’s moving in the casing, the magnetic field strength in the coil changes correspondingly to the change of the magnetic flux surrounding magnetic objects in order to generate induction voltage and by the usage of Casing Collar Locator circuit is used to measure the depth of the wellbore as length of the casing is standard 50 feet the collar so we have a pulse indicating the collar every 50 feet so from that concept we can know the depth of the wellbore.

The most common current CCL design consists of a coil located between two magnets. The magnets are cylindrical with like poles facing each other (north to north or south to south) to focus the lines of flux outward in a plane perpendicular to the axis of the CCL tool. This like-pole facing each other arrangement produces a CCL more sensitive to small changes in metal mass, creating a better chance of detecting the small gap in flush joint pipe, or collars in heavily corrosion-encrusted casing. Many other CCL designs exist; two coils arranged on either side of a single magnet is probably the next most

common arrangement. In addition, there are many exotic designs that have come and gone over the years. The Analog Services, Inc. collection even includes a bizarre beast with 14 magnets and six coils.

Casing Collar Locator divided into two types which are Shooting CCL and Logging CCL, it will be good thing to discuss each type and showing the differences between them and that will be provided in the next Section with explaining each type of Casing Collar Locator which give you a huge knowledge about the Casing Collar Locator.

The first type which we will talk about is equipped with down hole amplifiers. Sometimes logging CCLs are built into tools, and sometimes they are used separately as is the case with most cement bond tools. The CCL log is generally displayed between tracks one and two, sometimes called the depth track, and usually to the right of said depth track, on the suggested American Petroleum Institute (API) log format. However, the CCL record is occasionally displayed elsewhere on certain specialty logs. This type of Casing Collar Locators is called Active CCLs.

The second type of CCL is containing no amplifier and are most commonly run for depth control with perforating guns. Because the voltage generated by a shooting CCL presents a potential, although extremely remote danger when electric blasting caps (detonators) are located below the CCL, it is often said that the diodes used in the shooting CCL circuit are there for safety purposes. In truth, they are used because the old non-resistor zed caps would short out the CCL signal. Modern resistor zed caps probably do not need said diodes, and it is generally believed that a shooting CCL cannot accidentally fire a cap. Nevertheless, it is still a darn good idea to use the blocking diodes, and have them installed in the proper orientation (they are absolutely necessary when using non-resistor zed caps). To be able to shoot with both polarities, a "double diode" is required with the pair in parallel and turned in opposite directions. A few designs use pairs of diodes in series frequently called a quad diode, again often said to be for extra safety, but in actuality probably to prevent clipping of the CCL signal in cases where it exceeds 0.6 volts (the "turn-on" voltage for a typical silicon diode). This type of CCL which explained above is called Shooting Casing Collar Locator.

The Casing Collar Locator circuit will only work when the tool is powered up. Making it necessary to simulate a piece of log while the tool power is on to check collar. All the components, blocks and the method that used for achieving the goal of the Casing Collar Locator circuit will be explained and discussed with details and with the schematics of the circuit in chapter five.

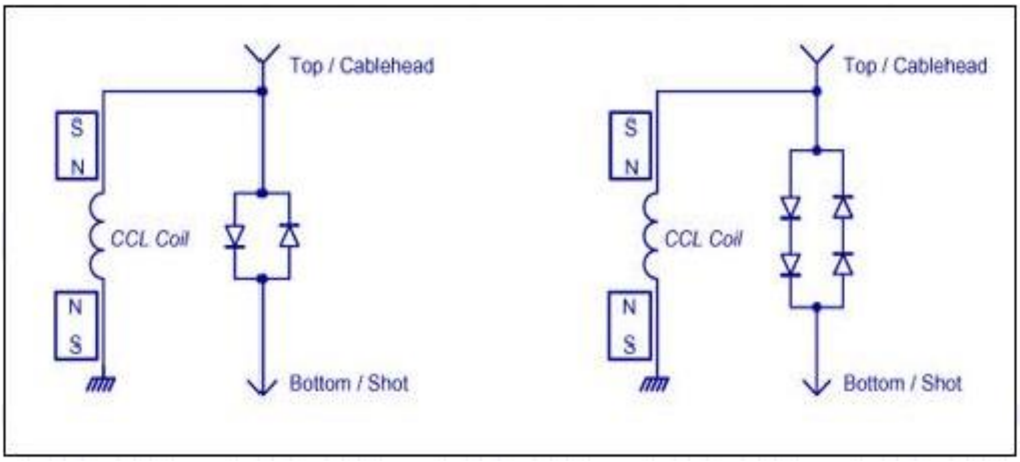


Figure 2-4 shooting CCL Schematic

2.4 Tool Components

In this section we will talk about the regulations between the three circuits in GPLT. Figure 2.5 shows that a general block diagram about the tool starting from the top which is the panel connected to the tool in the wellbore through mono cable from that panel the operator or the engineer control the operation of the tool and can control which circuit will operate. Then the panel on the top send 50 volts to the tool and this value of the voltage can make the Casing Collar Locator circuit and the Firing protection circuit to operate. If the voltage coming to the Firing protection circuit is positive 50 so it will power on the Gamma Ray circuit and sending to it 35 volts which is the value of voltage that Gamma Ray section will operate Correctly and at the same time the Firing protection circuit blocked the perforation circuit from work by never send to it the voltage required that can make the perforation operate correctly, but if the panel sends a negative voltage enter to the Firing protection circuit and to Casing Collar Locator circuit, there are some things that will happen. First, the Casing Collar Locator circuit will be blocked as it can never be operated with negative value of voltage, second when the negative value of voltage enter to the Firing Protection Circuit, the Gamma Ray circuit will be blocked as it is never operate in negative and positive voltages together, only one of them and as we used the positive voltage to operate the Gamma Ray section so the Gamma ray circuit cannot operate on the negative values of voltages and that negative voltage will operate the perforating circuit as the Firing protection circuit send to the perforation circuit a negative voltage of 100 volts which is necessary to operate it. The signals which are sent from the panel on the top sent over a mono cable so we have the input to the circuit and the output from it will be sent on the same cable which is the mono cable. The output of the circuit which is sending to the panel on the top through the mono cable will be the counts per second which indicating the natural Gamma Ray or the pulses of the Casing Collar Locator circuit which indicating the locations of collars and helps to know the depth of the wellbore.

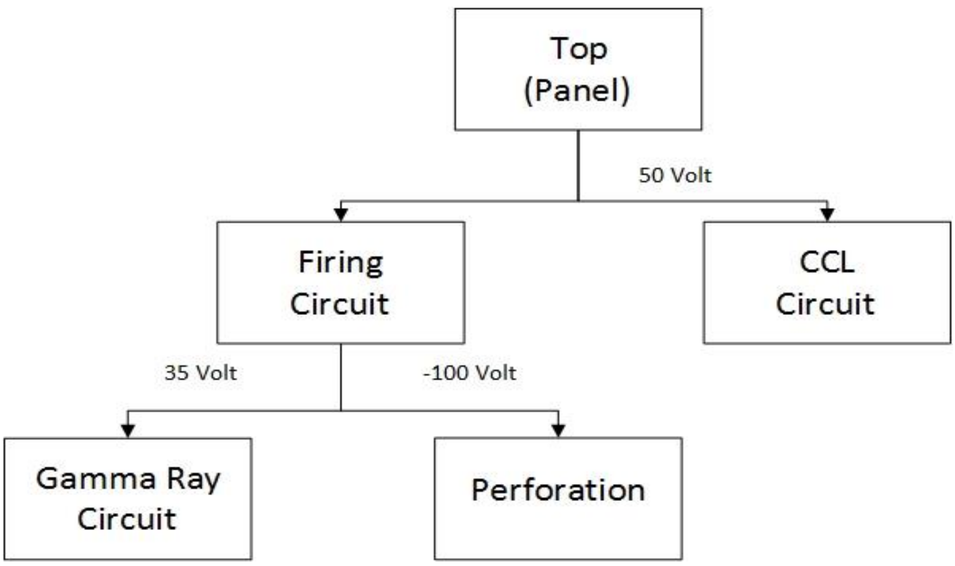


Figure 2-5 GPLT tool block diagram

Chapter 3: Gamma Ray Circuit

3.1 Overview:

As mentioned in chapter 1, PMT senses gamma rays of earth's geological layers, rocks (Igneous, Sedimentary and Metamorphic) and formations. Each kind of rocks and formations has unique radiation level so one with little experience in petroleum services field can determine the rocks and formations along the well and their specific depth by checking the log sheet.

GR circuit is composed of three main circuits: pulse shaping and discriminator circuit, line driver circuit and high voltage circuit. High voltage circuit is the supply of PMT as PMT needs 1550v to operate. PMT output mainly looks like impulses (very short duration and varying amplitude pulses) plus background signal called noise (in fact this background signal isn’t noise. They are impulses results from gamma radiation of the air) so pulse shaping and discriminator circuit is used to strip the noise and reshape the output to be uniform pulses (specific pulse width and amplitude) to be counted by the panel at the surface of earth. Before output pulses are sent to the panel, they have to pass through line driver circuit.

3.2 Standard Design of Gamma Ray Circuit:

Mimic gamma ray circuit is shown below in figure 3.1. Figure 3.1 shows clearly sections of mimic gamma ray circuit. Pulse shaping and discriminator section is highlighted by red frame, line driver section is highlighted by a blue frame, high voltage section is highlighted by magenta frame and PMT is highlighted by green frame.

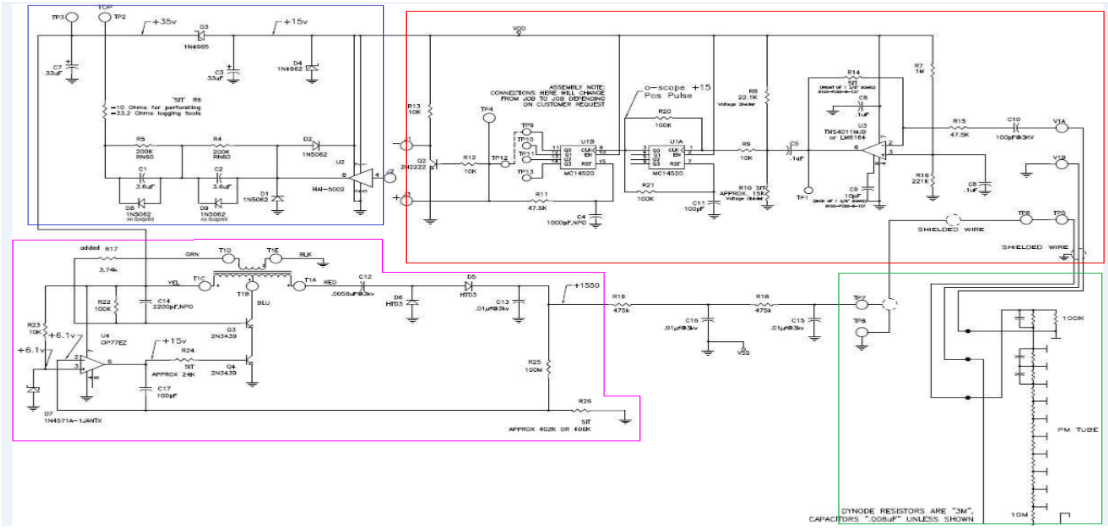


Figure 3-1 Mimic gamma ray circuit

3.2.1.1 Inverting operational amplifier:

Output signal of PMT passes through a coupling capacitor to remove DC component of signal. Then signal need to be amplified as it is always within millivolts ranges. Concerning PMT output sign there are two types of PMT, one type has positive output and the other has negative output. Most common used type in GPLT tools is the second type which has negative output. At the surface, panel supplies GPLT by a positive 50 volts. As discussed in chapter2, the 50v input supply is regulated to 35v then a zener diode is used to drop this voltage to 15v which is the supply for the whole gamma ray circuit. Upon this, inverting amplifier is used because of the restrictions of operational amplifier supply. According to job place and conditions, PMT output level differs due to rocks characteristics so gain can be easily controlled and tuned by negative feedback resistor that’s why this resistor is made SIT resistor. Another important consideration is the biasing of the op-amp by R7 and R16 resistors. This biasing is necessary in single supply op-amp applications to control the output signal swing. In other words add offset to output to be allowed to swing between the supply and ground levels. After op-amp signal passes through a coupling capacitor to remove DC offset and then add a desired DC offset to signal. This offset is also varying according to the job conditions and place so resistor R10 is made SIT.

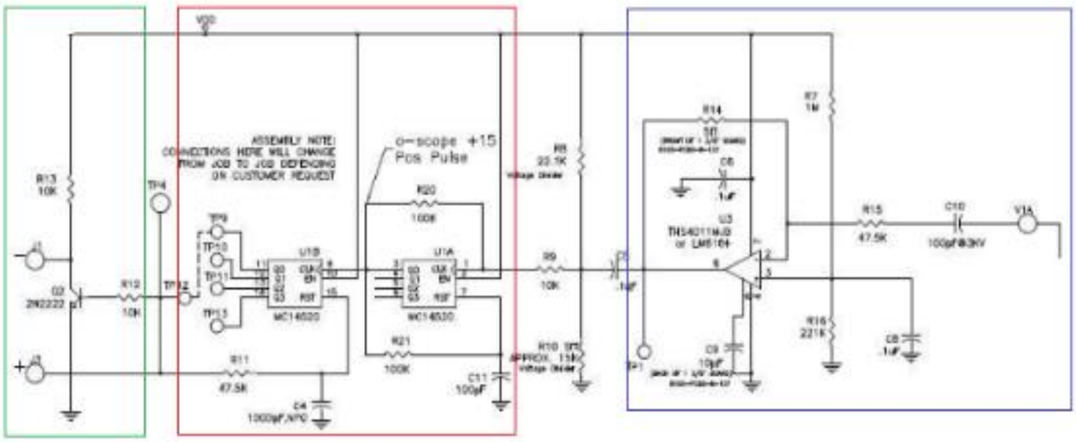


Figure 3-2 Pulse shaping and discriminator subsections

This offset should be tuned carefully to make op-amp output signal suitable for logic levels of the next subsection as will be discussed below. Figure 3.3 shows input and output of op-amp

For more clarification of single supply op-amp operation, one can refer to Op-amp Single Supply Design Techniques and Applications Texas instruments application note in [6] or Appendix A.

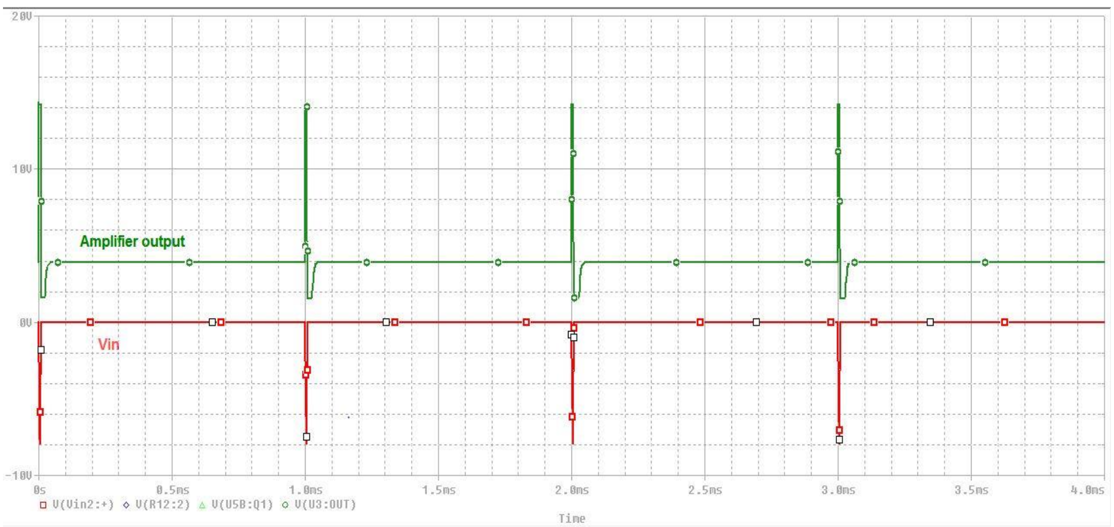


Figure 3-3 Input and output of inverting op-amp amplifier

3.2.1.2 Four bits counter:

Regarding to second subsection, this part should eliminate noisy impulses and reshape the impulses to be uniform pulses which can then be counted by the panel to draw the log sheet as mentioned earlier in this chapter. Taking the advantage of determined logic levels of the 4-bit counter noisy impulses can be removed. According to this counter datasheet any voltage levels below 4v is considered zero, above 11v is considered one and between 4v and 11v is don't care state while 15v is the supply of the counter. Op-amp output is applied to clock terminal of the 4-bit counter. Now any input impulse to 4-bit counter above 11v is considered one and the counter is incremented by one to make Q_0 terminal equals 15v. Due to nature of input impulses, it is not guaranteed that the input is maintained enough time for 4-bit to react and increment its output by one so a feedback resistor is added between Q_0 and clock terminals. To control the pulse width of the output signal, RC section is added between $Q_0$and reset terminals of 4-bit counter. The only restriction on this RC section is the expected range of frequencies of gamma rays because it is not intended to count the op-amp output impulses. Gamma rays frequency is within 1 KHz and 10 KHz so RC charging time should not exceed 100 us. In RC

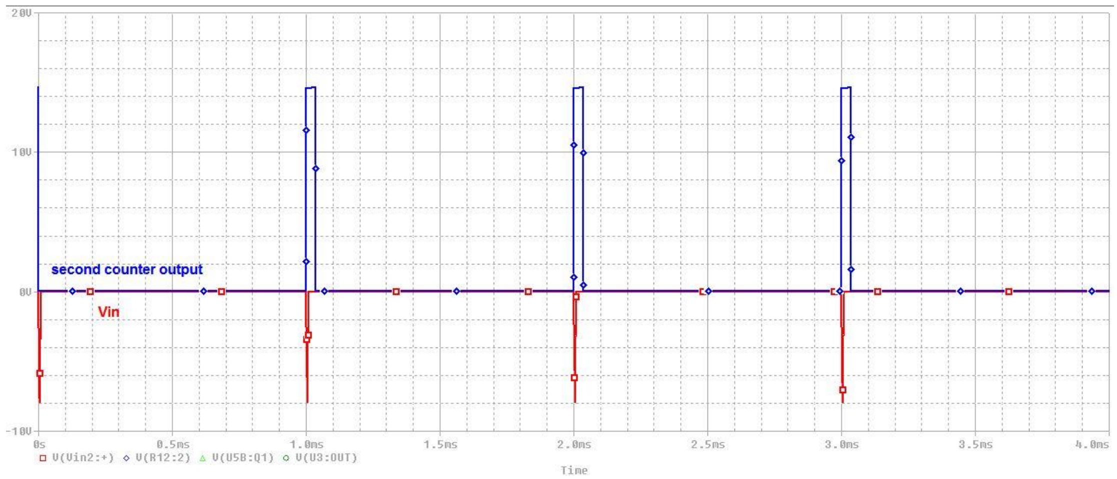


Figure 3-4 PMT output and 4-bit counter output

Section, for capacitor to fully charge, 4 τ is required which is 40 us for the values of resistor and capacitor in the schematic of figure 3.2. After the first 4-bit counter, signal should have uniform amplitude of 15v and uniform pulse width of 40 us. Another 4-bit counter is added with the same configuration except that there is no feedback resistor as the input to the second 4-bit counter is now uniform pulses. Due to the RC section of the second 4-bit counter has larger time constant and hence output is also uniform 15v amplitude and uniform larger pulse width. 4-bit counter output is shown below in figure 3.4.

For more information about 4-bit counters used in gamma ray circuit, one may refer to its datasheet in [2]. It is important to read the 4-bit counter datasheet as it will be used in new designs in next sections of this chapter.

3.2.1.3 Resistor transistor logic:

Concerning the last subsection of pulse shaping and discriminator, it is a common resistive load inverter known as resistor transistor logic (RTL). Simply this part invert the 4-bit counter output pulses. In other words the tight output pulses of figure 3.4 would be low voltage and the low part of signal would be high which makes the pulses very wide. When low voltage is applied to BJT base, BJT is off and hence its output is 15v. when high voltage is applied to the base, BJT operates in saturation and maximum current pass through it hence output is approximately 0.2v. This subsection adds the option to take 4-bit counter tight pulses output or BJT wide pulses output through J3 or J1 jumpers respectively.

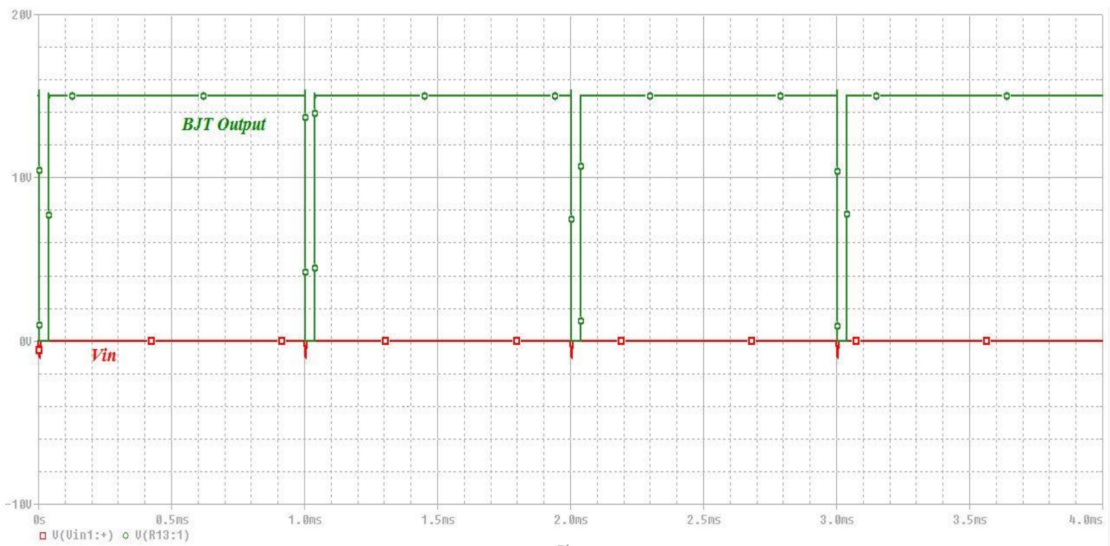


Figure 3-5 PMT output and BJT output

3.2.2 Line driver:

A line driver is an electronic amplifier circuit designed for driving a load such as a transmission line. The amplifier's output impedance may be matched to the characteristic impedance of the transmission line. Line drivers are commonly used within digital systems, e.g. to communicate digital signals across circuit-board traces and cables.

Line Driver circuit is simply, an amplifier used to improve the strength of an analog or digital signal at its source by driving the input to the transmission line with a higher than normal signal level. This increases the quality of a transmission line over a long run of cable. An example is an amplifier used to extend the range of an RS-232C digital signal beyond 50 feet (15 meter) while maintaining a specified bit error ratio.

In mobile audio, the usage of line driver allows an amplifier's gain to be set lower, reducing low-level noise. Line Drivers may also be used to enhance distortion in guitar amplifiers.

We know that for any type of transmission line, it is adding some attenuation to the signal or pulse which is carry the gamma ray count and will be calibrated by software in the panel to API American Petroleum Institute unit which is the gamma ray standard unit will be driven to the top of the tool. We reduce the effect of this attenuation of the signal by increasing the DC level of the signal using the voltage signal 50 volts coming from the panel on the top and reducing some ripples which added to the circuit is done with the help of two stages of capacitor parallel to the diode.

The role of each capacitor is to decrease the ripples of the output pulse coming from the amplifier, so the line driver stage makes that, first the buffer shown above in figure 3.1 which is its role is to pass the signal with approximately the same voltage level (gain ≈ 1) that is used to prevents loading effect (response of any device differs as the load impedance varies) as it pulls no current from preceding stage, but due to the un perfection of that buffer it adds some ripples to the pulse coming from pulse shaper stage which is before the line driver stage. 50 volt on the top makes the output pulse has been raised over this DC voltage, after two stages of the capacitor and diode in parallel, each stage decreases the ripples on the pulse. After the role of the line driver stage the signal is driven to the mono cable to the panel on the top with lower attenuation and losses.

3.3 New gamma ray circuit design

3.3.1 Pulse shaping and discriminator design 1

Mimic pulse shaping and discriminator circuit uses 4-bit counter logic IC which is composed of several gates. These gates in turn are made up many transistors so these 4-bit counters should be noisy more than other circuit components like resistors, MOSFETs or even op-amps.

This design depends mainly on envelope detector. Figure 3.6 shows the schematic of the circuit. This circuit can be divided to five subsections. First subsection is an inverting amplifier and is highlighted by blue frame. Second subsection is a common drain amplifier or source follower amplifier and is highlighted by a red frame. The third subsection is envelope detector and is highlighted by a black frame. The fourth one is an op-amp comparator and is highlighted by yellow frame. The fifth subsection is a BJT inverter and is highlighted by green frame.

The first subsection was explained previously in section 3.2.1. Also the fifth subsection was explained in the same section.

3.3.1.1 Source follower amplifier:

One of the MOSFET amplifier configurations, we shall discuss is that obtained by establishing a signal ground at the drain and using it as a terminal common to the input port, between gate and drain, and the output port, between source and drain. This circuit is called common drain or grounded-drain amplifier**.** However, it is known more popularly as the source follower, for a reason that will become apparent shortly.

The source follower features a very high input resistance, a relatively low output resistance, and a voltage gain that is less than but close to unity. It finds application in situations in which we need to connect a voltage-signal source that is providing a signal of reasonable magnitude but has a very high internal resistance to a much smaller load resistance which is, as a unity-gain voltage buffer amplifier. The source follower is also used as the output stage in a multistage amplifier, where its function is to equip the overall amplifier with a low output resistance, thus enabling it to supply relatively large load currents without loss of gain (i.e., with little reduction of output signal level.).

Common drain or source follower amplifier stage acts as a buffer. It passes the signal with approximately the same voltage level (gain ≈ 1) that's why it is called source follower. It also prevents loading effect (response of any device differs as the load impedance varies) as it pulls no current from preceding stage. Further details about the proof of unity gain and operation of source follower amplifier which is prevent the loading effect can be found in Appendix C.

3.3.1.2 Envelope detector:

Envelope detector is commonly used in many communication and electronics applications. The most common application is the communication transceiver. Receiver ends uses envelope detector in non-coherent methods to trace the envelope of the modulated signal. This envelope is the modulating signal or the desired received signal.

An envelope detector is an electronic circuit that takes a high-frequency signal as input and provides an output which is the envelope of the original signal. The envelope detector schematic is shown in figure 3.6 highlighted by a black frame. On the positive cycle of input signal, the diode conducts and the capacitor charges up to the peak voltage of the input signal. As the input signal falls below this peak value, the diode is cut off because the capacitor voltage (which is very nearly to peak voltage) is greater than the input signal voltage, thus causing the diode to open. The capacitor now discharges through the resistor at a slow rate (with a time constant equals to RC). During the next positive cycle, the same drama repeats. When the input signal becomes greater than the capacitor voltage, the diode conducts again. The capacitor again charges to the peak value of this (new) cycle. The capacitor discharges slowly during the cutoff period, thus charging the capacitor voltage very slightly.

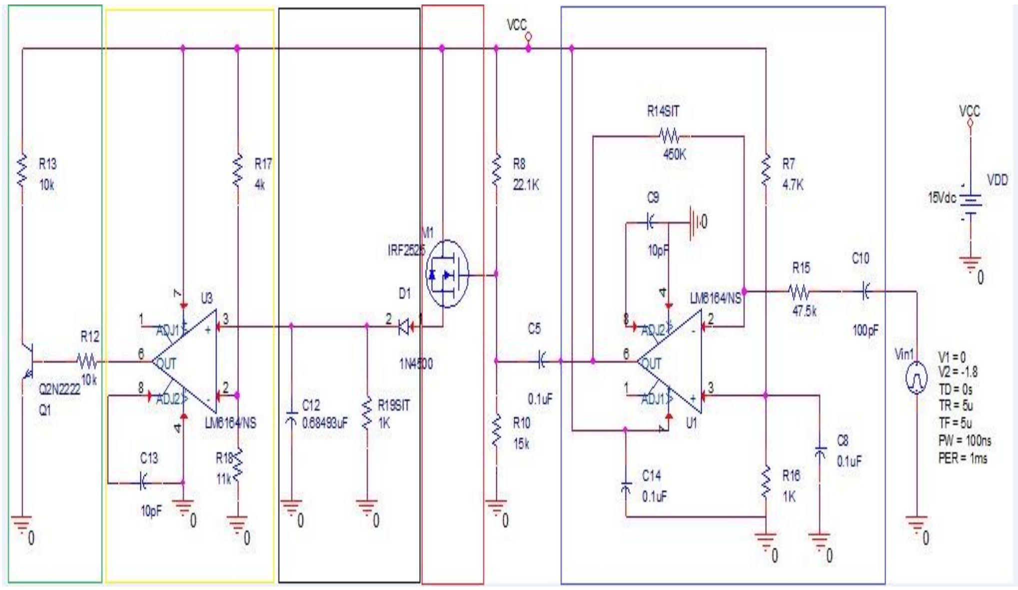


Figure 3-6 Pulse shaping and discriminator design 2 schematic

Envelope detector subsection tries to make signal continuous instead of being discrete. Simply its capacitor charges through the diode and discharges through a parallel resistor. The capacitor charges to the peak of the signal. Then through lower levels of signal it relaxes to these lower voltage levels.

3.3.1.3 Envelope detector design:

Design of envelope detector needs to consider the nature of its input signal. It should be considered that discharging state should have appropriate time constant. During each positive, the capacitor charges up to the peak voltage of the input signal and then decays slowly until the next positive cycle as shown in figure 4.7. The output voltage, thus, closely follows the envelope of the input. Capacitor discharge between positive peaks causes a ripple signal of frequency ω_c in the output. This ripple can be reduced by increasing the time constant RC so that the capacitor discharges very little between the positive peaks (RC >> $\frac{1}{\omega_c}$). Making RC too large,

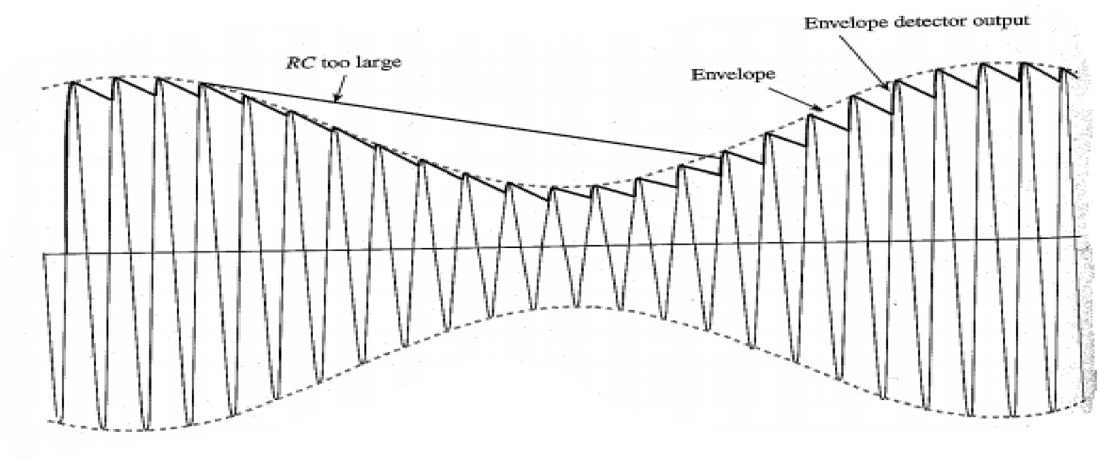


Figure 3-7 Envelope detector output

however, would make it impossible for the capacitor voltage to follow the envelope as shown below in figure 3.7. Thus, RC should be large compared to $\frac{1}{\omega_c}$ but should be small compared to 2πB, where B is the highest frequency in modulating signal (in other words the highest frequency in the envelope). This, incidentally, also requires that ω_c >> 2πB , a condition that is necessary for a well-defined envelope.

As mentioned above in section 3.2.1.2 that 4-bit counters which are used in mimic pulse shaping and discriminator circuit is useful in new designs of pulse shaping and discriminator. Design equations will use some numbers in this datasheet. So referring to 4-bit counters datasheet in [7]is very useful.

Rise time of impulses inputs to envelope detector equals 4 us. As charging the capacitor is done through the diode then $t_r = 4\tau_r = 4r_f C = 4$ us where r_f is the forward diode resistance. As diodes are not ideal in reality so it is not a short circuit while they are forward biased, however, its forward resistance is low valued. r_f depends mainly on diode characteristics like p type and n type doping areas, temperature of operation and forward current.

$r_f = \frac{V_T}{I_D}$ where V_T is the thermal voltage and as mentioned before it depends on diode characteristics and temperature of operation. In case of GPLTs the operating temperature is approximately 150 degree Celsius.

$$V_T = \frac{K\,T}{q} = \frac{1.38064852\ x\ 10^{-23}\ x\ (150+273)}{1.60217662\ x\ 10^{-9}} = 0.0365\text{v}$$

where K is Boltzmann constant in m^2 kg $s^{-2}\ K^{-1}$, T is temperature in Kelvin and q is electron charge in Coulombs.

As mentioned earlier in chapter 2 that gamma ray circuit consumes 35mA from the panel inside a truck at the surface. It can be assumed that most of this current flows through the source follower MOSFET to the envelope detector. This assumption can be accepted as the other paths from the 15v supply to ground cannot pull up much current as voltage division resistors have large values and op-amp supply current is very small (around 6mA) as specified in its datasheet in [8].

For the previous listed justifications, assume diode forward current equals 25mA.

$$r_f = \frac{0.0365}{25 \ x \ 10^{-3}} = 1.46\Omega$$

From charging equation mentioned above, capacitor value can be calculated:

$$C = \frac{t_r}{4 \ r_f} = \frac{4 \ x \ 10^{-6}}{4 \ x \ 1.46} = 0.684932 \text{ uF}$$

Discharging state:

As mentioned before, frequency of input gamma ray signal should be considered in design. So consider the scenario shown below in figure 3.8 as the case for discharging state.

Capacitor charging and discharging follow the following exponential equation: $V_c = V_f - (V_f - V_i) e^{-\tau/t}$ where V_c is the capacitor voltage, V_f is the final voltage that capacitor should charges up to it, V_i is the initial voltage of the capacitor, τ is the time constant and equals to RC and t is the charging or discharging time in seconds.

As shown above in figure 3.8, let capacitor discharges to 11v at midpoint between two successive impulses. This value (11v) is specified as the true impulses in the mimic design.

$t = - \tau_f \ln(\frac{V_f - V_c}{V_f - V_i})$ where τ_f is the discharging time constant.

$$= - \ln(\frac{0 - 11}{0 - 15}) \ \tau_f = 0.31015 \ \tau_f$$

Design is based on smallest gamma ray signal period which is 0.1 ms for the highest gamma ray frequency within the range mentioned earlier in this chapter in section 3.2.1.2 (gamma ray signal frequency is within 1KHz to 10KHz). So the discharging time should be half the smallest gamma ray signal period.

So $0.31015 \ \tau_f$ = 0.31015RC =50 us

Then R = 235.37Ω

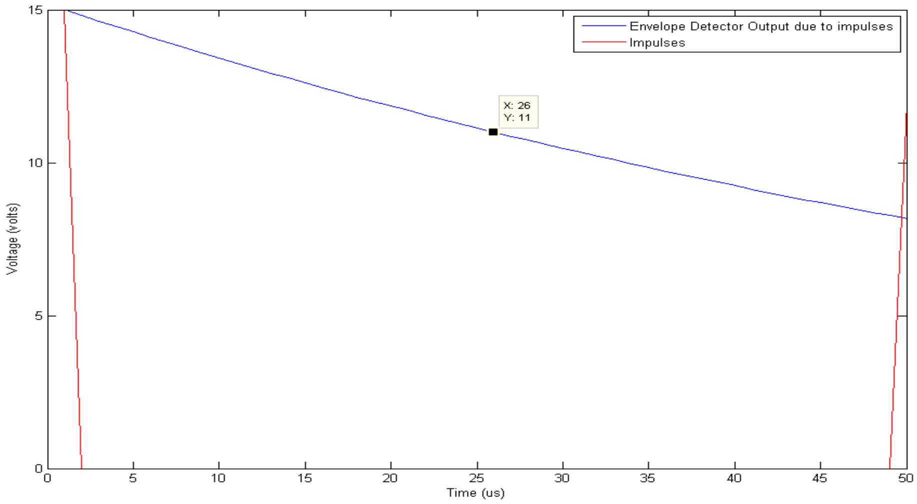


Figure 3-8 Envelope detector response due to impulse input

Design equations are very easy, conceptual and can be applied for any desired pulse width output pulses. Figure 3.9 shows the PMT output and the envelope detector output.

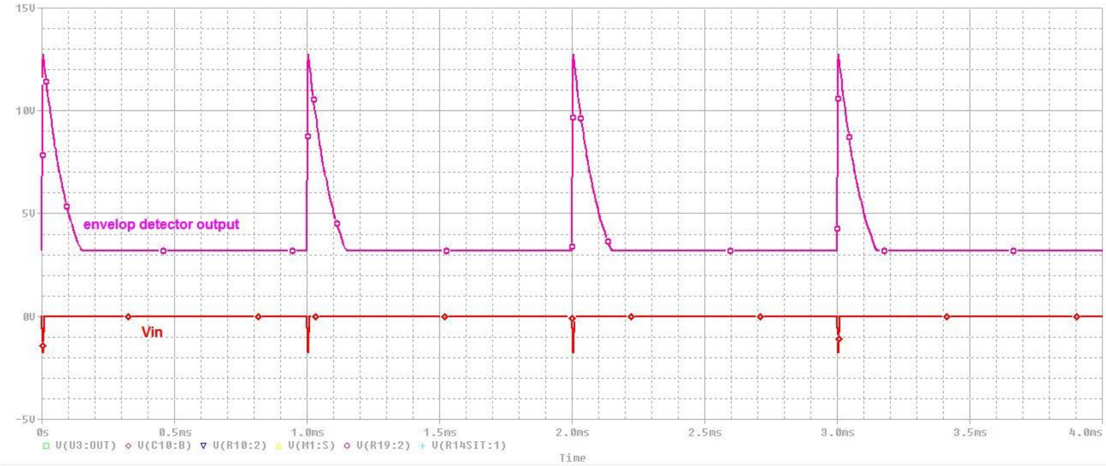


Figure 3-9 PMT output and envelope detector output

3.3.1.4 Operational amplifier comparator:

The comparator is an electronic decision making circuit that makes use of operational amplifiers very high gain in its open-loop state, that is, there is no feedback resistor. The Op-amp comparator compares one analogue voltage level with another analogue voltage level, or some preset reference voltage, V_{ref} and produces an output signal based on this voltage comparison. In other words, the op-amp voltage comparator compares the magnitudes of two voltage inputs and determines which is the larger of the two.

Voltage comparators either use positive feedback or no feedback at all (open-loop mode) to switch its output between two saturated states, because in the open-loop mode the amplifiers voltage gain is basically equal to A_{vo}. Then due to this high open loop gain, the output from the comparator swings either fully to its positive supply rail, +Vcc or fully to its negative supply rail, -Vcc on the application of varying input signal which passes some preset threshold value.

The open-loop op-amp comparator is an analogue circuit that operates in its non-linear region as changes in the two analogue inputs, V+ and V- causes it to behave like a digital bistable device as triggering causes it to have two possible output states, +Vcc or -Vcc. Then we can say that the voltage comparator is essentially a 1-bit analogue to digital converter, as the input signal is analogue but the output behaves digitally.

V_{ref} is determined by a voltage divider of resistors R17 and R18 as shown in above in figure 3.6. This threshold voltage is 11v as in mimic design. The comparator output is shown in figure 3.10.

Further clarification about configurations and operation of op-amp comparators can be found in Appendix B.

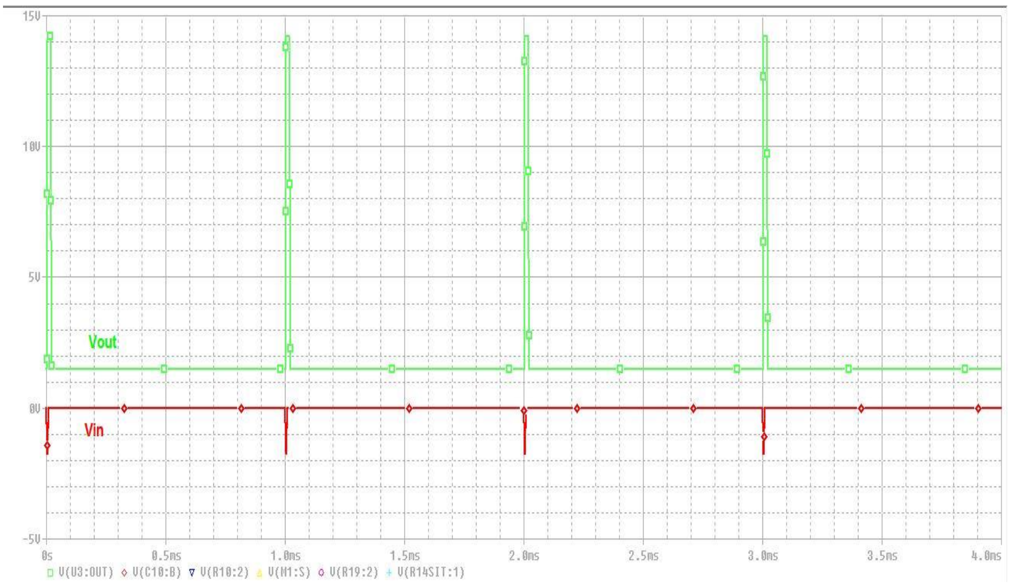


Figure 3-10 PMT output and op-amp comparator output

3.3.2 Pulse shaping and discriminator design 2:

This design is very similar to mimic design. It uses logic circuits to make use of the advantage of determined logic levels of the D-flip flop to eliminate noisy impulses. This design uses D-flip flop with exactly the same specs and characteristics of 4-bit counters which is used in mimic design. Not only are 4-bit counters and D-flip flop used in mimic design and this new design respectively having the same characteristics but also the two designs use the same configuration. Figure 3.11 shows the schematic of this design.

Following the same procedure in studying the previous circuits. This design can be divided into three subsections. First subsection is an inverting amplifier and is highlighted by blue frame. Second subsection is a D-flip flop and is highlighted by a red frame. The third one is a BJT inverter and is highlighted by green frame.

Inverting op-amp amplifier stage was explained clearly earlier in this chapter in section 3.2.1.1. Also section 3.2.1.3 has explained the resistor transistor logic using BJT stage (BJT inverter).

3.3.2.1 D-flip flop:

D-flip flop is a sequential logic device. Just like sequential logic devices, D-flip flop is made of latches which are considered the basic building block of any sequential logic devices. Latches are often called level-sensitive because their output follows their inputs as long as they are enabled. They are transparent during this entire time when the enable signal is asserted. There are situations when it is more useful to have the output change only at

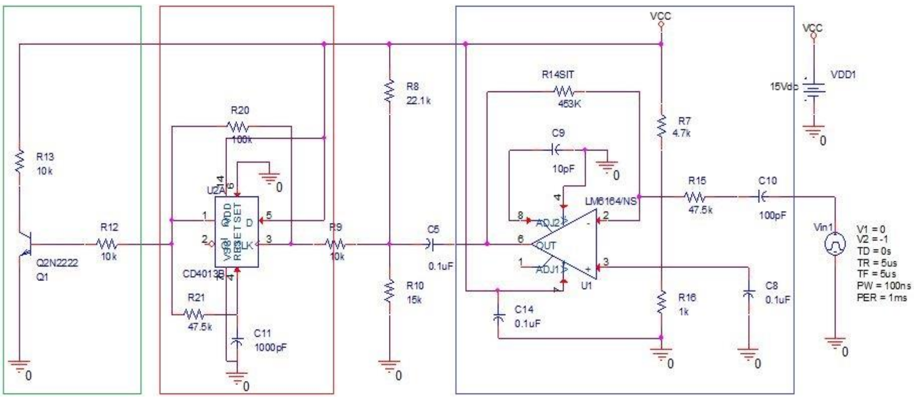


Figure 3-11 schematic of pulse shaping and discriminator design2 the rising or falling edge of the enable signal. This enable signal is usually the controlling clock signal. Thus, we can have all changes synchronized to the rising or falling edge of the clock. An edge-triggered flip-flop achieves this by combining in series a pair of latches. Figure 3.12(a) shows a positive edge-triggered D flip-flop where two D latches are connected in series and a clock signal Clk is connected to the E input of the latches, one directly, and one through an inverter. The first latch is called the master latch. The master latch is enabled when Clk = 0 and follows the primary input D. When Clk is a 1, the master latch is disabled but the second latch, called the slave latch, is enabled so that the output from the master latch is transferred to the slave latch. The slave latch is enabled all the while that Clk = 1, but its content changes only at the beginning of the cycle, that is, only at the rising edge of the signal because once Clk is 1, the master latch is disabled and so the input to the slave latch will not change. The circuit of Figure 3.12(a) is called a positive edge-triggered flip-flop because the output Q on the slave latch changes only at the rising edge of the clock. If the slave latch is enabled when the clock is low, then it is referred to as a negative edge-triggered flip-flop. The circuit of Figure 3.12(a) is also referred to as a master slave D flip-flop because of the two latches used in the circuit. Figure 3.12(b) and (c) show the truth table and the logic symbol respectively.

Like mimic design, inverting op-amp amplifier output is applied to clock terminal of the D-flip flop. Again to maintain the voltage level of the applied impulses on clock terminal for a specific time mentioned in its datasheet which is required for D-flip flop to react, a feedback resistor is added between the output and the clock terminal. As mentioned before 4-bit counters used in mimic design and D-flip flop used in this design have the same characteristics hence above 11v is considered logic one for 15v supply operation. So applied impulses with voltage level more than 11v is held by feedback resistor and switches the applied input on D terminal of D-flip flop to its output. Also RC section is added between output terminal and reset terminal to control a desired pulse width of the output like in mimic design. This RC section time constant and its restrictions were explained slightly in section 3.2.1.2. The D-flip flop output is shown above in figure 3.13 which is the same as 4-bit counter output in the mimic design. For more information about D-flip flop used in this design, its datasheet can be found in [9].

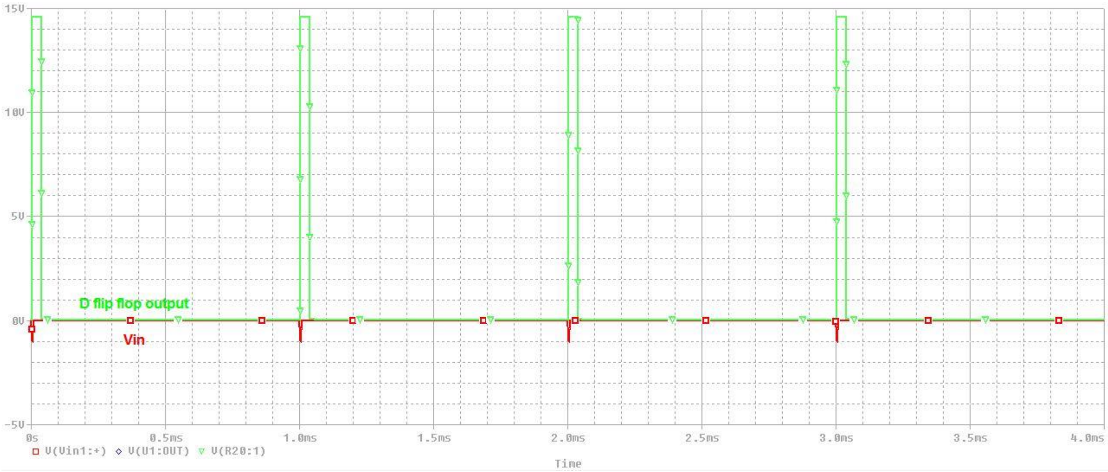


Figure 3-12 PMT output and D-flip flop output

3.3.3 Comparison between different designs:

Table 3.1 shown below explains the comparison between the preceding three designs of pulse shaping and discriminator section in gamma ray circuit which were explained within this chapter.

	Mimic and Design2 (D-flip flop)	Design1 (Envelope detector)
Noise generation	higher	lower
Area	larger	smaller
Cost	higher	lower
facility of design modification	simpler	slightly harder
facility of maintenance	easier	a bit harder

Table 3-1 Differences between different gamma ray designs

3.3.4 High Voltage:

One of the most useful as well as successful concepts in life generally and in science studying especially is divide and conquer concept. This concept is followed in studying complicated problems. Obviously this concept is the procedure followed from the beginning of this chapter in explaining the circuits including the new design circuit.

This procedure will be used through this section to study the high voltage circuit performance.

The target of this circuit is to generate high DC voltage which is used as a supply for PMT. The idea to generate this high voltage is to transform the available DC voltage, from the panel in a truck on the surface, to an AC voltage and hence transformer can be used to step up this lower AC voltage to a higher one. Once a high AC voltage is generated, it can be simply transformed again to DC. This is the most straightforward and systematic solution to generate a high DC voltage from available small DC voltage.

As area is one of the most important factors considered in GPLTs, transformer design should be paid great attention. Operating frequency of the transformer affects the coupling between the primary and secondary windings and hence affects the stepping up ratio. So transformer operates at low frequencies like 50 – 60 Hz (like transformers used in power planets) must have more iron to increase the coupling between primary and secondary windings. So a straightforward question comes arise, why some transformers in power planets operate at these low frequencies with huge structure rather than operating at high frequencies with small structures. Simply there is a tradeoff between the area and the operating frequency. As operating frequency increases losses increases highly as the Hysteresis loss is function of frequency and Eddy current losses is a strong function of frequency. Like any circuit design, the design should maximize the performance based on the requirements and compromise the tradeoffs.

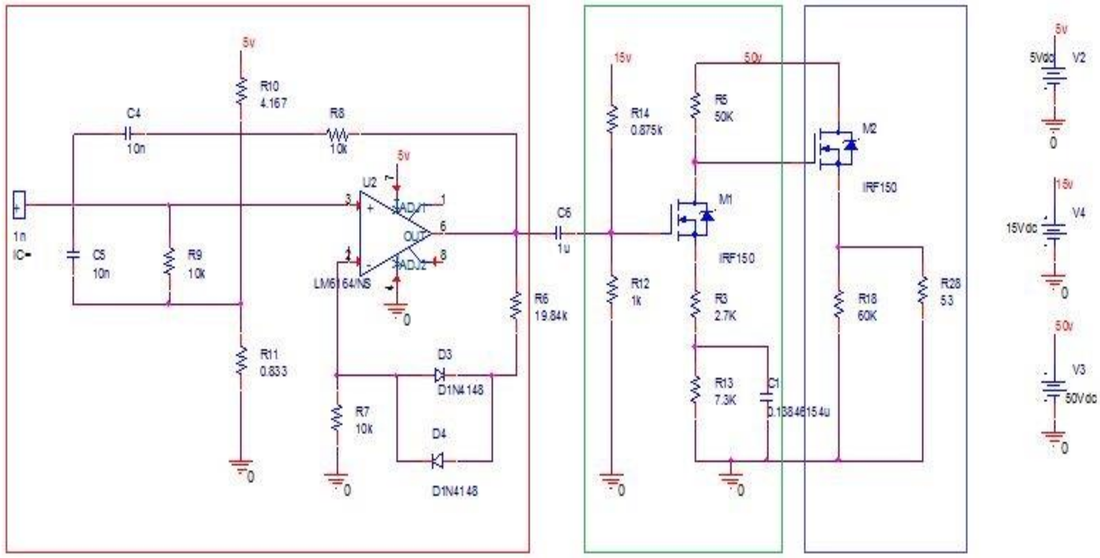


Figure 3-13 DC to AC converter

Based upon the previous paragraph and considering the design as a whole, the burden should not be placed on transformer only. So to decrease the design load and restrictions on transformer, a charge pump stage, specifically voltage doubler, is added after the transformer output. So the transformer task is now to step up its AC input to the desired voltage as a peak to peak AC voltage which is 1550v peak to peak. This is an alternative solution instead of using the transformer to directly step up its AC input to the desired voltage as an amplitude AC voltage which means 1550v AC amplitude or 3100v peak to peak and then uses a simple peak detector circuit to transform AC to DC.

To compromise the design to the limit, the input of the transformer should be maximized As much as possible. So amplifier stage is added and designed for maximum output swing before the transformer. This will be shortly discussed during this section.

3.3.4.1 High Voltage Design 1:

High voltage circuit can be divided into five subsections. Figure 3.14 shown above displays the first three subsections of high voltage design only. First subsection is an oscillator and is highlighted by red frame. Second subsection is a MOSFET common source amplifier and is highlighted by a green frame. The third one is MOSFET source follower and is highlighted by blue frame.

3.3.4.1.1 Oscillator:

An oscillator generates a signal, typically a periodic one. For example, the clock in a microprocessor resembles a square wave. A negative-feedback circuit can oscillate if Barkhausen's criteria are met. Figure 3.14 shown below displays a negative feedback system. The transfer function of this system is $\frac{H(s)}{1 + H(s)}$ which goes to infinity at a frequency of ω1 if $H(s = j\omega_1) = -1$, or, equivalently, $|H(j\omega_1)| = 1$ and $\angle H(j\omega_1) = 180^\circ$. The key point here is that the signal traveling around the loop experiences so much phase shift (i.e., delay) that, upon reaching the subtractor, it actually enhances X. With enough loop gain, the circuit continues to amplify X indefinitely, generating an infinitely large output waveform from a finite swing at X. In practice, X comes from the noise of the devices within the loop. Transistors and resistors in the oscillator produce noise at all frequencies, providing the "seed" for oscillation at ω_1. Certainly, oscillator output does not increase to infinity. Saturation or nonlinear effects in the circuit limit the output swing.

Startup condition is an important parameter of oscillator design. From the first Barkhausen criterion, the circuit may be designed for a unity loop gain at the desired oscillation frequency, ω_1.This is called the oscillation "startup condition." However, this choice places the circuit at the edge of failure: a slight change in the temperature, process, or supply voltage may drop the loop gain below one. For this and other reasons, the loop gain is usually quite larger than unity. (In fact, the design typically begins with the required output voltage swing rather than the loop gain.)

Wien-Bridge Oscillator design:

The Wien-bridge oscillator is a topology sometimes used in discrete design as it

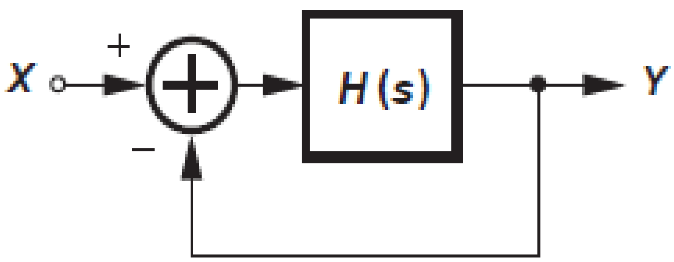


Figure 3-14 Negative feedback system

requires only one amplifying stage. Unlike the phase shift oscillator, however, the Wien-bridge configuration employs a passive feedback network with zero phase shift rather than 180◦ phase shift. The amplifier must therefore provide a positive gain so that the total phase shift at the frequency of oscillation is equal to zero (or 360◦). Figure 3.15 shows Wien-bridge oscillator architecture.

First a simple passive network with zero phase shift at a single frequency is constructed. Shown in Fig. 3.16 is an example. If R_1 = R_2 = R and C_1 = C_2 = C .

$$\frac{V_{out}}{V_{in}} = \frac{\frac{R}{1+SRC}}{\frac{R}{1+SRC}+\frac{1}{SC}+R} = \frac{SRC}{S^2R^2C^2+3SRC+1}$$

The phase thus emerges as

$$\angle\frac{V_{out}}{V_{in}}(S = j\,\omega) = \frac{\pi}{2} - tan^{-1}(\frac{3RC}{1-\omega^2R^2C^2}) = 0$$

$$\omega_1 = \frac{1}{RC}$$

Now this network is placed around an op-amp. Denoting the gain of the non-inverting amplifier by A, the magnitude of the above transfer function is multiplied by A and the result is equated to unity:

$$\left|\frac{j\omega RCA}{1-\omega^2R^2C^2+3j\omega RC}\right| = 1$$

At ω_1 , this equation yields that A = 3

So $R_{F1} \geq R_{F2}$

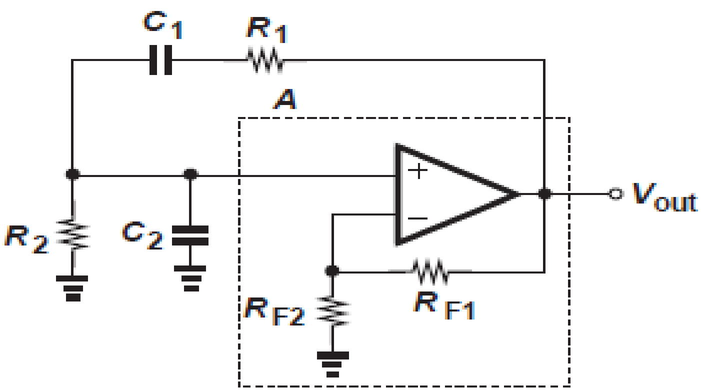


Figure 3-15 Wien-bridge oscillator

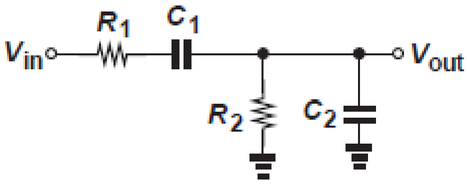


Figure 3-16 Phase shift network

To have an oscillating wave of 1 KHz, the two resistors are assumed to be 10 KΩ and hence the two capacitors are 10 nF. Also to have a gain of three R_{F2} is assumed to be 10 KΩ then R_{F1} should equal 20 KΩ. But R_{F1} is chosen to be 19.84 KΩ for maximum output performance without any signal distortion. Also two anti-parallel diodes are inserted in series with R_{F1} to avoid uncontrolled amplitude growth as shown in figure 3.13.

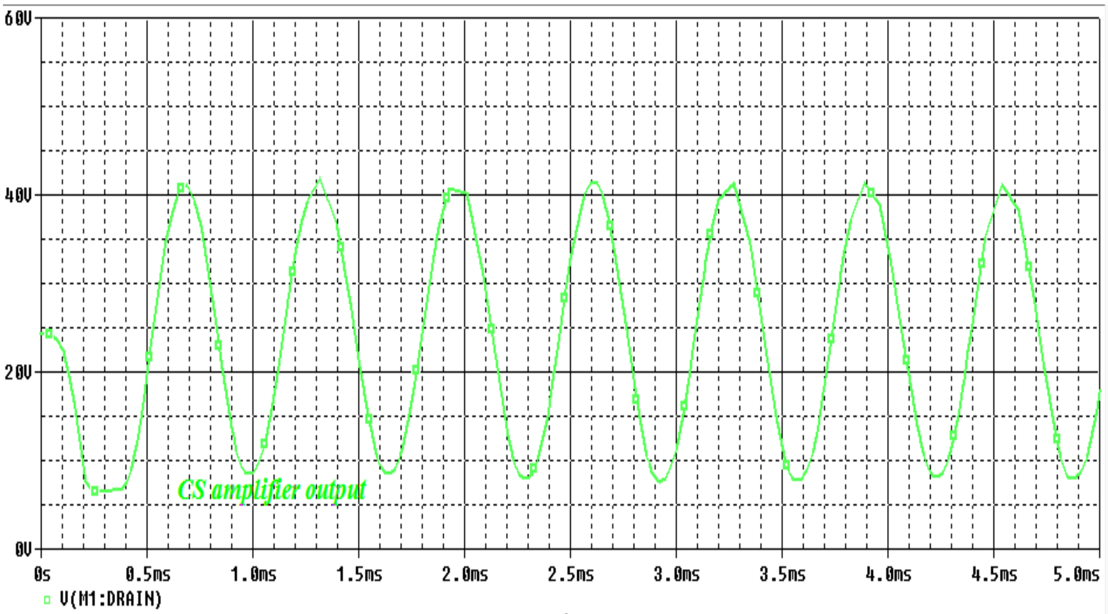


Figure 3-17 Oscillator Output

As mentioned earlier in this chapter an offset should be added to the output of op-amps when used with a single supply. To have a maximum output swing this offset should be at the midpoint between the rails which in this case 2.5v. As the gain of the circuit is three, a reference voltage of 0.833v should be added at the input to have 2.5v offset at the output. This is done by a voltage division using low valued resistors as shown in figure 3.13. This reference voltage can be generated by connecting a 4.2v zener diode between the 5v op-amp supply and the reference node. [10] Figure 3.17 shows Wien-bridge oscillator output.

3.3.4.1.2 Common source amplifier:

The amplifier circuit consists of an N-channel JFET, but the device could also be an equivalent N-channel depletion-mode MOSFET as the circuit diagram would be the same just a change in the FET, connected in a common source configuration. The JFET gate voltage Vg is biased through the potential divider network set up by resistors and is biased to operate within its saturation region which is equivalent to the active region of the bipolar junction transistor. Figure 3.18 shows the basic configuration of common source amplifier.

The input signal, (V_{in}) of the common source JFET amplifier is applied between the Gate terminal and the zero volts rail, (0v). With a constant value of gate voltage Vg applied the JFET operates within its "Ohmic region" acting like a linear resistive device. The drain circuit contains the load resistor, R_d. The output voltage, V_{out} is developed across this load resistance.

The efficiency of the common source JFET amplifier can be improved by the addition of a resistor, R_s included in the source lead with the same drain current flowing through this resistor. Resistor, R_s is also used to set the JFET amplifiers "Q-point".

The DC load line for the common source JFET amplifier produces a straight line equation whose gradient is given as: -1/(R_d + R_s) and that it crosses the vertical I_d axis at point A equal to V_{dd}/(R_d + R_s). The other end of the load line crosses the horizontal axis at point B which is equal to the supply voltage,V_{dd}.

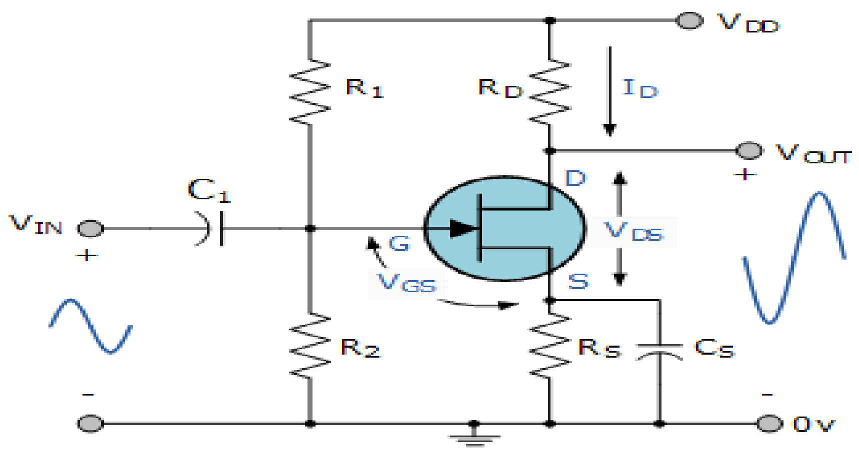


Figure 3-18 Common source amplifier

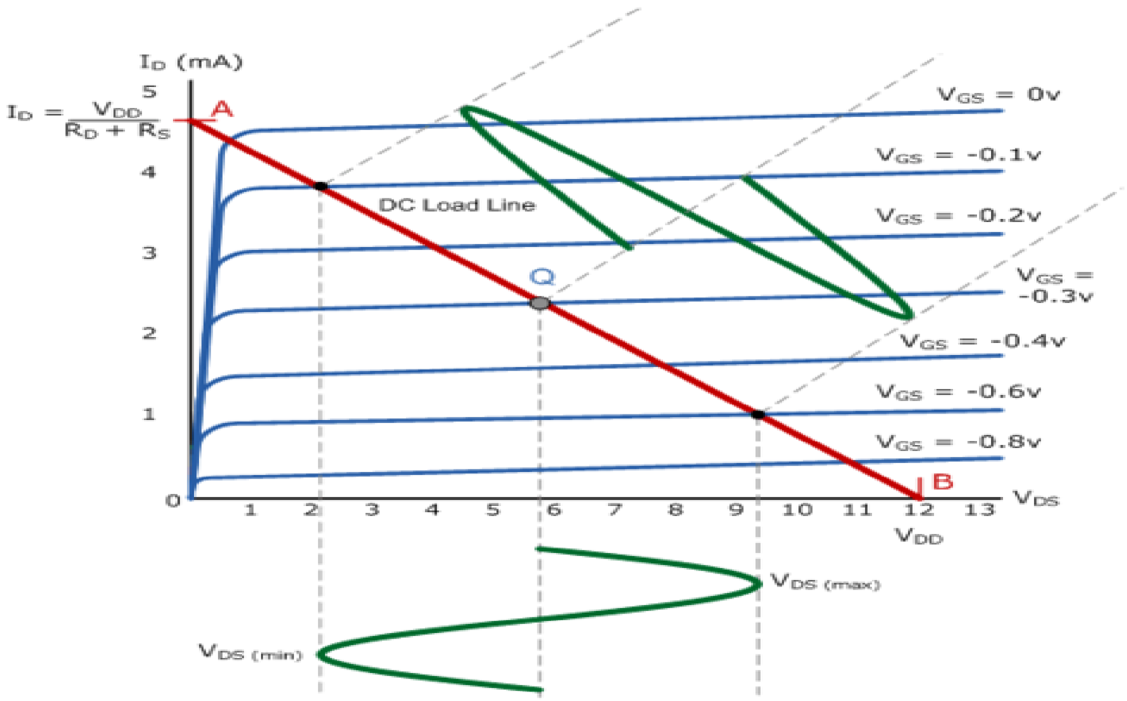


Figure 3-19 Common Source amplifier characteristics curves and load line

The actual position of the Q-point on the DC load line is generally positioned at the mid center point of the load line and is determined by the mean value of Vg which is biased negatively as the JFET is a depletion-mode device. Like the bipolar common emitter amplifier the output of the Common Source JFET Amplifier is 180o out of phase with the input signal. Figure 3.19 shown above shows Common Source amplifier characteristics curves.

As mentioned before this gain stage is added to increase the transformer input signal voltage to decrease the burden of transformer design.

Common source amplifier design:

Common source amplifier should be designed to achieve specific requirements like output swing, gain, power consumption, etc.

The most important parameters in this design is the output voltage swing and gain. In general output voltage swing should be maximized. Also concerning the gain parameters, it should be combined with the maximum output swing in order not to make output to distort due to large gain. Figure 3.17 shows that the oscillator output is around

2.5v peak to peak. Now the ideal task of the common source amplifier is to amplify the input signal to get 50v peak to peak output. This means gain that the gain is 20. Figure 3.20 shows circuit configuration to obtain the MOSFET characteristics curves with 10KΩ source degeneration resistor.

Let MOSFET to be biased by 8v and the source degeneration resistor to be 10KΩ. To have maximum output swing, many load resistors are tried and 50KΩ is found to have the best load line and hence the maximum output swing. Figure 3.21 shows clearly the MOSFET characteristics curves and load line of 50KΩ load resistor.

Now gain needs to be tuned so degeneration resistor should be divided into two series resistors. As the gain of degenerated common source amplifier is approximately $\frac{R_D}{R_S}$, R_S should be 2.7KΩ ($\frac{50K\Omega}{2.7K\Omega} = 18.5$). The rest 7.3KΩ should be made parallel with a capacitor which would be a short circuit at oscillation frequency. Capacitor value should be chosen to make its impedance at the oscillation frequency very small compared to the 7.3KΩ resistor to be dominant and hence cancels this resistor.

MOSFET is biased by 8v as mentioned before by adding a coupling capacitor to remove the DC component of the oscillator output. After that a voltage divider is added at the MOSFET gate to provide the needed 8v biasing voltage. In this circuit 5v, 15v and 50v supplies are used. As mentioned before 50v is the main voltage supply of the tool. 15v is already exists as a pulse shaping and discriminator supply. Finally 5v may be easily generated using a regulator.

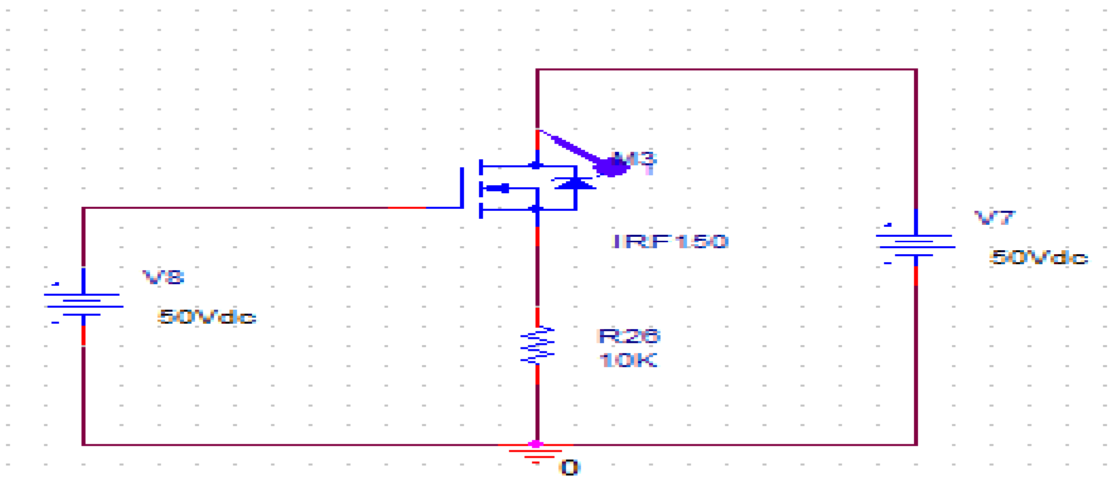


Figure 3-20 Circuit configuration to investigate MOSFET characteristic

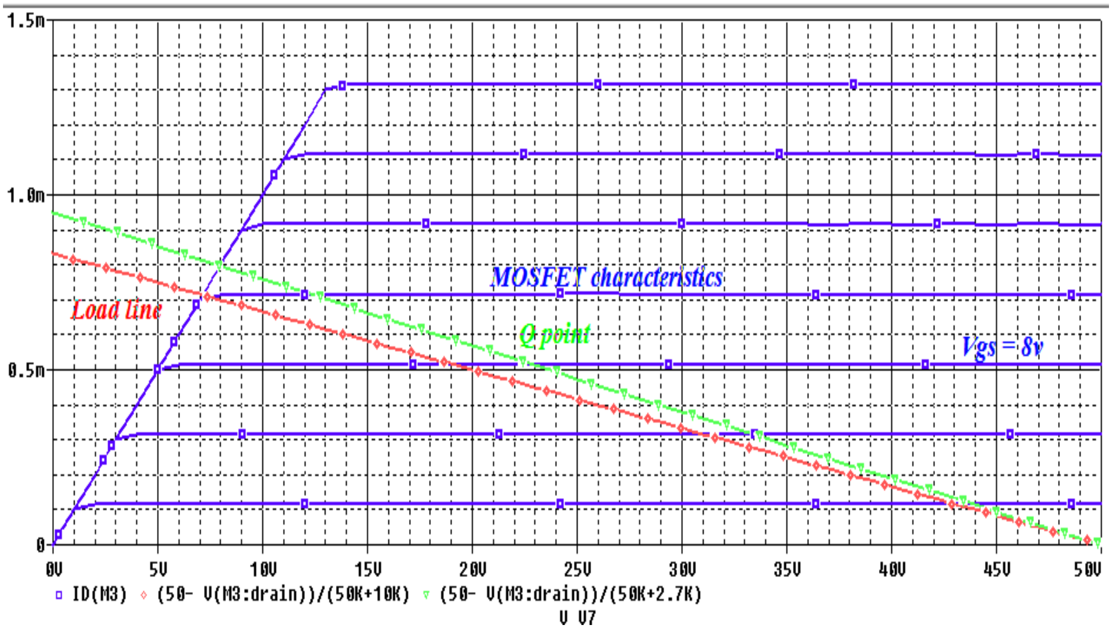


Figure 3-21 MOSFET characteristics curves and load line

3.3.4.1.3 Source follower amplifier:

Like gamma ray design1, this stage is added to prevent the loading effect and drive the transformer. This source follower should be designed to be capable of driving the transformer by the required current. This can be done by adding a resistor at the source which should be close to the input resistance of the transformer. Input resistance of transformer can be increased by adding a series resistance to it to make the degeneration resistor of the MOSFET takes any value and hence control the current of MOSFET. Figure 3.23 shows the source follower output.

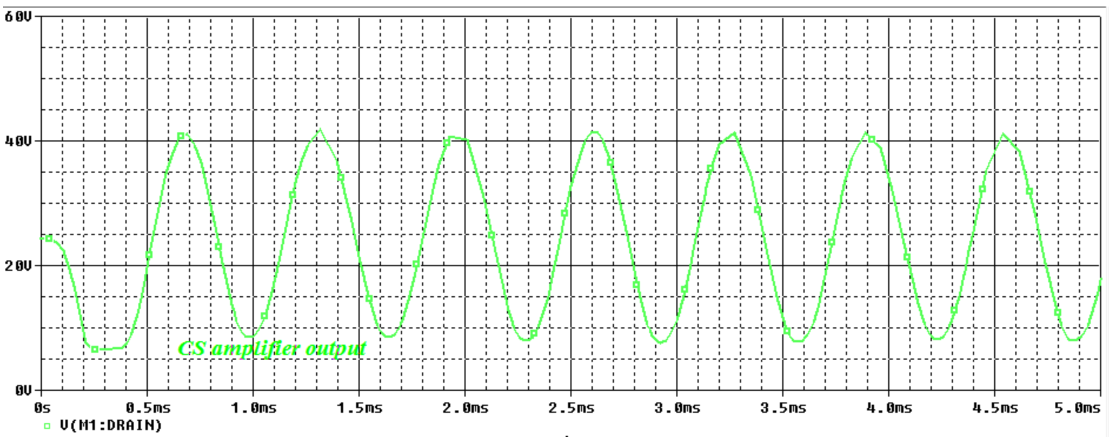


Figure 3-22 Common source amplifier output

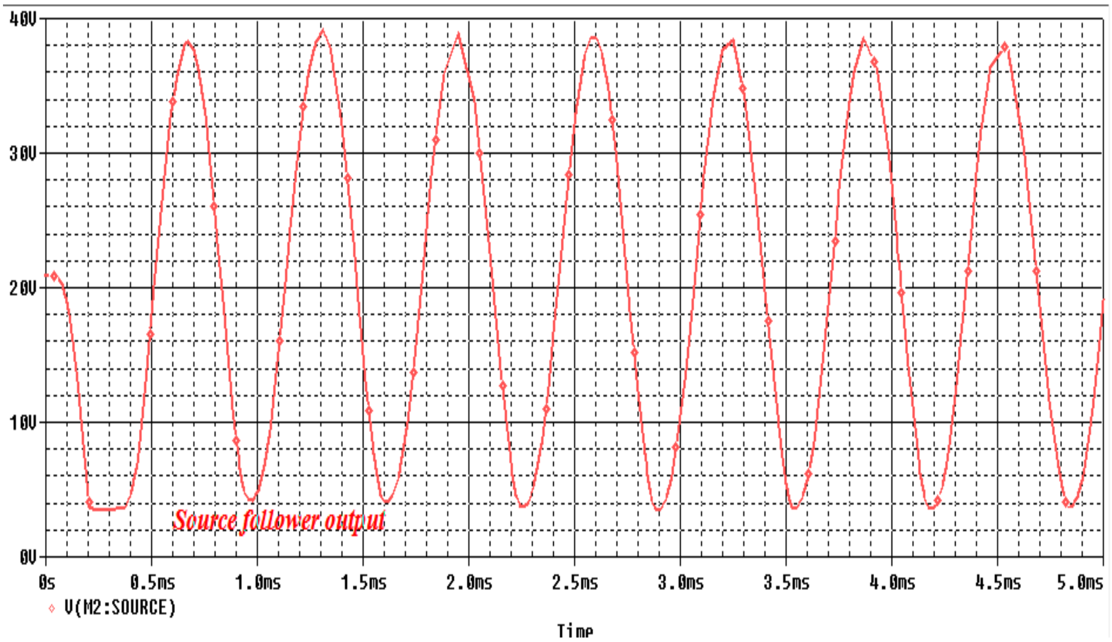


Figure 3-23 Source follower output

3.3.4.1.4 Transformer:

Transformer task and design considerations were explained at the beginning of this section. Figure 3.24 shows the transformer output.

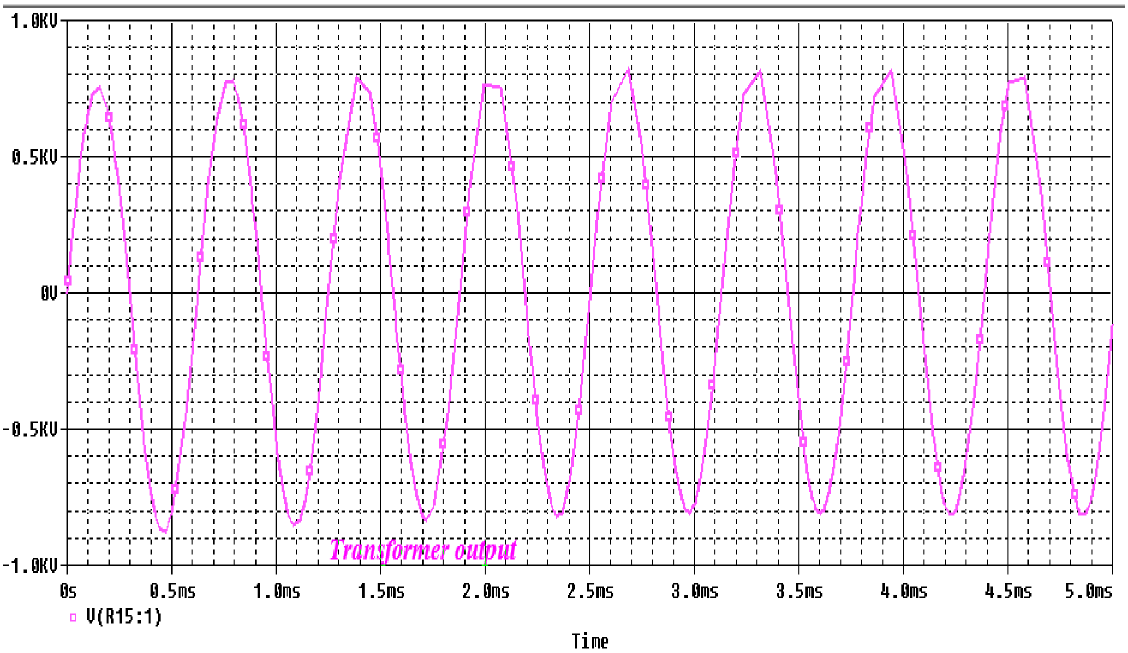


Figure 3-24 Transformer output

3.3.4.1.5 Charge pump

Capacitive charge-pump circuits are used in many applications. And though these circuits appear deceptively simple, engineers working on them need a thorough understanding of how they function. By analyzing the model of a basic charge-pump circuit, it's possible to derive expressions for efficiency and output voltage as functions of the pump's duty cycle, switching frequency, output and flying capacitances, switch and other series resistances, and load.

Due to the continuous power supply reduction, charge pumps circuits are widely used in integrated circuits (ICs) devoted to several kind of applications such as smart power, nonvolatile memories, switched capacitor circuits, operational amplifiers, voltage regulators, SRAMs, LCD drivers, piezoelectric actuators, RF antenna switch controllers, etc.

The main focus of this section of charge pump is to provide a deep understanding of the charge pumps behavior, to present useful models and key parameters and to organically and in details discuss the optimized design strategies.

Charge Pump (CP) is an electronic circuit that converts the supply voltage V_{DD} to a DC output voltage V_{Out} that is several times higher than V_{DD} (i.e., it is a DC-DC converter whose input voltage is lower than the output one). Unlike the other traditional DC-DC converters, which employ inductors, CPs are only made of capacitors and switches (or diodes), thereby allowing integration on silicon [10].

Analysis of charge pump

To show the behavior of an ideal CP, let us consider the one-stage topology in Fig.3.25, which comprises a single pumping capacitance, $C1$, two diodes acts as a switches, $D1$ and $D2$ (driven by two complementary phases), a clock signal whose amplitude is equal to the power supply V_{DD} like what is shown in Fig. 2, and a load represented by a current generator I_L and a capacitor $C2$ (also referred to as the bulk capacitor). During the first half period (0 to $T/2$), $D1$ and $D2$ are respectively in the forward and reverse regions so they considered as close and open and $C1$, being connected to the power supply, is charged to V_{DD}, while the output node is discharged by the current load, I_L which is the current after V2, which sinks a charge $I_L T/2$.

In the second half period ($T/2$ *to* T), the diodes D1 and D2 change their state , the clock signal now equals VDD, thus part of the charge stored in $C1$ is transferred both to the capacitive load, $C2$, and, for an amount of $I_L T/2$, to the current load. Hence, at each cycle the output voltage will increase up to the final asymptotic value, equal to

$$Vout \downarrow steady\ state = 2\,VDD - \frac{\mathrm{IL\ T}}{C1}$$

In conclusion, according to its name, a Charge Pump takes charges from the power supply via the capacitor $C1$, pumps these charges into the output load and, thanks to the output capacitor $C2$, and allows to increase the output voltage up to an ideal value that, except for the loss due to the current load, is twice the power supply.

The main advantage provided by diodes instead of switches is the absence of the switch control signals. The main drawback is the reduction of the Charge Pump output voltage. Indeed, when a diode is forward biased (i.e., when the corresponding switch must be closed), it causes a voltage loss equal to the diode threshold voltage, $V\gamma$, which reduces the output voltage of a factor (N +1) $V\gamma$. This reduction is particularly critical under low power supplies, and determines also a loss in the Charge Pump efficiency.

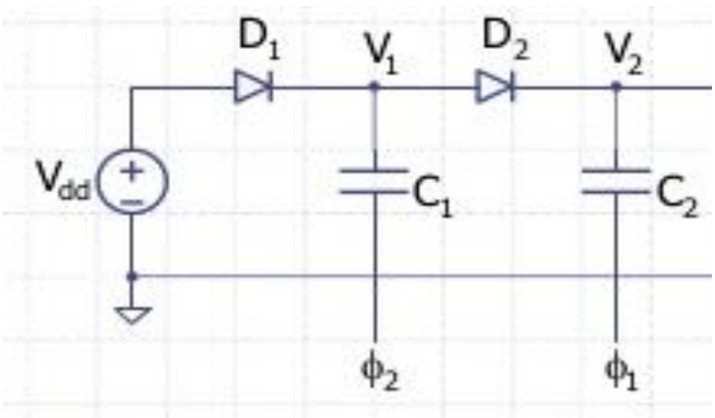


Figure 3-25 Charge pump conviguration

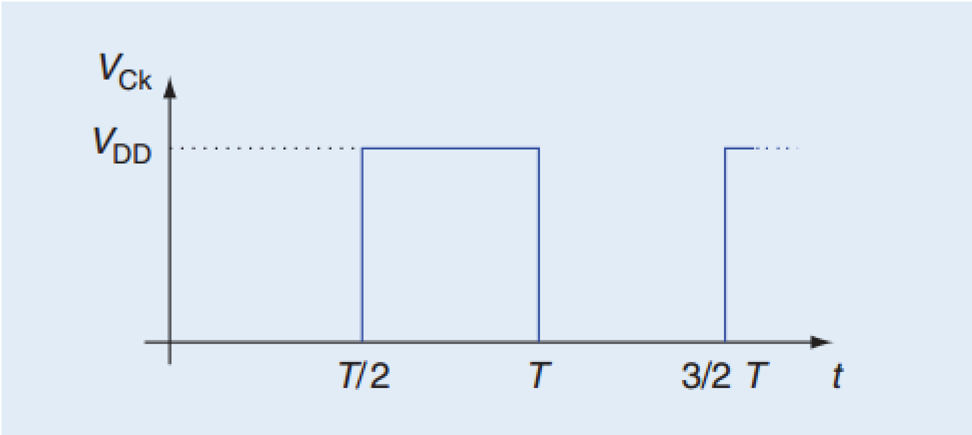


Figure 3-26 Clock signal of the charge pump in fig.3.25

The output of the charge pump which is voltage doubler output is shown in figure 3.27

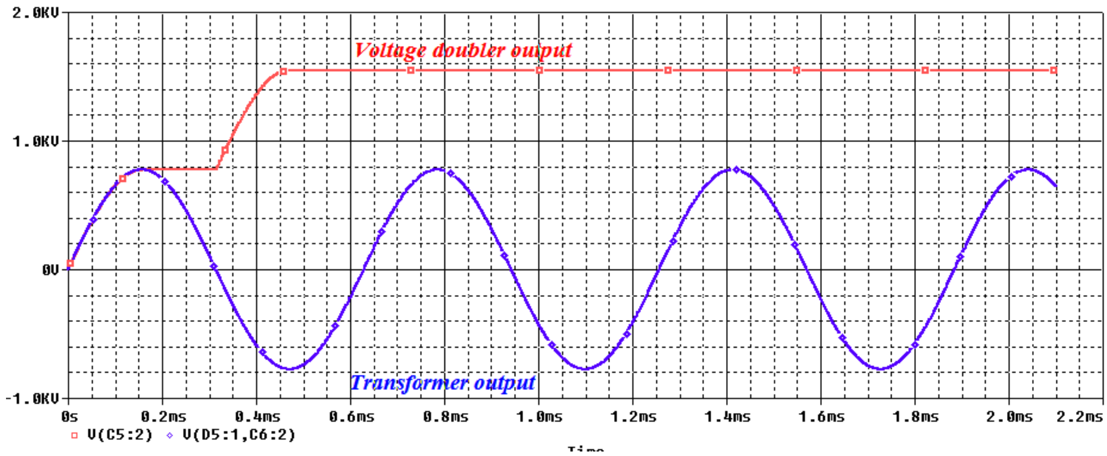


Figure 3-27 Transformer output and voltage doubler output

3.3.4.1.6 Comparison between different high voltage circuit designs

	Mimic high voltage design	High voltage design1
Area	smaller	larger
Complexity	simple	complicated
Facility of maintenance and test	Easy	harder

Table 3-2 Differences between different high voltages

3.3.4.1.7 Implementation problems:

This circuit is implemented on white boards but there was no output. Most probably the problem was using the available op-amps which are the same used in gamma ray circuits in implementing Wien-bridge oscillator. As mentioned before, the circuit uses the noise as an initial input to start oscillations. So noise level should exceeds the threshold voltage of op-amp MOSFETs which is quite large as this op-amp can be used with up to 32v input supply voltage.

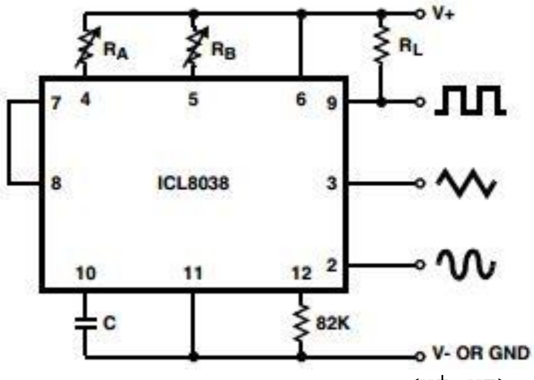
3.3.4.2 High voltage design 2:

First Solution is to use Thunder Series ICs which is high voltage DC to DC converter which can convert 5v or 12v or 24v to 1500v and output current value is in mA. [11] This solution will save high area and reduce Circuit noise and ripples can be removed using external output capacitor (see Appendix D).

3.3.4.3 High voltage design 3:

Second solution is using ICL8038 as s function generator can be operated either from a single power supply (10V to 30V) or a dual power supply (±5V to ±15V). With a single power supply the average levels of the triangle and sine wave are at exactly one-half of the supply voltage, while the square wave alternates between V+ and ground. Therefore output sinusoidal signal Amplitude is $0.22\times\ V_{supply}$ with frequency up to 100 KHz. For any given output frequency, there is a wide range of RC combinations that will work, however certain constraints are placed upon the magnitude of the charging current for optimum performance. At the low end, currents of less than 1μA are undesirable because circuit leakages will contribute significant errors at high temperatures. At higher currents (I > 5mA), transistor betas and saturation voltages will contribute increasingly larger errors. Optimum performance will, therefore, be obtained with charging currents of 10μA to 1mA. If pins 7 and 8 are shorted together as shown in figure 3-14. The Symmetry of all waveforms can be adjusted with the external timing resistors. [12] where there are two external resistors are connected to pins 4,5 in order and if two resistors are equal then duty cycle is 50%. Value of two resistors is

Figure 3-28 Oscillator circuit using ICL8038



determined by required current value where $I = \frac{0.22(V^{+}-V^{-})}{R_{4,5}}$. [2] so for I=1mA and supply voltage is 15v and 0v then R= 3.3KΩ. and frequency is determined by using timing capacitor on pin 10 where $f = \frac{0.33}{RC}$ Hz and for R= 3.3KΩ then C = 1μF. To minimize sine wave distortion, the 82kΩ resistor between pins 11(ground pin) and pin 12 is best made variable as shown in figure 3-14 Using non-inverting amplifier will provide suitable gain then using buffer to provide sufficient current to transformer.

Chapter 4: Firing Circuit

4.1 Overview

Firing circuit is a circuit has two main sections. First section is a voltage regulator circuit which used to maintain constant output voltage, however changes that happen to input voltage. This section output is input to GAMMA Ray circuit. Second section is perforation supply circuit which is used to supply perforation gun with required voltage for perforation. Also firing circuit must isolate Voltage regulator section from Perforation section. Perforation detonator can be positive detonator which mean that it is activated by using positive voltage or negative detonator which is activated by using negative voltage.in our tool perforation is done through negative detonator. As shown in figure 4.1 when control panel sets positive voltage on mono cable precisely 50v then Firing circuit perforation section is deactivated and voltage regulator section is activated to stable its output to 35v as an input voltage to GAMMA Ray circuit and by applying negative voltage (-100v or -200v) so voltage regulator section is deactivated so its output is zero therefore GAMMA Ray is off and perforation detonator is activated

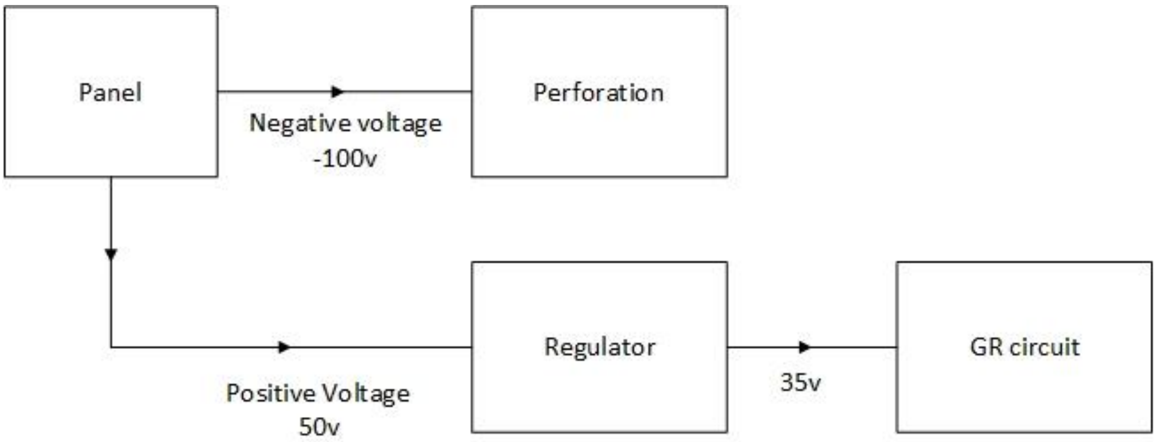


Figure 4-1 Firing circuit block diagram

4.2 Voltage regulator

Voltage regulators are used to provide a stable power supply voltage independent of load impedance, input-voltage variations, temperature, and time. Low-dropout regulators are distinguished by their ability to maintain regulation with small differences between supply voltage and load voltage. For example, as a lithium-ion battery drops from 4.2 V (fully charged) to 2.7 V (almost discharged), an LDO can maintain a constant 2.5 V at the load. The dropout voltage is the difference between the output voltage and the input voltage at which the circuit quits regulation with further reductions in input voltage. Voltage regulators are classified to three classes: Low drop-out linear regulator (LDO), standard regulators, quasi-LDOs. Standard regulators used NPN pass transistors. Quasi-LDOs use Darlington structure to implement a pass device made of an NPN pass transistor and PNP. Dropout voltage of standard regulator is higher than quasi-LDO. LDO regulators are usually the optimal choice based on dropout voltage where dropout voltage of LDO regulators is less than quasi-LDO. for choosing the right regulator for a specific application, the type and range of input voltage (e.g., the output voltage of the dc-to-dc converter), needs to be considered. Also important are the required output voltage, maximum load current, minimum dropout voltage, quiescent current, and power dissipation. All linear voltage regulators reduce an input voltage to a constant output voltage across a load. They are not capable to increase the voltage. A voltage controlled current source is used to provide the regulated output voltage. [13]As shown in figure 4.2 LDO needs to maintain a constant voltage at output with variations of load condition. Therefore, it requires a feedback loop in the system to monitor the output. Furthermore, in order for the system to be stable, a compensation circuitry needs to be included. For most linear regulators, a compensation scheme is part of the feedback path, while for LDOs, it requires an external load capacitor to achieve internal stability frequency response of the LDO system highly depends on load conditions. Load resistance significantly affects pole locations, resulting in the loss of stability due to the decrease in phase margin.

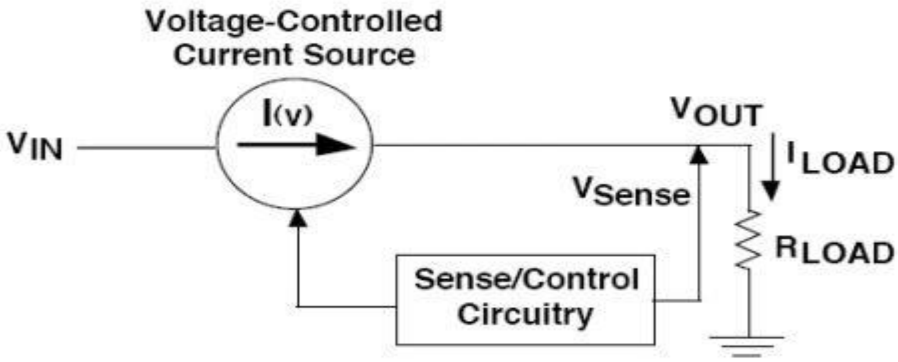


Figure 4-2 Linear voltage regulator [12]

Therefore, the stability issue for LDO system becomes the main challenge for LDO design. Another characteristic of any linear regulator is that it requires a finite amount of time to correct the output voltage after a change in the load current demand. This time lag defines the characteristic called transient response, which is a measure of how fast the regulator returns to steady-state condition after a load change. [14]

4.3 Firing Circuit Mimic

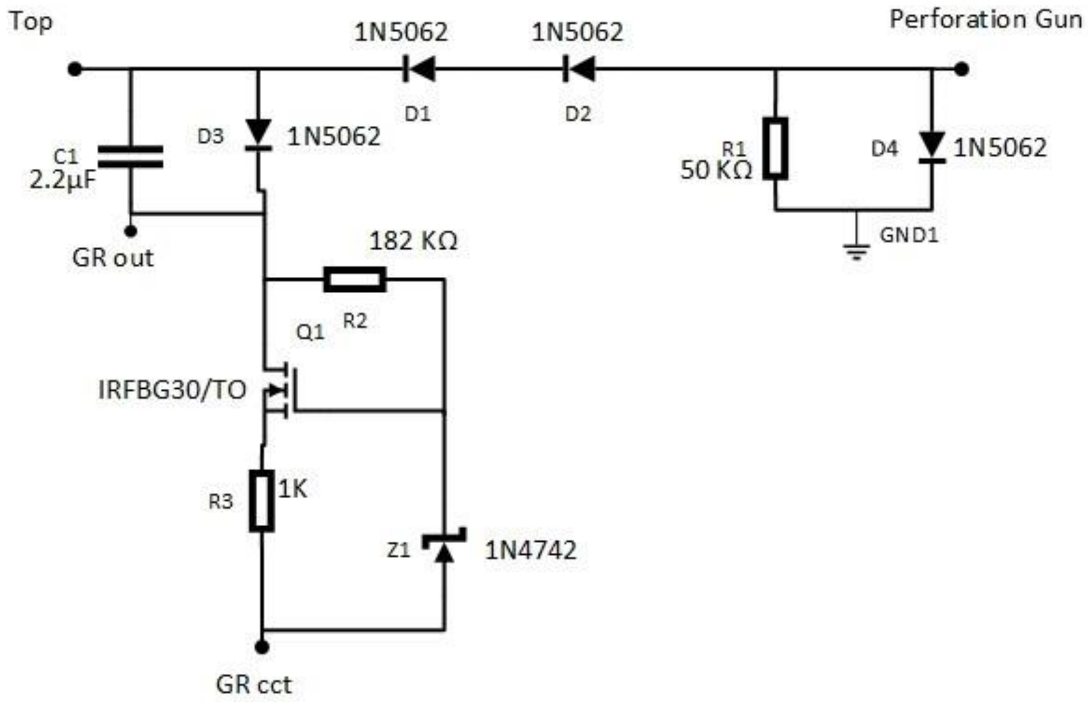


Figure 4-3 Mimic Firing circuit

As shown in figure 4.3 simple LDO consists of MOSFET & two resistor and zener diode is used so if V_{in} From TOP point $= -100v\ or - 200v. D_3$ is reverse but $D_1 and\ D_2$ are forward for DC signal C_1 is very high impedance (open circuit) so LDO is deactivated so detonator voltage$\simeq\ -100v$ is activated and perforation is done as shown in figure 4.4.

From TOP point if $V_{in} = 50v. D_3$ is forward but $D_1 and\ D_2$ are reverse for DC signal C_1 is very high impedance (open circuit) so detonator is deactivated and LDO is activated so GAMMA Ray circuit is ON. LDO here is power MOSFET which acts in saturation region.

4.3.1 Analysis

$$\because V_{DS} \geq V_{GS} - V_{th}\ or\ V_{GD} \leq V_{th}$$

Voltage drop on R_2 around 2.6v so $V_G = 46.7v$ and $V_D = 49.1v\ so\ for$

$$\therefore V_{th} = 4v \quad \therefore V_{GD} < V_{th}$$

$$\therefore I_{R_2} = \frac{2.6v}{182\ k\Omega} = 14\ \mu\text{A} \therefore I_D = 48.5\ mA. \quad \because I_g = 0$$

$$\therefore I_z = I_{R_2}$$

$$\because V_z = 12v$$

$$\therefore V_{out}(GR\ input) = 35v \text{ as shown in figure 4.5}$$

Figure 4-4 Firing circuit response for negative input voltage

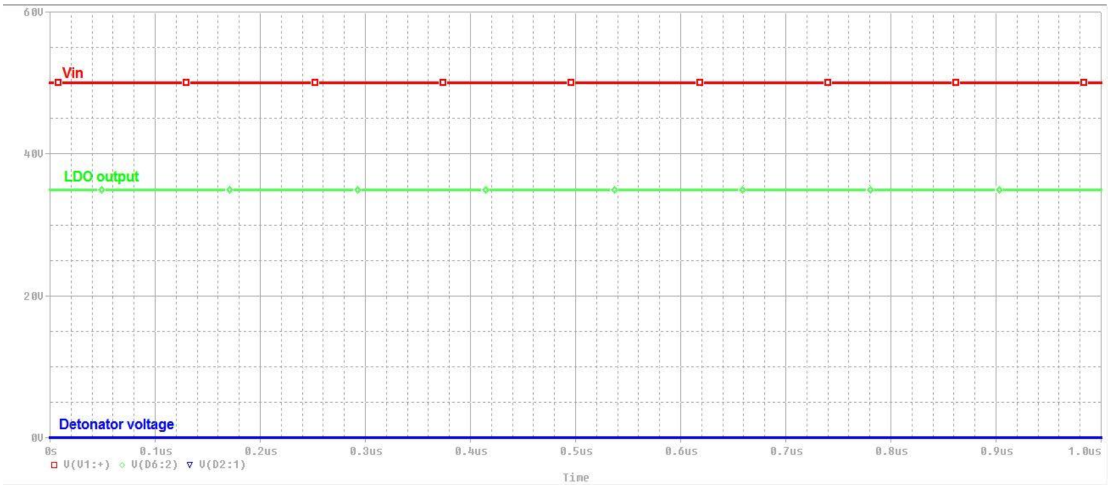


Figure 4-5 Firing circuit response for positive input voltage

4.4 Firing Circuit new design

LDO is replaced by LM117 linear voltage regulator and perforation supply section is the same as shown in figure 4.6.

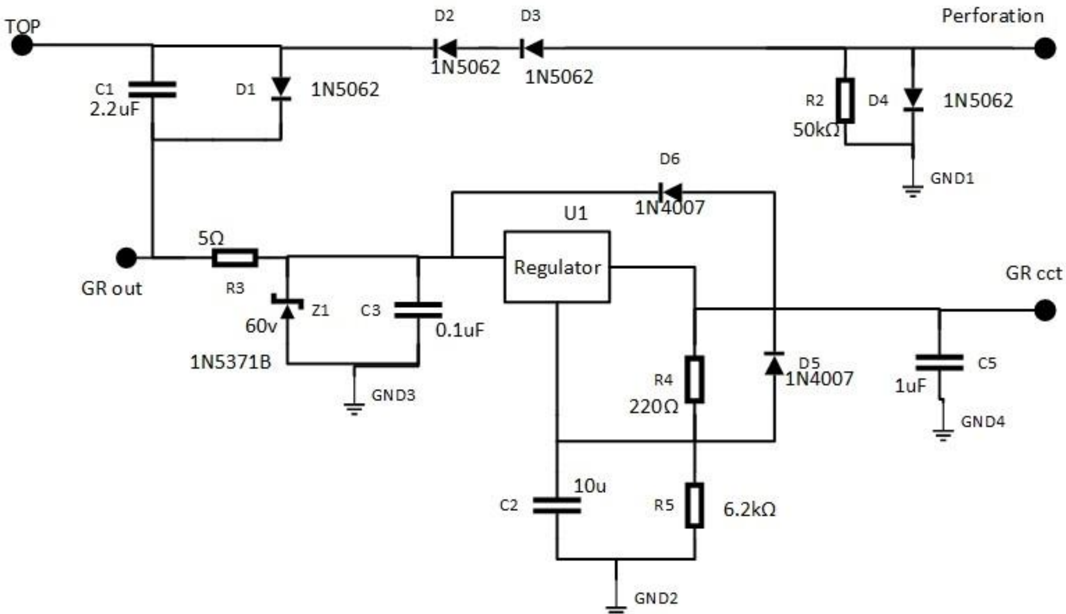


Figure 4-6 Firing circuit new design

4.4.1 LM117 regulator

The LM117 HV of adjustable 3-pin positive voltage regulators are capable of supplying in excess of 1.5 A over a 1.25-V to 37-V output range and wide temperature range up to 150ºc. They are exceptionally easy to use and require only two external resistors to set the output voltage. The LM117 HV and LM317-N offer full overload Operating Temperature Range protection such as current limit, thermal overload protection and safe area protection. By connecting a fixed resistor between the adjustment pin and output, the LM117 and LM317-N can be also used as a precision current regulator. An input bypass capacitor is recommended to reduce the input ripple voltage amplitude. A 0.1 µF disc or 1 µF solid tantalum on the input is suitable input bypassing for almost all applications. [8] When external capacitors are used with any IC regulator, it is sometimes necessary to add protection diodes to prevent the capacitors from discharging through low current points into the regulator. When an output capacitor is connected to a regulator and the input is shorted, the output capacitor will discharge into the output of the regulator. The discharge current depends on the value of the capacitor, the output voltage of the regulator, and the rate of decrease of V_{in}. The bypass capacitor on the adjustment terminal can discharge through a low current junction. Discharge occurs when either the input, or the output, is shorted. D_6 protects against C_5 and D_5 protects against C_2. Input output relation is $V_{out} = 1.25v\left(1+\frac{R_5}{R_4}\right) + \left(I_{adj} \times R_5\right)$. [3] LM117 can handle input voltage up to 60v.an output capacitor is used to improve transient response and increase stability. an LVR alternative to LM117 is TPS7A4001. The TPS7A4001 device is a very high voltage tolerant linear regulator and is able to withstand continuous DC or transient input voltages of up to 100 V. The TPS7A4001 device is stable with any output capacitance greater than 4.7 µF and any input capacitance greater than 1 µF and minimum dropout voltage is 290 mv. [9] Input output relation is $V_{out} = \left(1+\frac{R_1}{R_2}\right)V_{FB}$ as shown in figure 4.7.

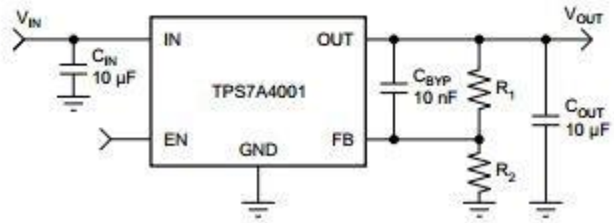


Figure 4-7 TPS7A4001 regulation circuit [9]

4.4.2 Analysis

if V_{in} From TOP point $= -100v\ or - 200v. D_1$ is reverse but $D_3\ and\ D_2$ are forward. for DC signal C_1 is very high impedance (open circuit) so LVR is deactivated so detonator voltage $\simeq\ -100v$ is activated and perforation is done as Mimic case.

From TOP point if $V_{in} = 50v. D_1$ is forward but D_2 and D_2 are reverse. for DC signal C_1 is very high impedance (open circuit) so detonator is deactivated and LVR is activated so GAMMA Ray circuit is ON. 60v zener diode is used to ensure LM117 LVR input does not exceed 60v. C_3 is an input bypass capacitor to remove input ripples. C_5 is output capacitor used to improve transient response. C_2 is bypass cap used to pass adjacent pin to ground.

$$\because V_{out} = 1.25v\left(1 + \frac{R_5}{R_4}\right) + \left(I_{adj} \times R_5\right)$$

$$\because required\ V_{out} = 35v\ \&\ I_{adj} = 60\ \mu A$$

$$\because R_1 = 240\Omega\ or\ 220\Omega\ or\ 150\Omega$$

$$\therefore if\ R_1 = 220\Omega$$

$$\therefore R_2 \simeq 6\ K\Omega$$

$$so\ for\ R_2 = 6\ \text{K}\Omega \therefore V_{out} = 35v\ as\ shown\ in\ figure\ 4.8$$

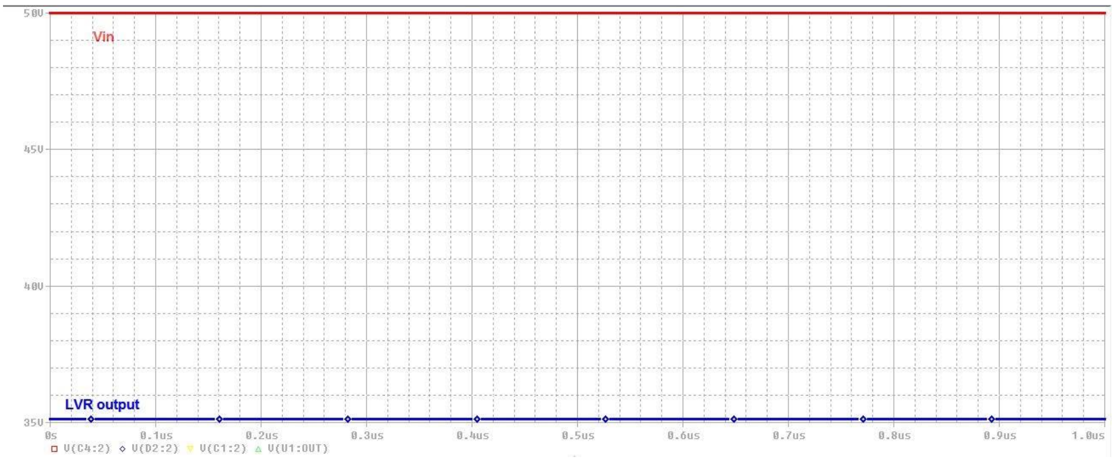


Figure 4-8 Firing circuit new design response for positive input voltage

GAMMA Ray circuit output has 3 paths to pass first one through C_1 to Top then to control panel and second one through $C_1$to detonator and third one is to LVR. Second path contain 50 KΩ resistor and third path has multiple resistors so first path is the least resistive path. Therefore, first path is the chosen path for GAMMA Ray circuit output.

The table shown below shows the difference between the standard design of firing circuit and the new design of firing

	Mimic Firing circuit	New Design firing cci
Area	Less	bigger
Protection	low	high

Table 4-1 Compression between two designs

Chapter 5: Casing Collar Locator (CCL)

In this chapter we will discuss and focus on the Casing Collar Locator (CCL) circuit in details and all things about this circuit its function, usage and the circuit itself with all components and full explanation about the standard schematic of the Casing Collar Locator circuit then the explanation of the new and modified design of the circuit all of these explanations is followed by the simulation results of the circuit and the PCB layout of the circuit. All of the previous points will be illustrated in this chapter. First of all, an overview of the Casing Collar Locator circuit will help in understanding the circuit and its function.

5.1 Overview

CCL circuit is used to know depth inside a cased-hole well by locating collars that connects two successive casings and the length of each casing is standard (40feet). The density of the material of the casings is different from the density of the material of the collars and this helps in the operation of the CCL circuit. Figure 5.1 shows that a cross section for the casing and the collar which is connect two successive casings with each other. This figure is only to get an obvious shape about the casing and the collars which connect them.

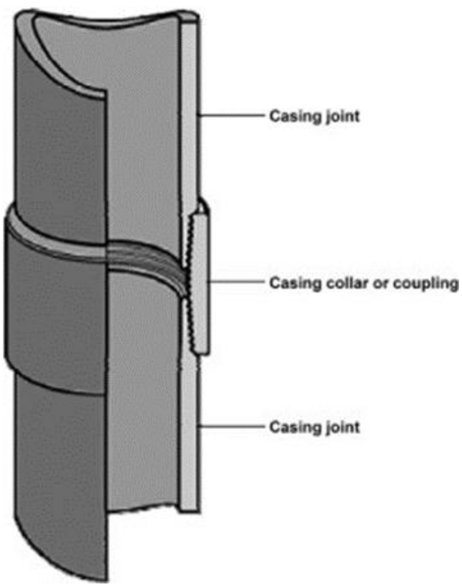


Figure 5-1 cross section for the casing and the collar

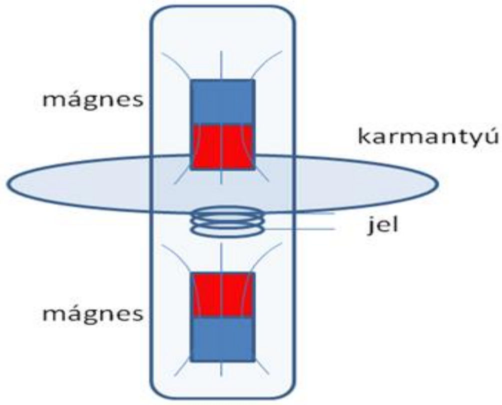


Figure 5-2 the shape of the position of the two magnets surrounding the coil

Figure 5.2 shows that the shape of the position of the two magnets surrounding the coil which is the way the two magnets must be to make the magnetic field crosses the casings and the collars.

Before starting to explain the block diagram, schematic of the Casing Collar Locator circuit with its details we will show and explain an important concept which is used in the Casing Collar Locator circuit which is the current amplifiers in the bipolar junction transistor and MOSFETs to be easy to understand the schematic of the CCL circuit.

5.2 Current Amplifiers

All types of transistor amplifiers operate using AC signal inputs which alternate between a positive value and a negative value so some way of "presetting" the amplifier circuit to operate between these two maximum or peak values is required. This is achieved using a process known as Biasing. Biasing is very important in amplifier design as it establishes the correct operating point of the transistor amplifier ready to receive signals, thereby reducing any distortion to the output signal.

The aim of any small signal amplifier is to amplify all of the input signal with the minimum amount of distortion possible to the output signal, in other words, the output signal must be an exact reproduction of the input signal but only bigger (amplified).

To obtain low distortion when used as an amplifier the operating quiescent point needs to be correctly selected. This is in fact the DC operating point of the amplifier and its position may be established at any point along the load line by a suitable biasing arrangement. The best possible position for this Q-point is as close to the center position

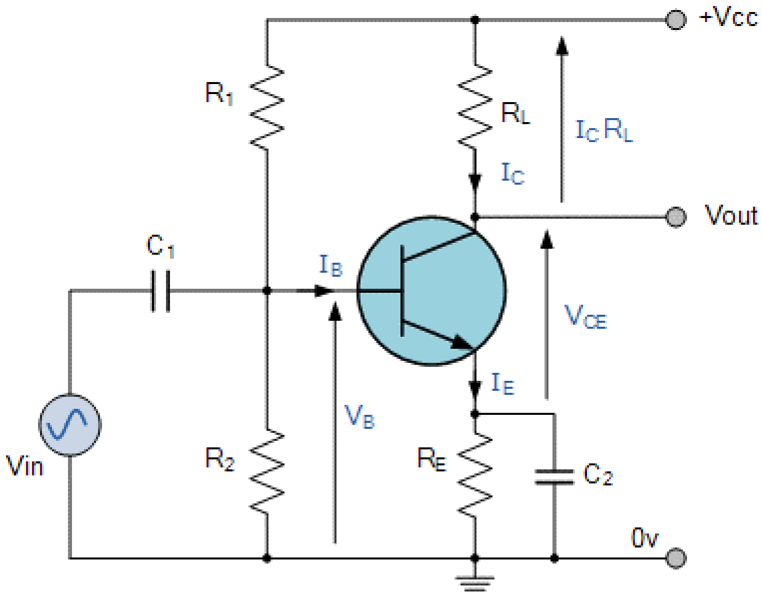


Figure 5-3 Common Emitter Amplifier

of the load line as reasonably possible, thereby producing a Class A type amplifier operation, i.e. Vee = 1/2Vcc. Consider the Common Emitter Amplifier circuit shown below in figure 5.3.

The Base of the transistor used in a common emitter amplifier is biased using two resistors as a potential divider network. This type of biasing arrangement is commonly used in the design of bipolar transistor amplifier circuits and greatly reduces the effects of varying Beta, (β) by holding the Base bias at a constant steady voltage. This type of biasing produces the greatest stability.

One of the most important concept on the current amplifiers is the method used to bias the transistor to be in active region and get the best location of Q point to be stable. The methods of the biasing the circuits of bipolar junction transistor and the same methods of biasing used in the MOSFETs will be shown below.

5.3 Biasing in BJT Amplifiers Circuits

The biasing problem is that of establishing a constant dc current in the collector of the BJT. This current has to be calculable, predictable, and insensitive to variations in temperature and to the large variations in the value of β encountered among transistors of the same type. Another important consideration in bias design is locating the dc bias point in the (Ic~Vce) plane to allow for maximum output signal swing. In this section, we shall deal with various approaches to solving the bias problem in transistor circuits designed with discrete devices.

To make the Q point stable different biasing circuits are tried. The Q point is also called as operating bias point, is the point on the DC load line (a load line is the graph of output current vs. output voltage in any of the transistor configurations) which represents the DC current through the transistor and voltage across it when no ac signal is applied. The Q point represents the DC biasing condition. When the BJT is biased such that the Q point is halfway between cutoff and saturation than the BJT operates as a CLASS-A amplifier. The three circuits or biasing arrangements which are practically used are explained below.

Before presenting the "good" biasing schemes, we should point out why two obvious arrangements are not good. First, attempting to bias the BJT by fixing the voltage VBE by, for instance, using a voltage divider across the power supply VCC, as shown in Fig. 5.4, is not a viable approach: The very sharp exponential relationship (Ic – Vbe) means that any small and inevitable differences in VBE from the desired value will result in large differences in Ic and in VCE. Second, biasing the B J T by establishing a constant current in the base, as shown in Fig. 5.5, where IB = (VCC - 0.7)/RB, is also not a recommended approach. Here the typically large variations in the value of β among units of the same device type will result in correspondingly large variations in Ic and hence in VCE.

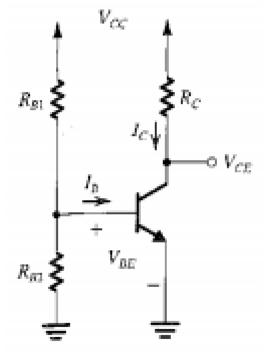


Figure 5-4 biasing using voltage divider [15]

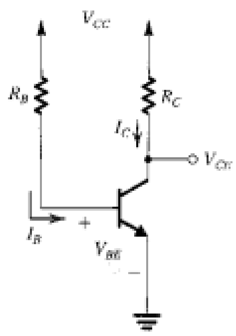


Figure 5-5 biasing using constant base current [15]

5.3.1 Biasing Using a Collector-to-Base Feedback Resistor

Figure 5.6 shows a simple but effective alternative biasing arrangement suitable for common-emitter amplifiers. The circuit employs a resistor RB connected between the collector and the base. Resistor RB provides negative feedback, which helps to stabilize the bias point of the BJT. Analysis of the circuit is shown in Fig. 5.7, from which we can write the following equations

$$VCC = IE\ RC + IB\ RB + VBE$$

$$= IE\ RC + \frac{IE}{\beta+1}\ RB + VBE$$

Thus the emitter bias current is given by

$$IE = \frac{VCC - VBE}{RC + {RB}/{\beta+1}}$$

It follows that to obtain a value of IE that is insensitive to variation of β, we select (RB/(β + 1) < Rc) Note, however, that the value of RB determines the allowable signal swing at the collector, since

$$VCB = I_B\ R_B = I_E\ \frac{RB}{\beta+1}$$

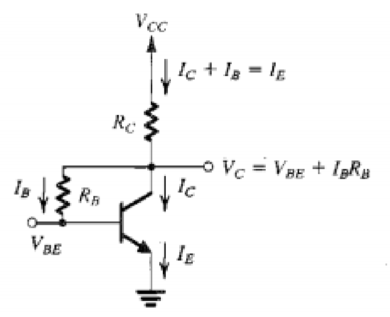


Figure 5-7 analysis of circuit in Fig 5.7 [15]

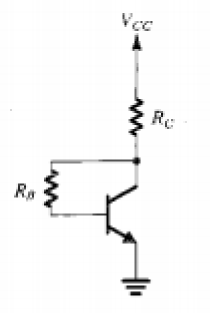


Figure 5-6 amplifier biased by feedback resistor [15]

5.3.2 Biasing Using a Constant-Current Source

The BJT can be biased using a constant-current source I as indicated in the circuit of Fig. 5.8. This circuit has the advantage that the emitter current is independent of the values of β and RB. Thus RB can be made large, enabling an increase in the input resistance at the base without adversely affecting bias stability. Further, current-source biasing leads to significant design simplification, as will become obvious in later sections and chapters .A simple implementation of the constant-current source I is shown in Fig 5.8.

The circuit utilizes a pair of matched transistors Qt and Q2, with Qx connected as a diode by shorting its collector to its base. If we assume that Qi and Q2 have high β values, we can neglect their base currents. Thus the current through Q, will be approximately equal to

$$I_{REF} = \frac{VCC-(-VBE)-VBE}{R}$$

Now, since QX and Q2 have the same VBE, their collector currents will be equal, resulting in

$$I = I_{REF} = \frac{VCC+VEE-VCBE}{R}$$

Neglecting the Early effect in Q2, the collector current will remain constant at the value given by this equation as long as Q2 remains in the active region. This can be guaranteed by keeping the voltage at the collector, V, greater than that at the base (-VEE + VBE). The connection of Qi and Q2 in Fig.5.8 is known as a current mirror.

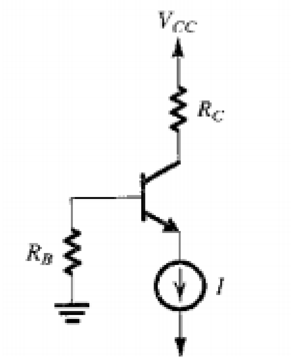


Figure 5-9 BJT biased using a current source [15]

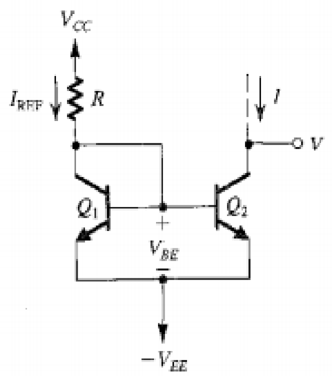


Figure 5-8 Circuit for implementing the current source [15]

Now, after briefly discussed and explain the current amplifiers concept in transistor and explain clearly the methods of biasing the transistor, we shall to start to demonstrate in details the Casing Collar Locator Standard design and the new design. [15]

5.4 CCL Standard design

To show the Casing Collar Locator circuit and get a big picture about the circuit and its components. The best way to do so is to demonstrate and explain the block diagram of the Casing Collar Locator circuit for get obvious vision about the circuit.

5.4.1 CCL Block diagram

The CCL circuit is divided into blocks that shows its operation clearly. Each block in the block diagram of Figure 5.10 shows a particular function in this circuit that keeps its operation. The first block is the coil, CCL concept is based on inducing a current in a coil that is put between two magnets in a particular position according to faraday's law that is why this coil is used as a part of the circuit.

The second block can be a protection element that protect the circuit from incoming signals that can hurt it because the circuit works in a particular range; if the incoming signal is out this range, the protection element works and prevents this signal from getting to the circuit. From the other hand, this block can be an operation improvement element that is used to keep the circuit operation to be stable and work properly.

The third block is current amplifier. This block is the heart of the CCL circuit because this current amplifier works only when there is an induced current in the coil and because of this current amplifier, A CCL signal can be noticed in the surface system when working in a cased-hole well.

The fourth block is the wire line. The wire line is the cable that connects the hardware tool with the truck or the surface system. This wire line has resistance and its current value changes in the instants during which a current is induced in the coil.

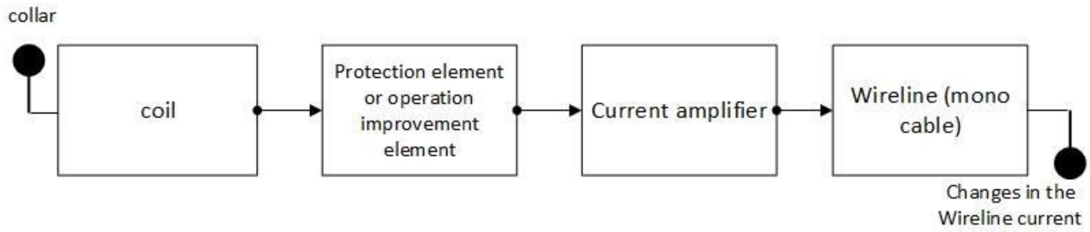


Figure 5-10 block diagram of CCL circuit

Now, we go to the next step in the explanation of the Casing Collar Locator circuit which is the step in it the schematic of the standard design of Casing Collar Locator circuit will be discussed and clearly explained.

5.4.2 Standard CCL schematic

The schematic shown in Figure 5.11 shows a Casing Collar Locator, now its operation will be explained. At the test point TP3, the coil is connected and put between two magnets in a particular position. In any case-hole well casings are put inside this well to prevent it from collapsing and any two successive casings is connected using a collar. The density of the material of the collar is different from the density of the material of the casings and this helps in the operation of the CCL circuit. When the CCL circuit is moved inside a cased-hole well and moved in front of a collar, the position of the two magnets makes magnetic field crosses the collar and the casings but the density differs from the casings material to the collars material so according to faraday's law a current is induced in the coil when the coil is moved in front of a collar.

The incoming CCL signal must not be out a particular range to avoid damaging the CCL circuit so a protection element is used for that reason. This element is the TVS (transient voltage suppressor). The TVS has symmetric I/v characteristics than allows incoming signals to enter the circuit is a particular range and prevents ranges that can cause damage to the CCL circuit.it is known that the CCL signal is 2.5 volts peak to peak.

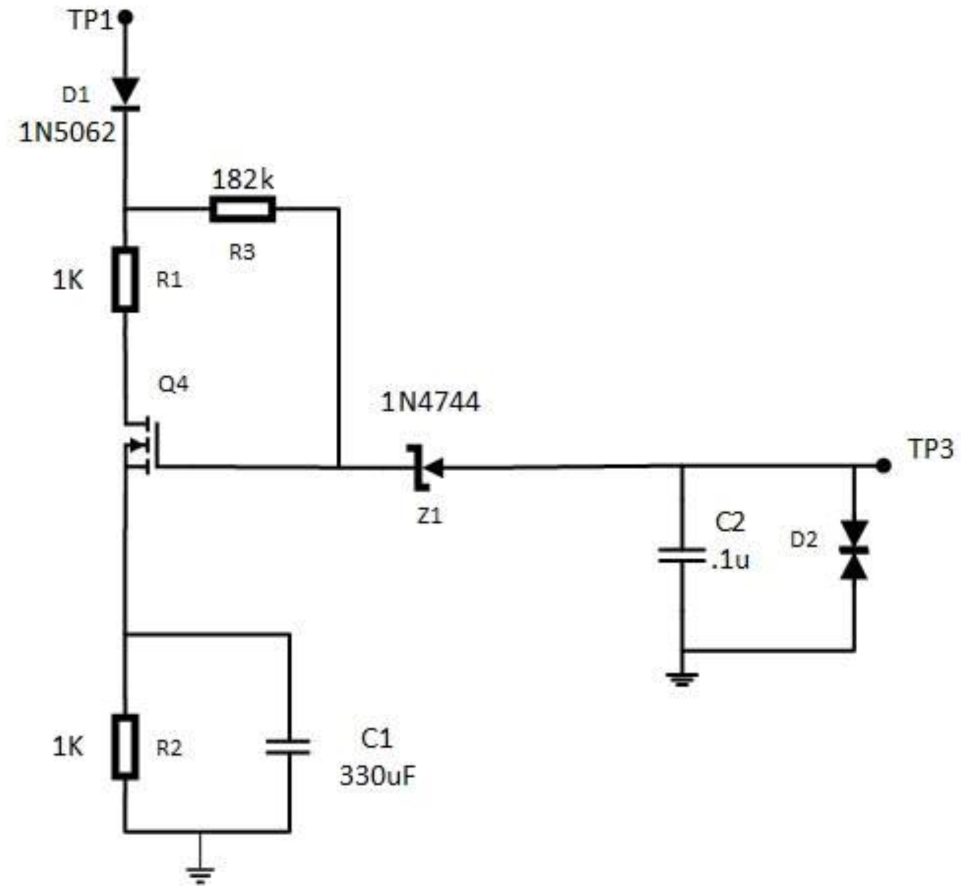


Figure 5-11 schematic of standard CCL

The schematic shown above shows a CCL, now its operation will be explained. At the test point TP3, the coil is connected and put between two magnets in a particular position. In any case-hole well casings are put inside this well to prevent it from collapsing and any two successive casings is connected using a collar. The density of the material of the collar is different from the density of the material of the casings and this helps in the operation of the CCL circuit. When the CCL circuit is moved inside a cased-hole well and moved in front of a collar, the position of the two magnets makes magnetic field crosses the collar and the casings but the density differs from the casings material to the collars material so according to faraday's law a current is induced in the coil when the coil is moved in front of a collar.

The incoming CCL signal must not be out a particular range to avoid damaging the CCL circuit so a protection element is used for that reason. This element is the TVS (transient voltage suppressor). The TVS has symmetric I/v characteristics than allows incoming signals to enter the circuit is a particular range and prevents ranges that can cause damage to the CCL circuit.it is known that the CCL signal is 2.5 volts peak to peak.

A capacitor parallel to the coil is used to stabilize the voltage value of the coil, because the induced current in the coil is varying with time so it is needed to be stabilized using a parallel capacitor that has not a parallel resistance to discharge.

The next part of the circuit is the most important part. It is the current amplifier part. The current amplifier works when there is an induced current in the coil and it works in saturation region according to the below equation:

$$Id = K(Vgs - Vth)^2$$

So when the capacitor that is connected to source discharges in the resistance parallel to it the voltage value of the source will be smaller so when it is subtracted from the gate voltage value and the threshold voltage then square the final value the currents of the MOSFET is amplified and this occurs only when there is an induced current in the coil.

The wire line that connects the hardware tool to the truck on the surface system has a resistance. When there is an induced current in the coil, the current amplifier works and at this instant and due to the increase in MOSFET current due to amplification, there is a change in current value in the wire line resistance. Using the surface system, the change in current value in the wire line can be measured and this is what is called the CCL signal or the CCL pulse.

The CCL circuit is biased using a 50 volts DC source that is connected to the test point TP3. There is a diode after the DC source that is forward biased to prevent direct connection to the source from the opposite direction and because that only one cable is used to deliver power to the circuit or bias it and measure the CCL signal (mono cable). Figure 5.12 shows that I/V characteristics if the TVS that is used as a protection element in the CCL circuit.

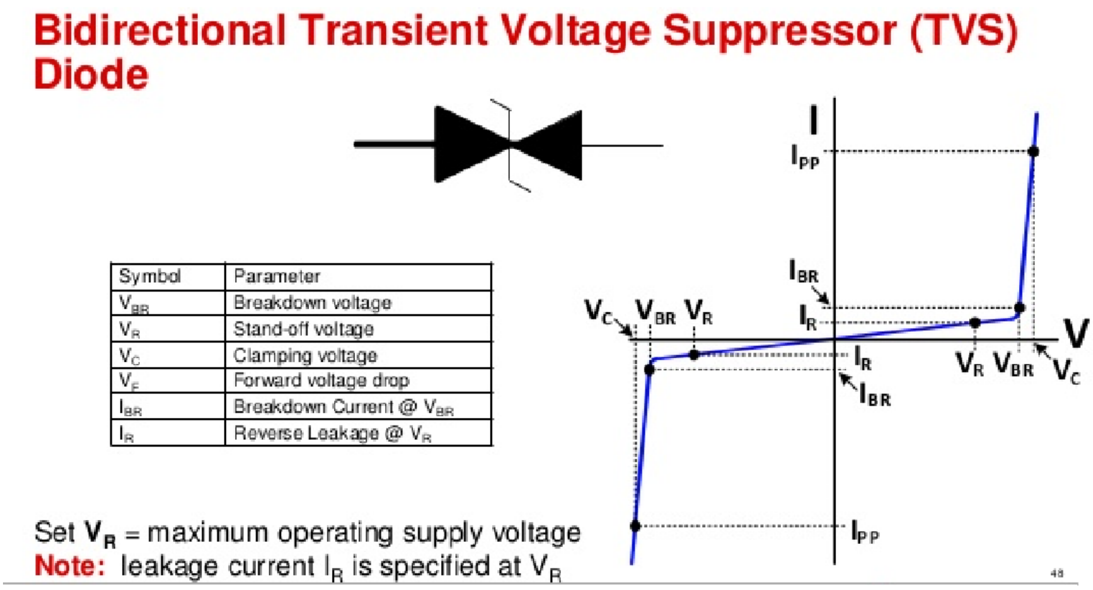


Figure 5-12 characteristics of the TVS

5.4.3 Simulation Results for standard CCL

Now, we shall to go to the simulation step with explanation of the simulation results and discuss the effect and the reason of the results.

As shown below in Figure 5.13, the CCL circuit is simulated using OrCAD pspice simulator to see the change in the currents value in the wire line resistance in the instants when there is a current induced in the coil. The coil, the casings and the collars in a cased-hole well are simulated here using a pulse source and make its specs (period, pulse width…. etc.) to simulate the reality inside any cased-hole well.

As shown above in the figure, the CCL circuit is simulated using OrCAD pspice simulator to see the change in the currents value in the wire line resistance in the instants when there is a current induced in the coil. The coil, the casings and the collars in a cased-hole well are simulated here using a pulse source and make its specs (period, pulse width…. etc.) to simulate the reality inside any cased-hole well.

As shown below in the figure 5.14, the red curve represents the current induced in the coil between the two magnets when it moves in front of a collar. The blue curve represents the changes in the current value in the wireline resistance at the instants of current induction in the coil and this change in current is due to the operation of the current amplifier when there is a current induced in the coil as said before

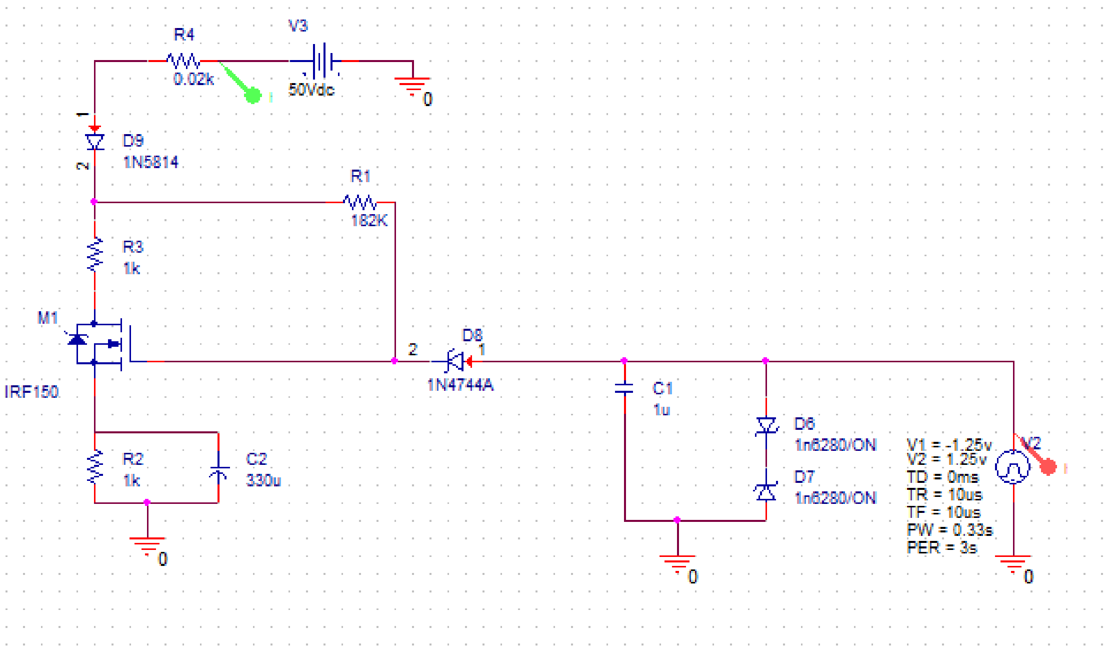


Figure 5-13 standard CCL simulation

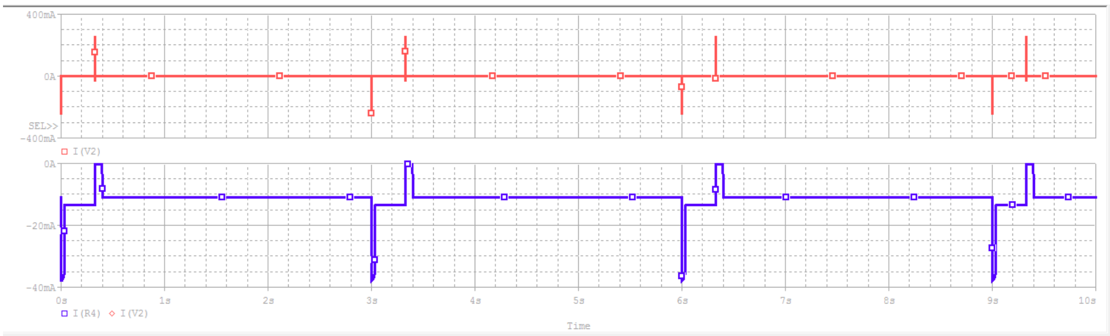


Figure 5-14 standard CCL simulation output

5.5 CCL New Design

Now, we will walk on the same steps as in standard design of Casing Collar Locator in the explanation of the Casing Collar Locator circuit of the new design made by the team project using the concept shown in the beginning of that chapter. The first step in explaining the CCL circuit of the new design is the same as the standard design which is the step in it the schematic of the standard design of Casing Collar Locator circuit will be discussed and clearly explained.

5.5.1 Schematic

This design works as a CCL circuit and it is better than the standard design in some things that will be discussed now. When a current induced in the coil in the instant of moving the CCL circuit in front of a collar inside the cased-hole well, the current amplifier works as discussed before in the standard design but here, two cascaded current amplifiers is used which make the CCL signal detected on the surface system is clearer than the standard design.

The diode 1N914 is a fast switching diode that is used with fast signals that occurs in small instants like CCL signals, so it is put after the coil to work as a fast switch takes the incoming signal to the two-cascaded current amplifier. It is used as an operation improvement element.

The two cascaded current amplifier works when there is an induced current in the coil. This two-cascaded current amplifier is biased using method called feedback resistance that is connected between the base and emitter. The 2N2222 BJT works in active region because VBE is higher than 0.2 volts that is why its emitter is connected to ground. The 2N3439 BJT must also work in active region, so to ensure that, a Zener diode is connected to its base with breakdown voltage equals 6.2 volts to ensure that always VBE is higher than 0.2 volts. When there is an induced current in the coil, the two-cascaded current amplifier works. The two BJTs works in active region and the incoming current to the base is multiplied by β so the collector current is amplified according to this equation:

$$Ic = \beta * Ib$$

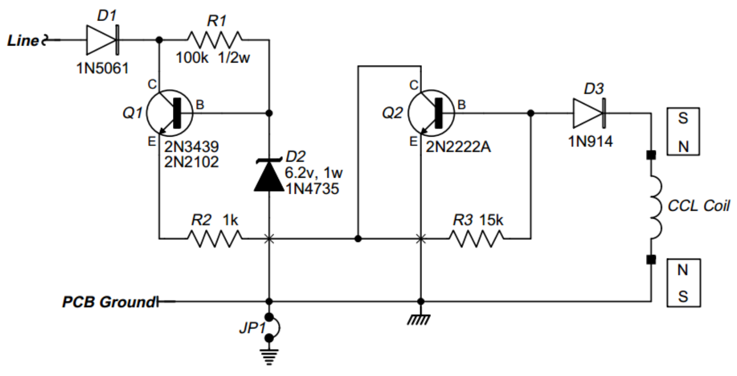


Figure 5-15 schematic of modified CCL design

The wire line that connects the hardware tool to the truck on the surface system has a resistance. When there is an induced current in the coil, the two-cascaded current amplifier works and at this instant and due to the increase in two-cascaded current amplifier current due to amplification, there is a change in current value in the wire line resistance. Using the surface system, the change in current value in the wire line can be measured and this is what is called the CCL signal or the CCL pulse.

The CCL circuit is biased using a 50 volts DC source that is connected to diode D1. This diode that is put after the DC source is forward biased to prevent direct connection to the source from the opposite direction and because that only one cable is used to deliver power to the circuit or bias it and measure the CCL signal (mono cable).

This design is better in the standard design because the two-cascaded current amplifier amplifies the current two times and this makes the detected CCL signal is clearer than the standard design because the current in the two-cascaded current amplifier is large due to amplification two times, so the change in wire line current will be noticed clearer. From the other hand, the response of the BJT transistor is faster than the response of the MOSFET and fast response is required in the CCL circuit because it is wanted that when the CCL circuit is moved on front of a collar, A CCL signal must be detected immediately in the surface system. In addition, the area taken in the PCB by this design is smaller than the area taken in the PCB by the standard design and in electronics area is too important and this circuit is put inside a housing made of metal so reducing area will reduce cost of the hardware tool.

5.5.2 Simulation Results for CCL New Design

Now, we shall to go to the simulation step with explanation of the simulation results and discuss the effect and the reason of the results.

As shown below in Figure 5.17, the CCL circuit is simulated using OrCAD pspice simulator to see the change in the currents value in the wire line resistance in the instants when there is a current induced in the coil. The coil, the casings and the collars in a cased-hole well are simulated here using a pulse source and make its specs (period, pulse width…. etc.) to simulate the reality inside any cased-hole well.

As shown below in Figure 5.17, the CCL circuit is simulated using OrCAD pspice simulator to see the change in the currents value in the wire line resistance in the instants when there is a current induced in the coil. The coil, the casings and the collars in a cased-hole well are simulated here using a pulse source and make its specs (period, pulse width…. etc.) to simulate the reality inside any cased-hole well.

As shown in Figure 5.18, the red curve represents the current induced in the coil between the two magnets when it moves in front of a collar. The blue curve represents the changes in the current value in the wire line resistance at the instants of current induction in the coil and this change in current is due to the operation of the two-cascaded current amplifier when there is a current induced in the coil as said before. the two-cascaded current amplifier amplifies the current two times and this makes the detected CCL signal is clearer than the standard design because the current in the two-cascaded current amplifier is large due to amplification two times, so the change in wire line current is clear as shown below.

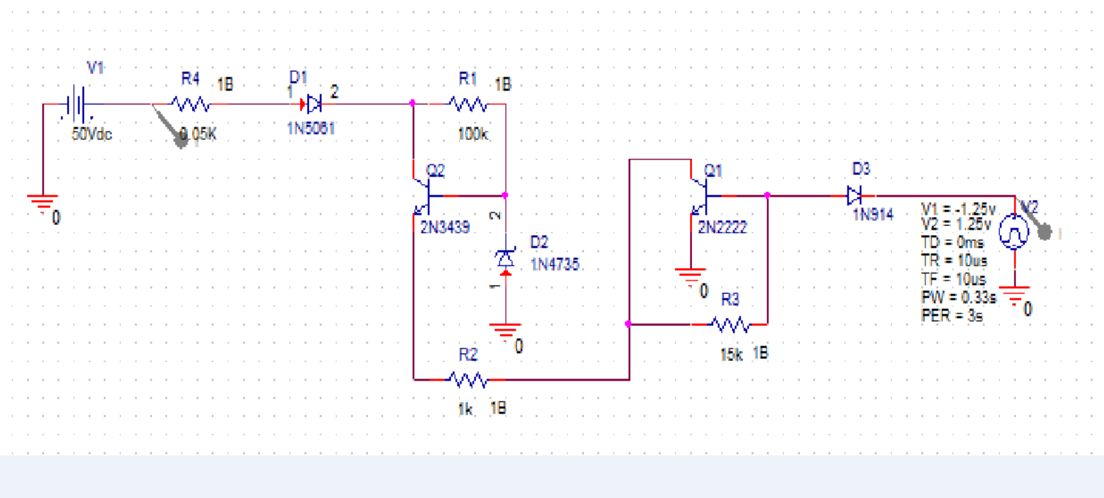


Figure 5-16 modified CCL simulation

Figure 5-17 modified CCL simulation output

5.6 CCL Testing

The last step now, after all the previous steps for the Casing Collar Locator in the standard design and in the new design. The last step now is to test CCL circuit and get the log file for this service.

The CCL signal detected in the surface system has a particular shape and it is called CCL log. Each pulse represents a CCL signal and means that the CCL circuit is moving now in front of a collar in a cased-hole well, so it locates collars. Figure 5.19 shows a CCL log that is detected using a CHIP panel in a truck using a surface system.

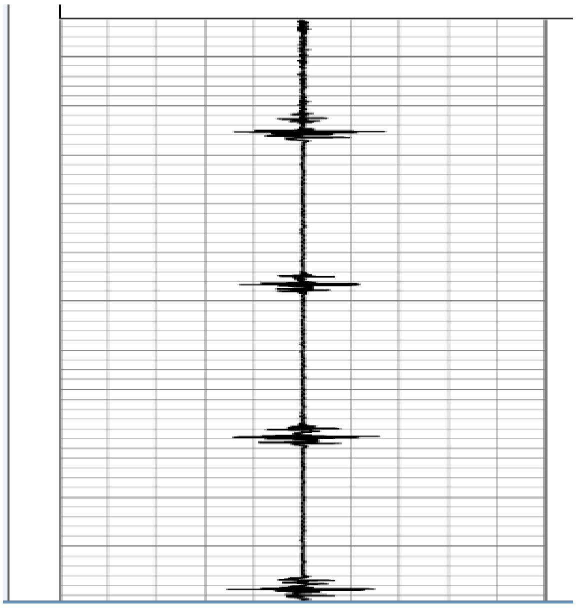


Figure 5-18 CCL Log

Chapter 6: PCB Layouts

6.1 GAMMA Ray Layouts

6.1.1 Mimic Design Layout

Layout of GAMMA Ray Mimic circuit is shown in fig 6-1 is bottom layer and fig 6-2 is package geometry.

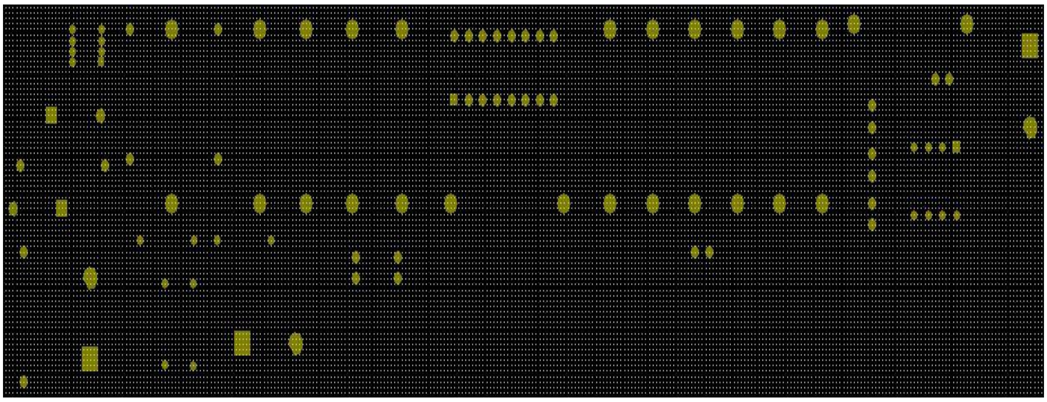


Figure 6-1 Bottom Layer

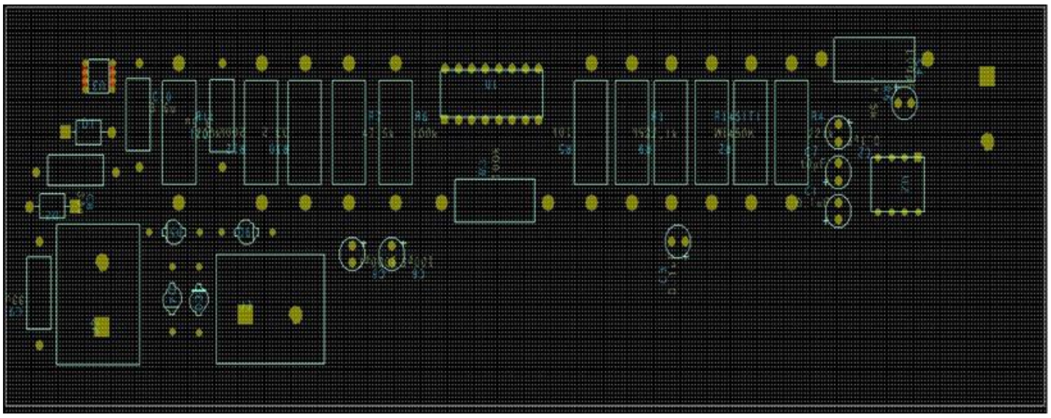


Figure 6-2 package geometry

6.1.2 New Design Layout

Layout of GAMMA Ray New Design circuit is shown in figure 6.3 is Bottom Layer & 6.4 is Package Geometry

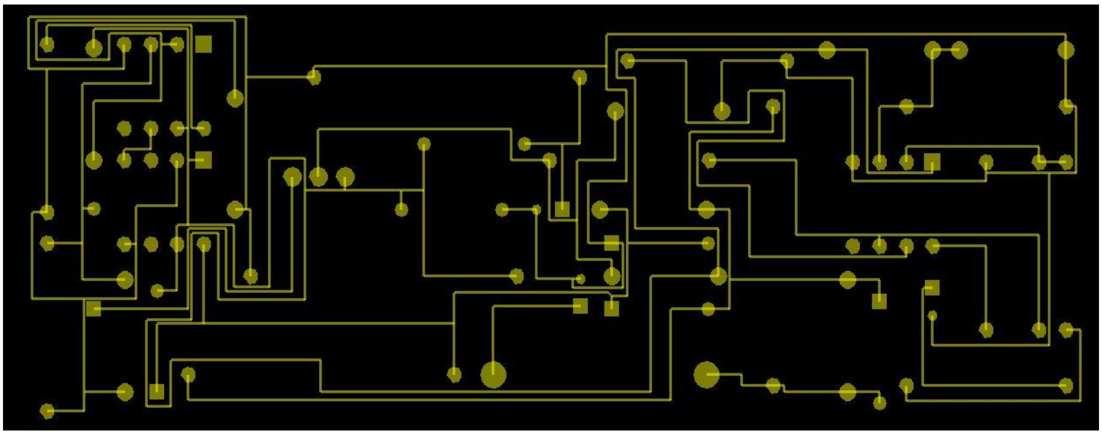


Figure 6-3 Bottom Layer for New Gamma Ray

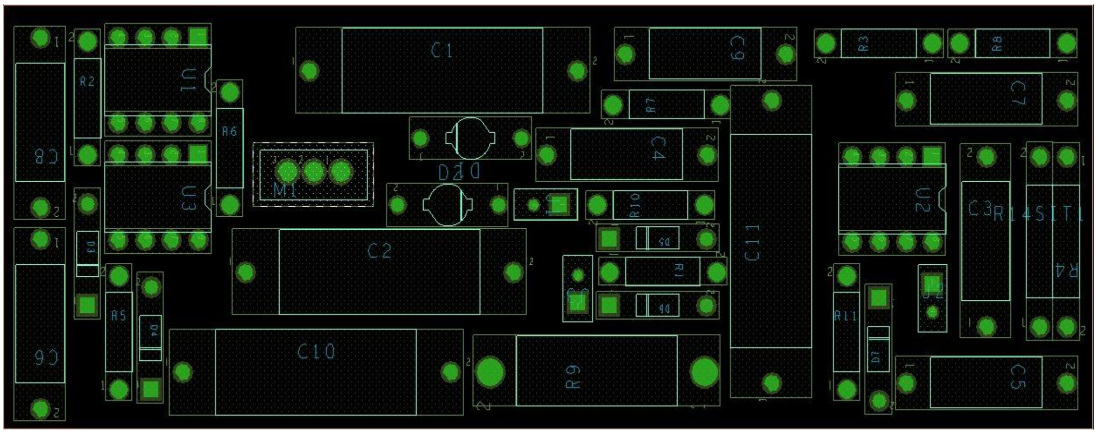


Figure 6-4 Package Geometry for New Gamma Ray

6.2 High Voltage Layouts

6.2.1 Mimic Design Layout

Layout of Mimic High Voltage Design circuit is shown in fig 6.5 is bottom layer and fig 6.6 is package geometry.

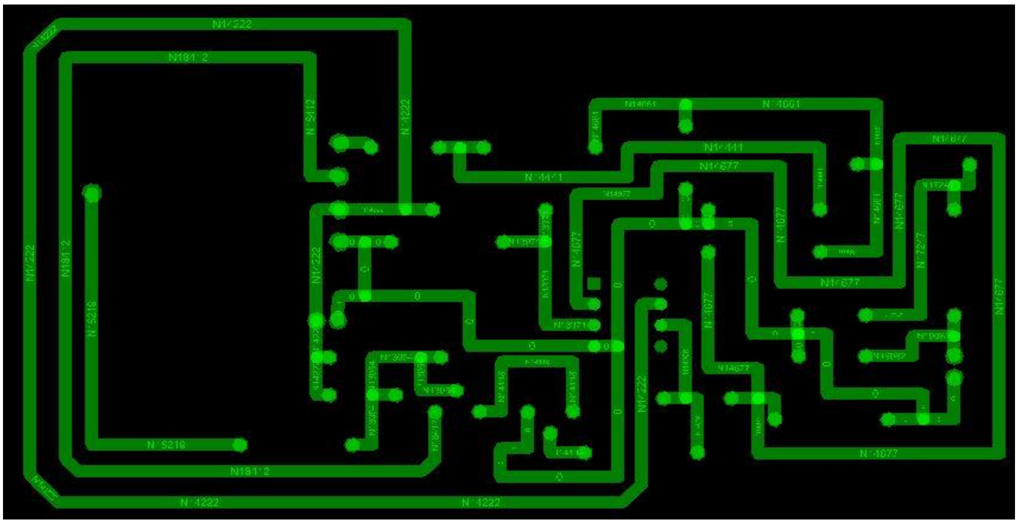


Figure 6-5 Bottom Layer for HV Mimic

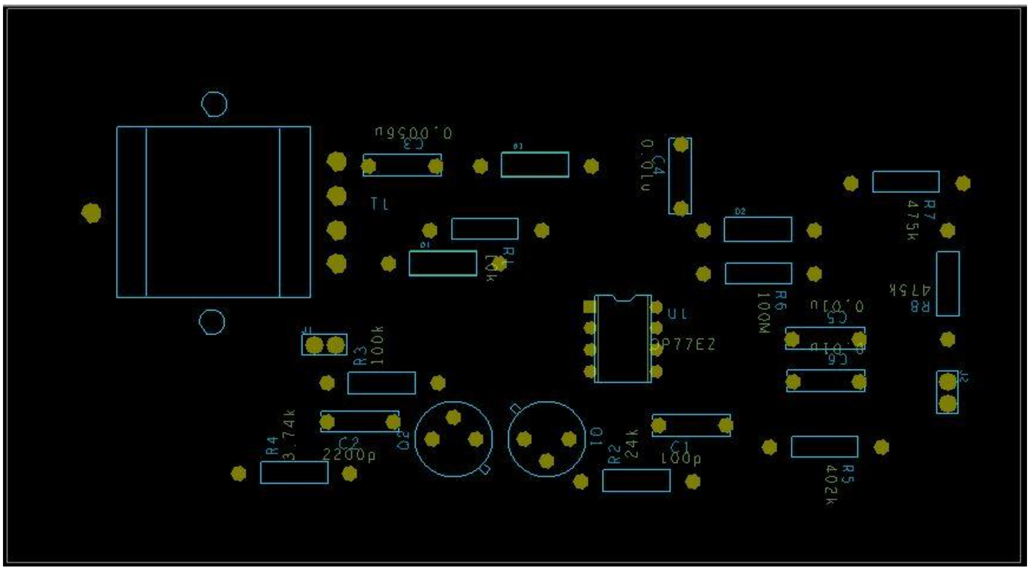


Figure 6-6 Package Geometry For HV Mimic

6.3 Firing Circuit Layouts

6.3.1 New Design Layout

Layout of firing circuit is divided to two layouts first on is LM117 LVR base is on separate layout as shown in figure 6.8 is bottom layer and figure 6.7 is package geometry and the whole circuit is on another layout as shown in Figure 6.9 is bottom layer and Figure 6.10 is package geometry this is done to reduce area as possible to meet tool housing requirement where tool housing has two sides with specific dimensions for Firing Circuit and GAMMA Ray Circuit and High Voltage Circuit.

6.3.1.1 LM117 LVR Layout

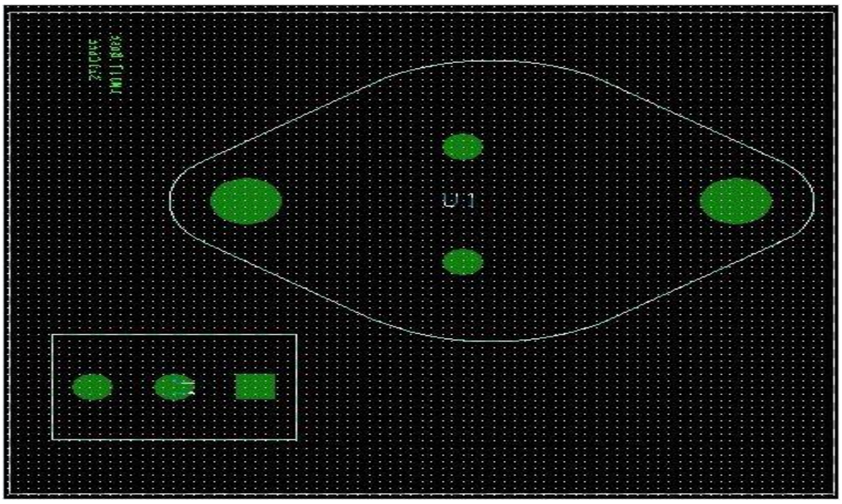


Figure 6-7 LM117 LVR base Package Geometry

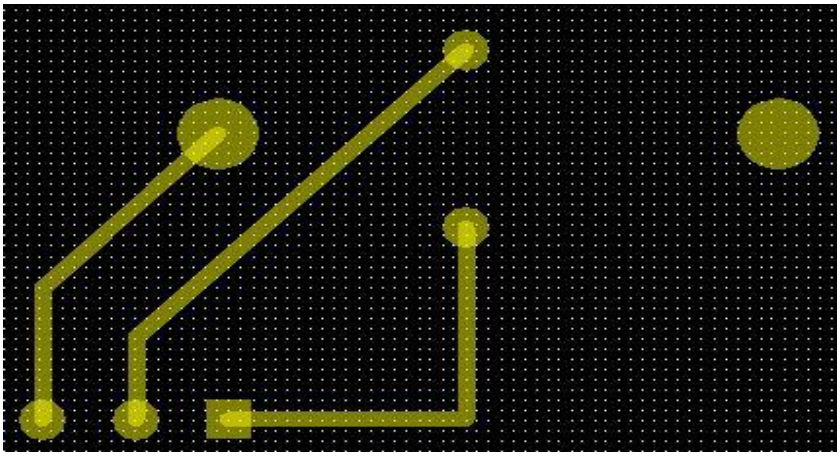


Figure 6-8 LM117 LVR base Bottom Layer

6.3.1.2 Rest of Firing Circuit

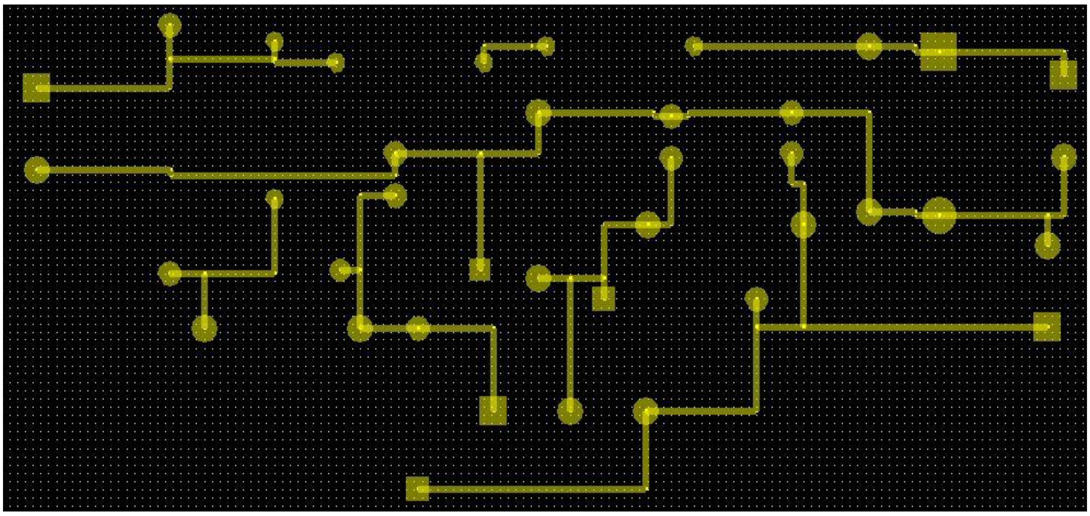


Figure 6-9 Bottom Layer of the Rest of Firing Circuit

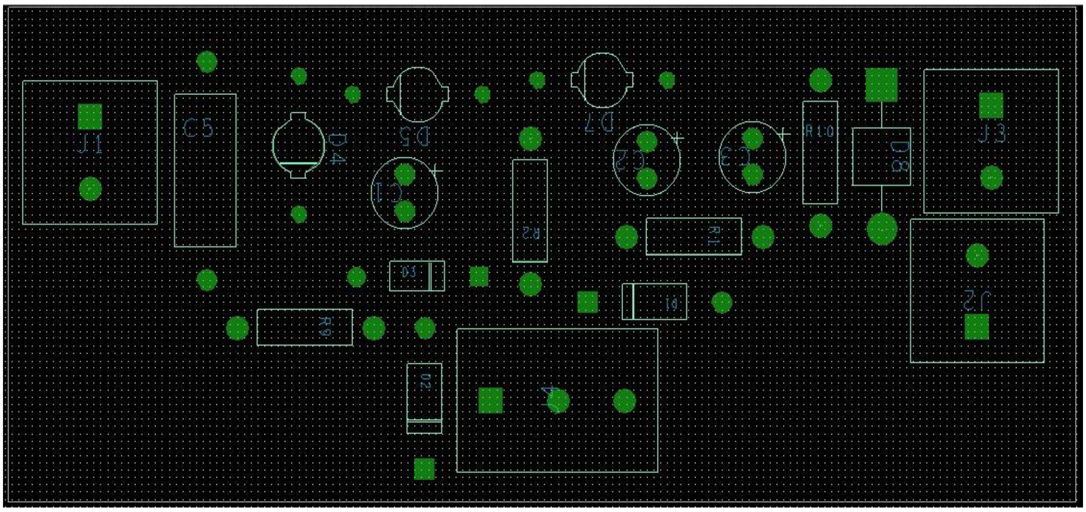


Figure 6-10 Package Geometry of the Rest of Firing Circuit

6.4 CCL Circuit Layouts

6.4.1 CCL Mimic Layout

Layout of Mimic CCL circuit is shown in figure 6.11 is bottom layer and figure 6.12 is package geometry.

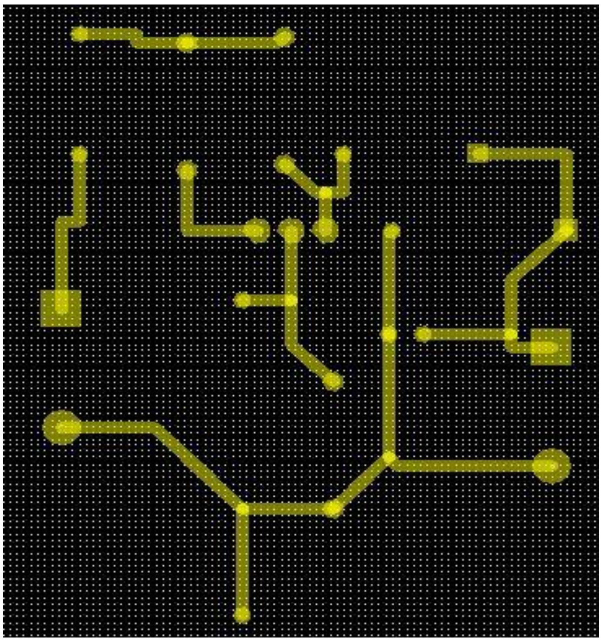


Figure 6-11 Mimic CCL Bottom Layer

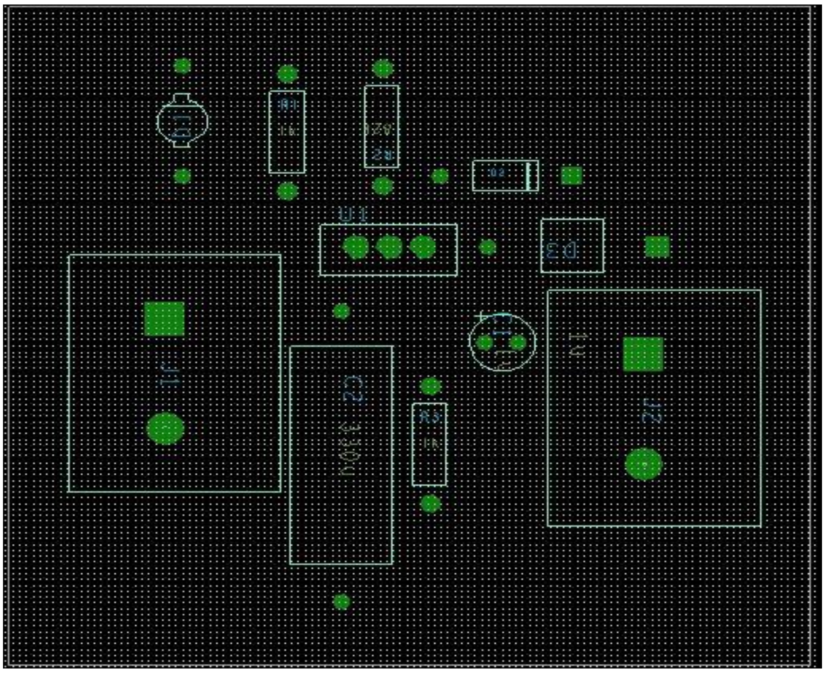


Figure 6-12 Mimic CCL Package Geometry

6.4.2 CCL New Design Layout

Layout of new design CCL circuit is shown in figure 6.13 where is bottom layer and 6.14 is package geometry.

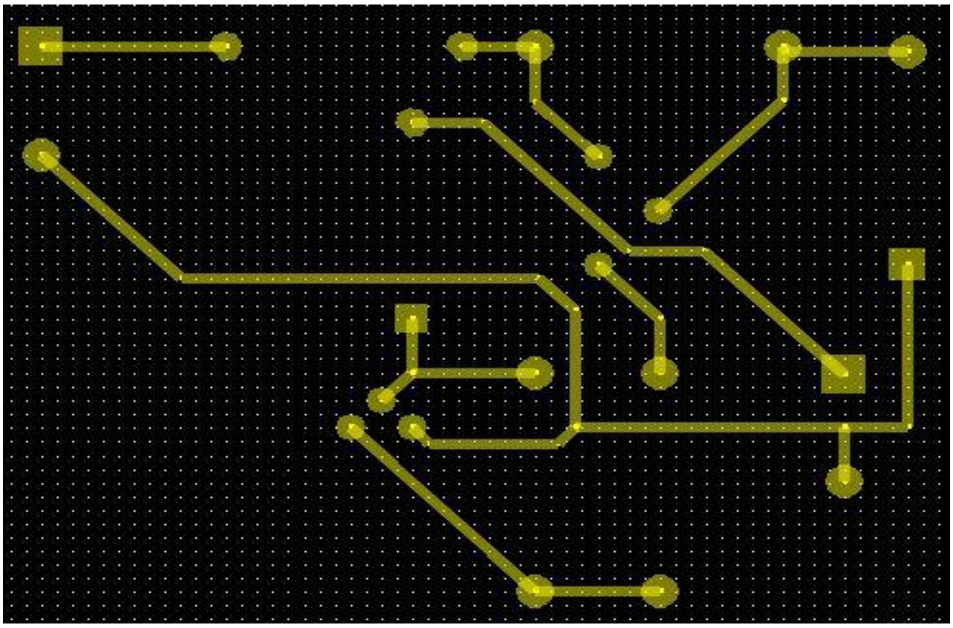


Figure 6-12 Bottom Layer for New CCL Design

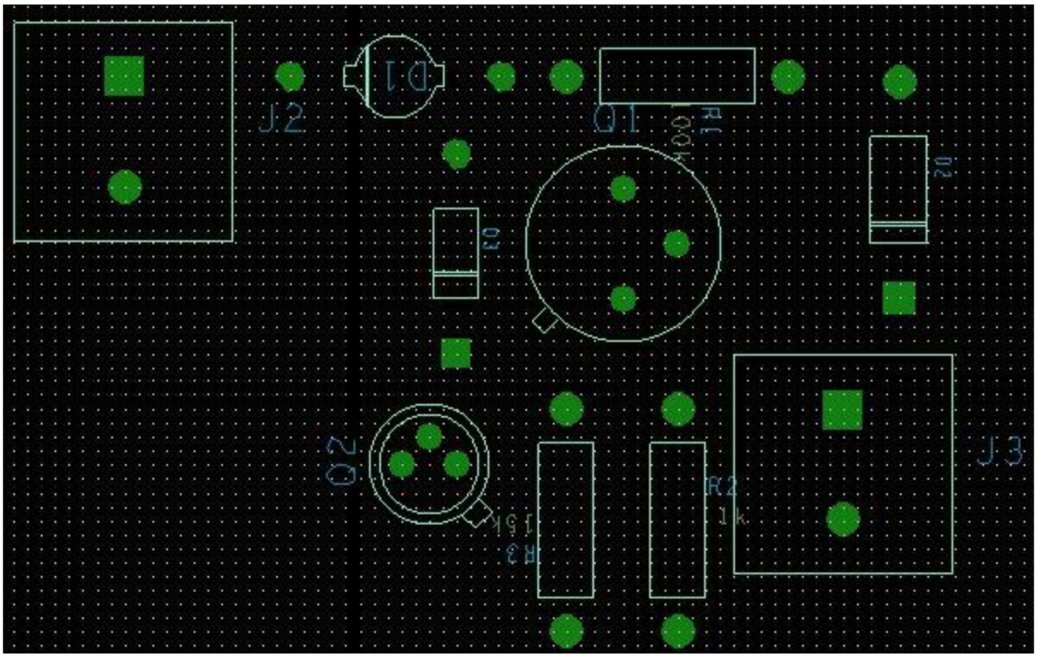


Figure 6-11 Package Geometry for New CCL Circuit

6.5 PCB images

Figure 6-13 Mimic CCL PCB

Figure 6-14 New CCL PCB

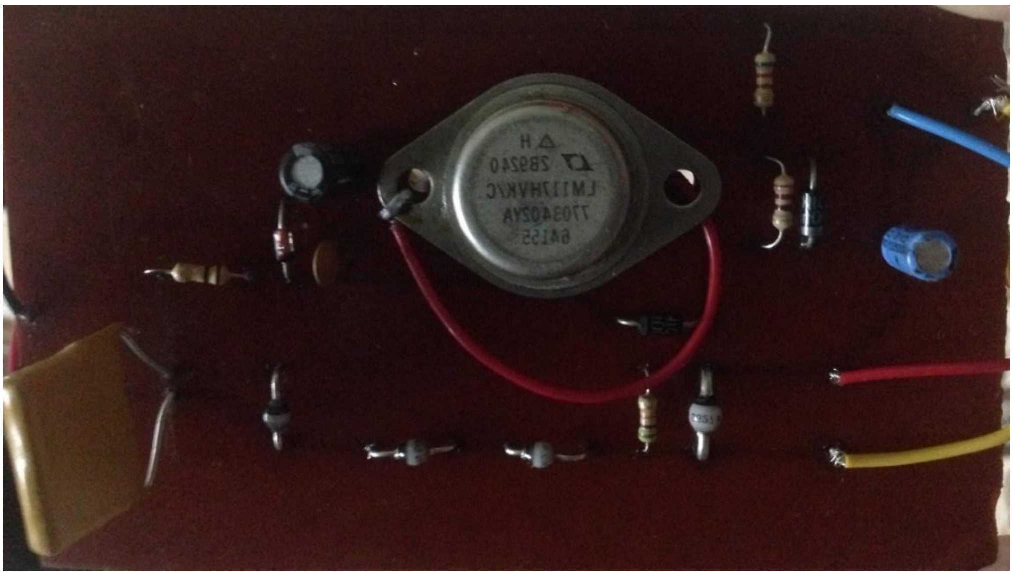


Figure 6-15 New Firing Circuit PCB

Conclusion

Electric logs represent a major source of data to geoscientists and engineers investigating subsurface rock formations. Logging tools are used to look for reservoir quality rock, hydrocarbons and source rocks in explorations wells, support volumetric estimates and geological modeling during field appraisal and development, and provide a means of monitoring the distribution of remaining hydrocarbons during production lifetime.

Oil and gas companies in acquiring open-hole log data make a large investment, logging activities can represent between 5% and 15% of total well costs. It is important therefore to ensure that the cost of acquisition can be justified by the value of information generated and that thereafter the information is effectively managed.

While drilling a well for exploration of hydrocarbons, data is collected, physical, in the case of sampling profiles and "electric ", magnetic, sonic, etc., logs are obtained by probes. Logs are sophisticated geophysical measurements recorded down hole. These measurements may be from spontaneous phenomena, such as the natural radioactivity (gamma ray log), or measurements of induced phenomena, such as the forming speed, or the speed of a sonic wave through a certain formation (sonic log). Nowadays, there is an extensive range of equipment that performs logs as well as techniques for making. We can divide these techniques into two main ones, these being the Wire Line (WL) and the Logging While Drilling (LWD). A big difference between them is the timing at which the measurements are made, being in the case of WL, these are performed post drilling and LWD, as its name indicates, performed simultaneously with the drilling. Both have their advantages and limitations.

Future work

The next step is to fabricate all the printed circuit boards with high temperature electronic components then these printed circuit boards will be put inside the tool housing that is made of metal then calibration is made and the tool is tested inside a well in a working site. In addition, after testing the tool, it can be sold to petroleum services companies to use it in their operations, so this tool can make competition with vendors that participate in this market.

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Appendix A:

Introduction

Most portable systems have one battery, thus, the popularity of portable equipment results in increased single supply applications. Split- or dual-supply op amp circuit design is straight forward because the op-amp inputs and outputs are referenced to the normally grounded center tap of the supplies. In the majority of split-supply applications, signal sources driving the op-amp inputs are referenced to ground. Thus, with one input of the op-amp referenced to ground, as shown in Figure 1, there is no need to consider input common-mode voltage
problems.

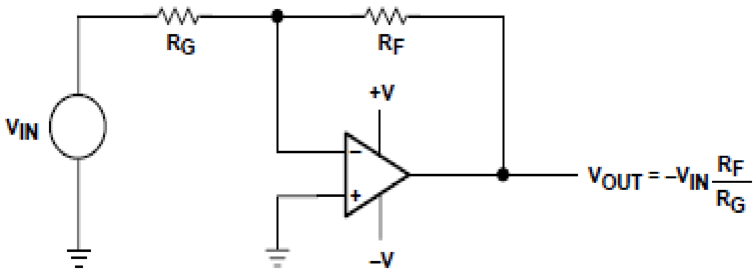


Figure 1. Split-Supply Op Amp Circuit

When the signal source is not referenced to ground (see Figure 2), the voltage difference between ground and the reference voltage shows up amplified in the output voltage. Sometimes this situation is okay, but other times the difference voltage must be stripped out of the output voltage. An input-bias voltage is used to eliminate the difference voltage when it must not appear in the output voltage (see Figure 3). The voltage (VREF) is in both input circuits, hence it is named a common-mode voltage. Voltage-feedback op amps, like those used in this application note, reject common-mode voltages because their input circuit is constructed with a differential amplifier (chosen because it has natural common-mode voltage rejection capabilities).

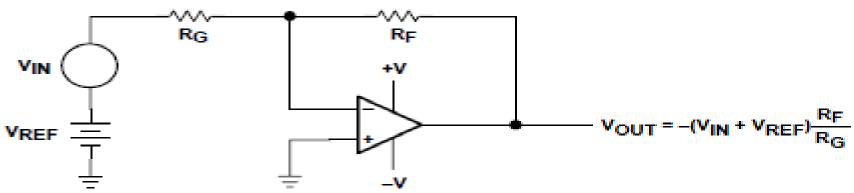


Figure 2. Split-Supply Op Amp Circuit With Reference-Voltage Input

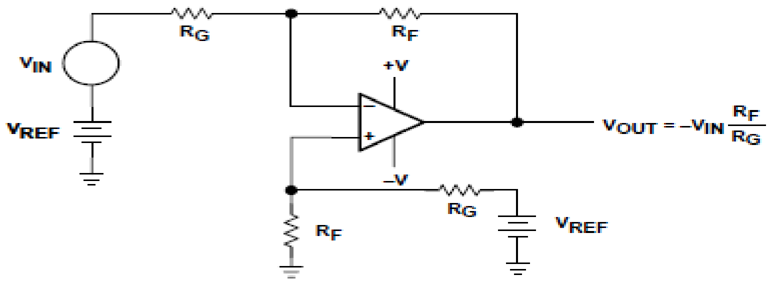


Figure 3. Split-Supply Op Amp Circuit With Common-Mode Voltage

When signal sources are referenced to ground, single-supply op amp circuits exhibit a large input common mode voltage. Figure 4 shows a single-supply op-amp circuit that has its input voltage referenced to ground. The input voltage is not referenced to the midpoint of the supplies like it would be in a split-supply application, rather it is referenced to the lower power supply rail. This circuit does not operate when the input voltage is positive because the output voltage would have to go to a negative voltage, hard to do with a positive supply. It operates marginally with small negative input voltages because most op amps do not function well when the inputs are connected to the supply rails.

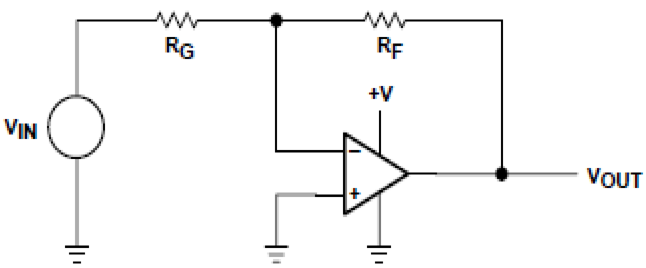


Figure 4. Single-Supply Op Amp Circuit

The constant requirement to account for inputs connected to ground or other reference voltages makes it difficult to design single-supply op amp circuits. This application note develops an orderly procedure which leads to a working design every time. If you do not have a good working knowledge of op amp equations, please reference the Understanding Basic Analog.... series of application notes available from Texas Instruments. Application note SLAA068 titled, Understanding Basic Analog-Ideal Op-Amps develops the ideal op-amp equations. Circuit equations are written with the ideal op-amp assumptions as specified in Understanding Basic Analog-Ideal Op-Amps; the assumptions are tabulated below for your reference.

PARAMETER NAME	PARAMETERS SYMBOL	VALUE
Input current	I_{IN}	0
Input offset voltage	V_{OS}	0
Input impedance	Z_{IN}	∞
Output impedance	Z_{OUT}	0
Gain	a	∞

Unless otherwise specified, all op amps circuits are single-supply circuits. The single supply may be wired with the negative or positive lead connected to ground, but as long as the supply polarity is correct, the wiring does not affect circuit operation. Use of a single-supply limits the polarity of the output voltage. When the supply voltage (VCC) = 10 V, the output voltage is limited to the range 0 ≤ VOUT ≤ 10. This limitation precludes negative output voltages when the circuit has a positive supply voltage, but it does not preclude negative input voltages when the circuit has a positive supply voltage. As long as the voltage on the op-amp input leads does not become negative, the circuit can handle negative input voltages. Beware of working with negative (positive) input voltages when the op amp is powered from a positive (negative) supply because op-amp inputs are highly susceptible to reverse voltage breakdown. Also, insure that all possible start-up conditions do not reverse bias the op-amp inputs when the input and supply voltage are opposite polarity.

Circuit Analysis

The complexities of single-supply op amp design are illustrated with the following example. Notice that the biasing requirement complicates the analysis by presenting several conditions that are not realizable. It is best to wade through this material to gain an understanding of the problem, especially since a cookbook solution is given later in this chapter. The previous chapter assumed that the op amps were ideal, and this chapter starts to deal with op amp deficiencies. The input and output voltage swing of many op amps are limited as shown in Figure 7, but if one designs with the selected rail-to-rail op amps, the input/output swing problems are minimized. The inverting circuit shown in Figure 5 is analyzed first.

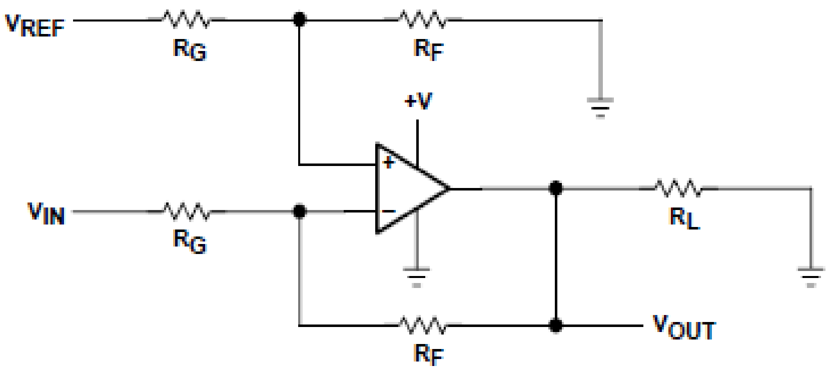


Figure 5. Inverting Op Amp

Equation 1 is written with the aid of superposition, and simplified algebraically, to acquire equation 2.

$$V_{out} = V_{ref}\left(\frac{R_f}{R_f + R_G}\right)\left(\frac{R_f + R_G}{R_f}\right) - V_{in}\frac{R_f}{R_G}$$

(1)

$$V_{out} = (V_{ref} - V_{in})\frac{R_f}{R_G}$$

(2)

As long as the load resistor (R_L) is a large value, it does not enter into the circuit calculations, but it can introduce some second order effects such as limiting the output voltage swing. Equation 3 is obtained by setting V_{ref} equal to V_{in}, and there is no output voltage from the circuit regardless of the input voltage. The author unintentionally designed a few of these circuits before he created an orderly method of op-amp circuit design. Actually, a real circuit has a small output voltage equal to the lower transistor saturation voltage, which is about 150 mV for a TLC07X.

$$V_{out} = (V_{ref} - V_{in})\frac{R_f}{R_G} = (V_{in} - V_{in})\frac{R_f}{R_G} = 0$$

(3)

When $V_{ref} = 0$, $V_{out} = -V_{in}\left(\frac{R_f}{R_G}\right)$, there are two possible solutions to equation 2.

First, when VIN is any positive voltage, VOUT should be negative voltage. The circuit cannot achieve a negative voltage with a positive supply, so the output saturates at the lower power supply rail. Second, when VIN is any negative voltage, the output spans the normal range according to equation 5.

$V_{in} \geq 0$ V_{out} = 0

(4)

$V_{in} \leq 0$ $V_{out} = |V_{in}| \frac{R_f}{R_G}$

(5)

When VREF equals the supply voltage (VCC) we obtain equation 6. In equation 6, when VIN is negative, VOUT should exceed VCC; that is impossible, so the output saturates. When VIN is positive, the circuit acts as an inverting amplifier.

$V_{out} = (V_{cc} - V_{in}) \frac{R_f}{R_G}$

(6)

The circuit is shown in Figure 6 and the transfer curve (V_{cc} = 5 V, $R_G = R_f$ = 100 kΩ, R_L = 10 kΩ) is shown in Figure 7.

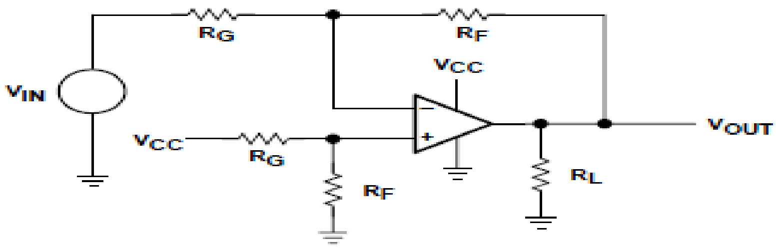


Figure 6. Inverting Op Amp With V_{CC} Bias

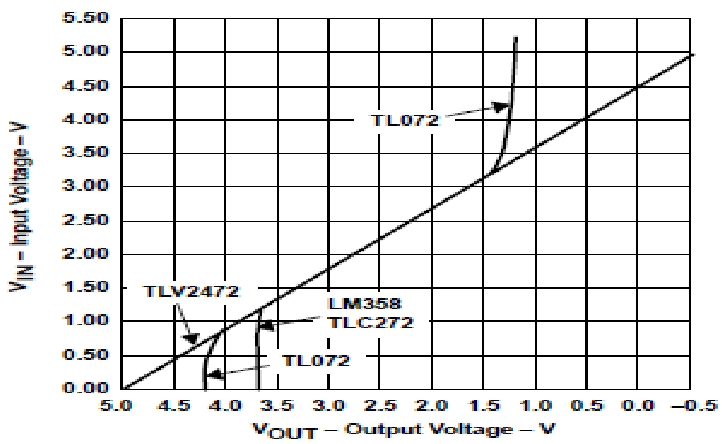


Figure 7. Transfer Curve for an Inverting Op Amp With V_{CC} Bias

Four op amps were tested in the circuit configuration shown in Figure 7. Three of the old generation op amps, LM358, TL07X, and TLC272 had output voltage spans of 2.3 V to 3.75 V. This performance does not justify the ideal op amp assumption that was made in the beginning of this application note unless the output voltage swing is severely limited. Limited output- or input-voltage swing is one of the worst deficiencies a single-supply op amp can have because the limited voltage swing limits the circuit's dynamic range. Also, limited-voltage swing frequently results in distortion of large signals. The fourth op amp tested was the newer TLV247X which was designed for rail-to-rail operation in single-supply circuits. The TLV247X plotted a perfect curve (results limited by the instrumentation), and it amazed the author with a textbook performance that justifies the use of ideal assumptions. Some of the older op amps must limit their transfer equation as shown in equation 7.

$$V_{out} = (V_{cc} - V_{in}) \frac{R_f}{R_G} \qquad \text{for } V_{out\,low} \leq V_{out} \leq V_{out\,high}$$

(7)

The non-inverting op-amp circuit is shown in Figure 8. Equation 8 is written with the aid of superposition, and simplified algebraically, to acquire equation 9.

$$V_{out} = V_{in} \left(\frac{R_f}{R_f + R_G} \right) \left(\frac{R_f + R_G}{R_f} \right) - V_{ref} \frac{R_f}{R_G}$$

(8)

$$V_{ref} = (V_{in} - V_{ref}) \frac{R_f}{R_G}$$

(9)

When $V_{ref} = 0$, $V_{out} = V_{in} \frac{R_f}{R_G}$, there are two possible circuit solutions. First, when V_{in} is a negative voltage, V_{out} must be a negative voltage. The circuit cannot achieve a negative output voltage with a positive supply, so the output saturates at the lower power supply rail. Second, when V_{in} is a positive voltage, the output spans the normal range as shown by equation 11.

$$V_{in} \leq 0 \qquad V_{out} = 0 \qquad (4)$$

$$V_{in} \geq 0 \qquad V_{out} = V_{in} \qquad (5)$$

The non-inverting op-amp circuit is shown in Figure 8 with V_{cc} = 5 V, R_G = R_f = 100 kΩ, R_L = 10 kΩ, and V_{ref} = 0. The transfer curve for this circuit is shown in Figure 9; a TLV247X serves as the op amp.

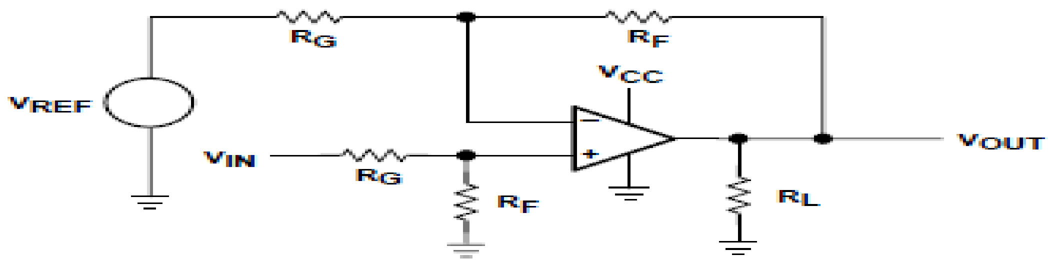


Figure 8. Noninverting Op Amp

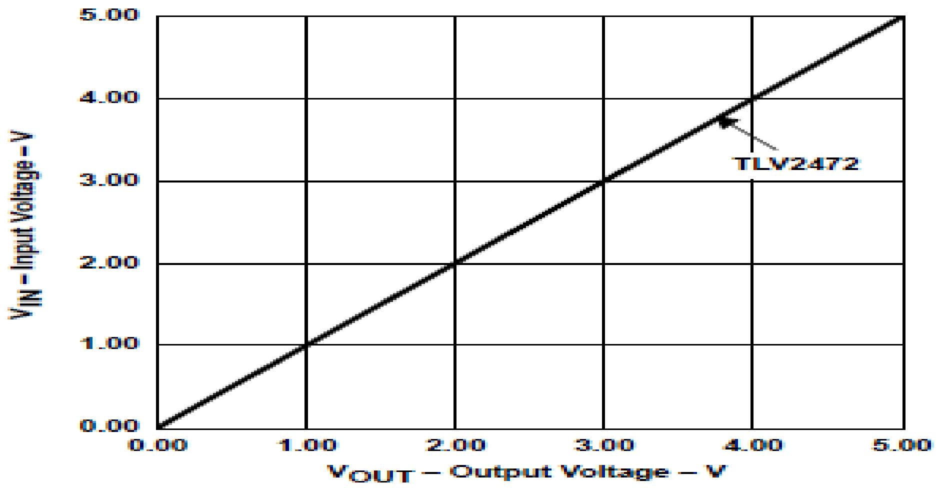
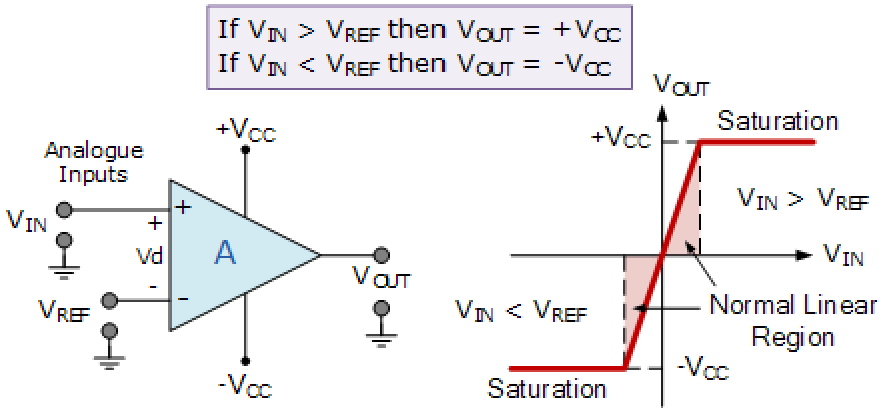


Figure 9. Transfer Curve for Noninverting Op Amp

Appendix B:

Op-amp Comparator Circuit



With reference to the op-amp comparator circuit above, first assume that V_{IN} is less than the DC voltage level at V_{ref}, ($V_{IN} < V_{ref}$). As the non-inverting (positive) input of the comparator is less than the inverting (negative) input, the output will be LOW and at the negative supply voltage, -Vcc resulting in a negative saturation of the output.

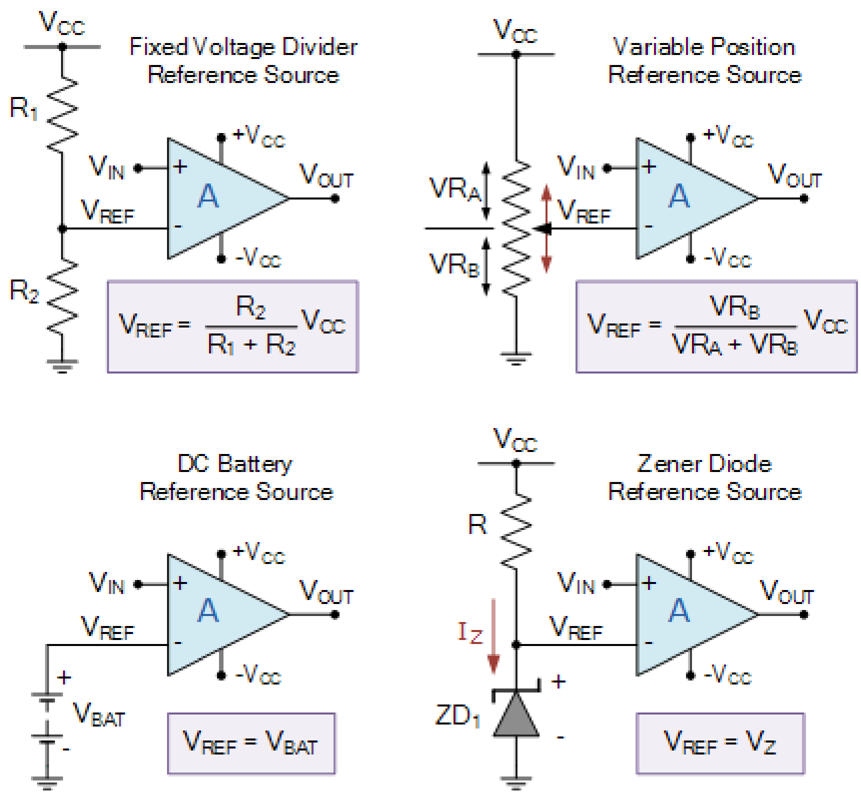
If now the input voltage is increased, V_{IN} so that its value is greater than the reference voltage V_{ref} on the inverting input, the output voltage rapidly switches HIGH towards the positive supply voltage, +Vcc resulting in a positive saturation of the output. If the input voltage V_{IN} is reduced again, so that it is slightly less than the reference voltage, the op-amp's output switches back to its negative saturation voltage acting as a threshold detector.

Then the op-amp voltage comparator is a device whose output is dependent on the value of the input voltage, V_{IN} with respect to some DC voltage level as the output is HIGH when the voltage on the non-inverting input is greater than the voltage on the inverting input, and LOW when the non-inverting input is less than the inverting input voltage. This condition is true regardless of whether the input signal is connected to the inverting or the non-inverting input of the comparator.

As mentioned before the value of the output voltage is completely dependent on the op-amps power supply voltage. In theory due to the op-amps high open-loop gain the magnitude of its output voltage could be infinite in both directions, (±∞). However practically, and for obvious reasons it is limited by the op-amps supply rails giving V_{OUT} = +Vcc or V_{OUT} = -Vcc.

As mentioned before that the basic op-amp comparator produces a positive or negative voltage output by comparing its input voltage against some preset DC reference voltage. Generally, a resistive voltage divider is used to set the input reference voltage of a comparator, but a battery source, zener diode or potentiometer for a variable reference voltage can all be used as shown.

Comparator Reference Voltages



In theory the comparators reference voltage can be set to be anywhere between 0v and the supply voltage but there are practical limitations on the actual voltage range depending on the op-amp comparator being device used.

Positive and Negative Voltage Comparators

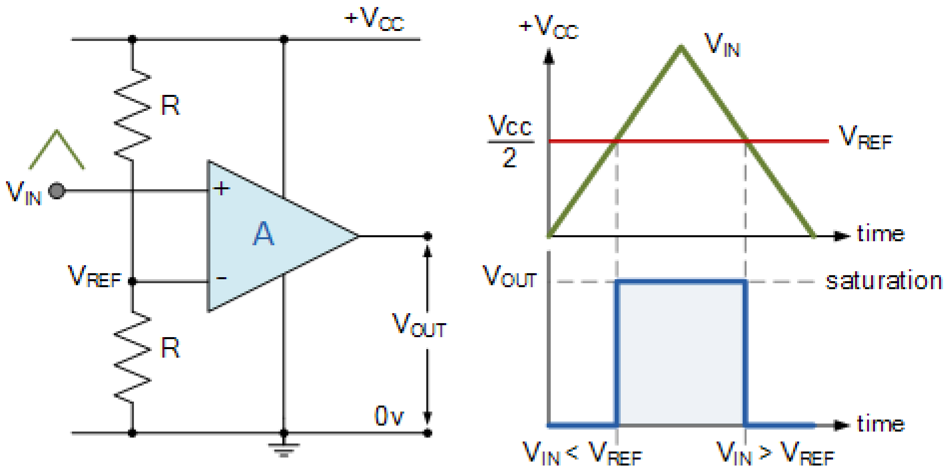
A basic op-amp comparator circuit can be used to detect either a positive or a negative going input voltage depending upon which input of the operational amplifier we connect the fixed reference voltage source and the input voltage too. In the examples above we have used the inverting input to set the reference voltage with the input voltage connected to the non-inverting input.

But equally the inputs of the comparator could be connected the other way around inverting the output signal to that shown above. Then an op-amp comparator can be configured to operate in what is called an inverting or a non-inverting configuration.

Positive Voltage Comparator

The basic configuration for the positive voltage comparator, also known as a non-inverting comparator circuit detects when the input signal, V_{IN} is ABOVE or more positive than the reference voltage, V_{ref} producing an output at V_{OUT} which is HIGH as shown.

Non-inverting Comparator Circuit



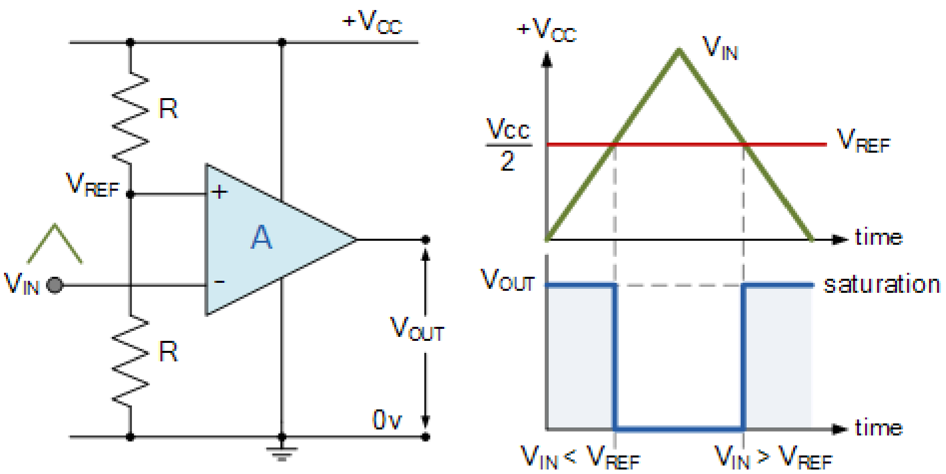
In this non-inverting configuration, the reference voltage is connected to the inverting input of the operational amplifier with the input signal connected to the non-inverting input. To keep things simple, it have been assumed that the two resistors forming the potential divider network are equal and: R1 = R2 = R. This will produce a fixed reference voltage which is one half that of the supply voltage, that is Vcc/2, while the input voltage is variable from zero to the supply voltage.

When V_{IN} is greater than V_{ref}, the op-amp comparators output will saturate towards the positive supply rail, Vcc. When V_{IN} is less than V_{ref} the op-amp comparators output will change state and saturate at the negative supply rail, 0v as shown.

Negative Voltage Comparator

The basic configuration for the negative voltage comparator, also known as an inverting comparator circuit detects when the input signal, V_{IN} is BELOW or more negative than the reference voltage, V_{ref} producing an output at V_{OUT} which is HIGH as shown.

Inverting Comparator Circuit



In the inverting configuration, which is the opposite of the positive configuration above, the reference voltage is connected to the non-inverting input of the operational amplifier while the input signal is connected to the inverting input. Then when V_{IN} is less than V_{REF} the op-amp comparators output will saturate towards the positive supply rail, Vcc.

Likewise the reverse is true, when V_{IN} is greater than V_{ref}, the op-amp comparators output will change state and saturate towards the negative supply rail, 0v.

Appendix C:

Figure.1 shows a common-drain amplifier. Since the drain is to function as a signal ground, there is no need for resistor RD, and it has therefore been eliminated. The input signal is coupled via capacitor CC1 to the MOSFET gate, and the output signal at the MOSFET source is coupled via capacitor CC2 to a load resistor RL. Since RL is in effect connected in series with the source terminal of the transistor (current source / acts as an open circuit as far as signals are concerned), it is more convenient to use the MOSFET's T model. The resulting small-signal equivalent circuit of the common-drain amplifier is shown in Figure.2. Analysis of this circuit is straightforward and proceeds as follows: The input resistance Rin is given by

$\mathrm{Rin} = \mathrm{RG}$ Thus,

$$\mathrm{Vi} = \mathrm{Vsig}\,\frac{Rin}{Rin+Rsig} = Vsig\,\frac{RG}{RG+Rsig}$$

Usually RG is selected to be much larger than Rsig with the result that

$$\mathrm{Vi} = \mathrm{Vsig}$$

To proceed with the analysis, it is important to note that ro appears in effect in parallel with RL, with the result that between the gate and ground we have a resistance (l/gm) in series with (RL|| ro). The signal Vi appears across this total resistance. Thus we may use the voltage divider rule to determine Vo as

$$Vo = Vi\,\frac{Rl||\,\mathrm{ro}}{(Rl||\,\mathrm{ro}) + {}^{1}/_{gm}}$$

From the above equation, the voltage gain Av is obtained as

$$Av = \frac{Rl||\,\mathrm{ro}}{(Rl||\,\mathrm{ro}) + {}^{1}/_{gm}}$$

And the open-circuit voltage gain Avo as

$$Avo = \frac{\mathrm{ro}}{ro + {}^{1}/_{gm}}$$

Normally ro > l/gm, causing the open-circuit voltage gain from gate to source, Avo in above equation, to become nearly unity. Thus the voltage at the source follows that at the gate, giving the circuit its popular name of source follower. Also, in many discrete-circuit applications, r0 > RL**,** which enables equation will be approximated by

$$Av = \frac{RL}{RL + {}^{1}/_{gm}}$$

The overall voltage gain Gv can be found by combining equations above, with the result that

$$Gv = \frac{RG}{RG + Rsig} * \frac{RL||\ ro}{(RL||\ ro) + {}^{1}/_{gm}}$$

Which approaches unity for RG **>** Rsig**,** r0 > 1 /gm, and ro > RL**.** To emphasize the fact that it is usually faster to perform the small-signal analysis directly on the circuit diagram with the MOSFET small-signal model utilized only implicitly, we show such as analysis in Figure.3. Once again, observe that to separate the intrinsic action of the MOSFET from the early effect, we have extracted the output resistance ro and shown it separately.

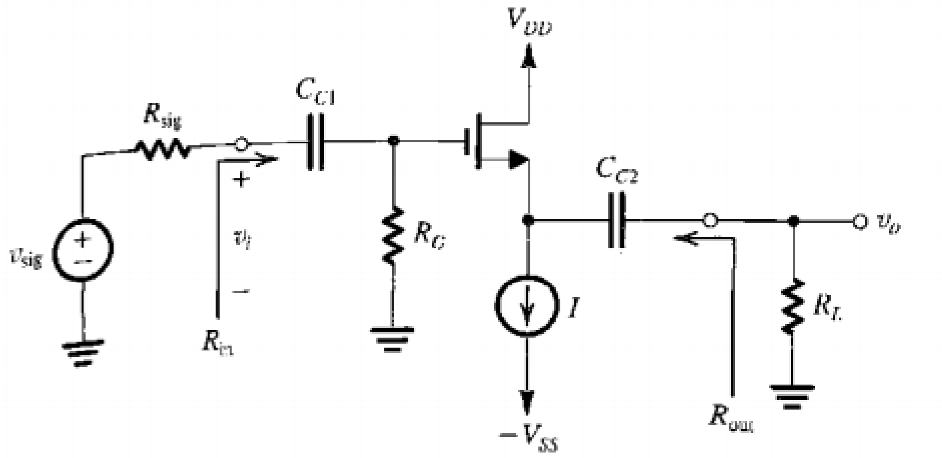
The circuit for determining the output resistance Rout is shown in Figure.4. Because the gate voltage is now zero, looking back into the source we see between the source and ground a resistance l/gm in parallel with ra\ thus,

$$Rout = ro||\ {}^{1}/_{gm}$$

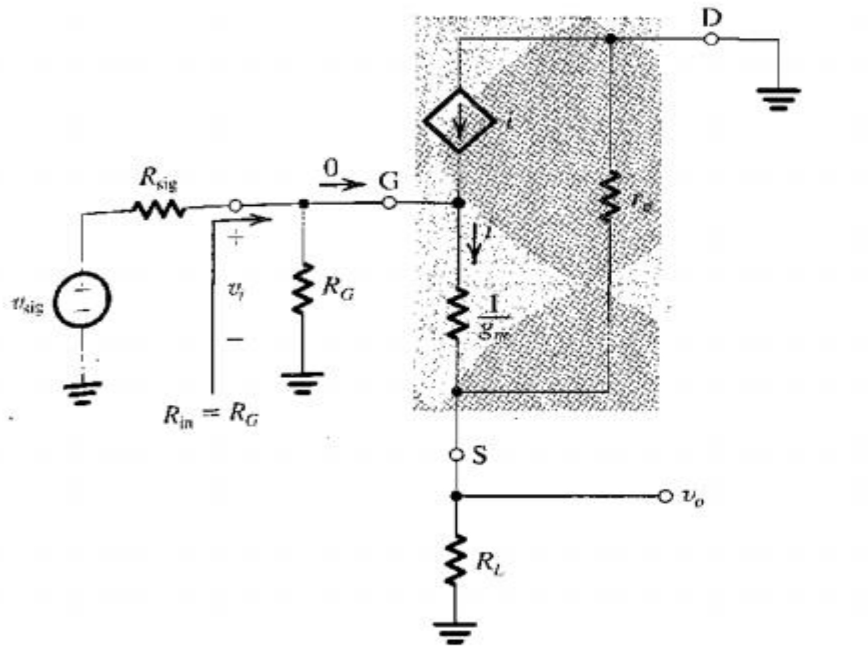
Normally, r0 > 1 /gm, reducing Rout to

$$Rout = {}^{1}/_{gm}$$

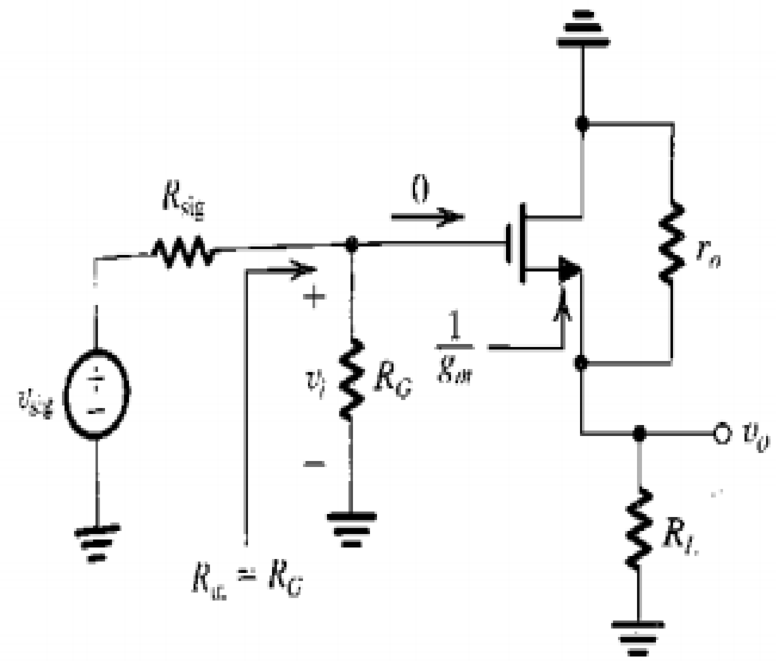
Which indicates that Rout will be moderately low. We observe that although the source-follower circuit has a large amount of internal feedback, its Rin is independent of RL (and thus Ri **=** Rin**)** and its Rout is independent of Rsig (and thus RD = Rout**).** The reason for this, however, is the zero gate current. In conclusion, the source follower features a very high input resistance, a relatively low output resistance, and a voltage gain that is less than but close to unity. It finds application in situations in which we need to connect a voltage-signal source that is providing a signal of reasonable magnitude but has a very high internal resistance to a much smaller load resistance which is, as a unity-gain voltage buffer amplifier. The source follower is also used as the output stage in a multistage amplifier, where its function is to equip the overall amplifier with a low output resistance, thus enabling it to supply relatively large load currents without loss of gain (i.e., with little reduction of output signal level.)



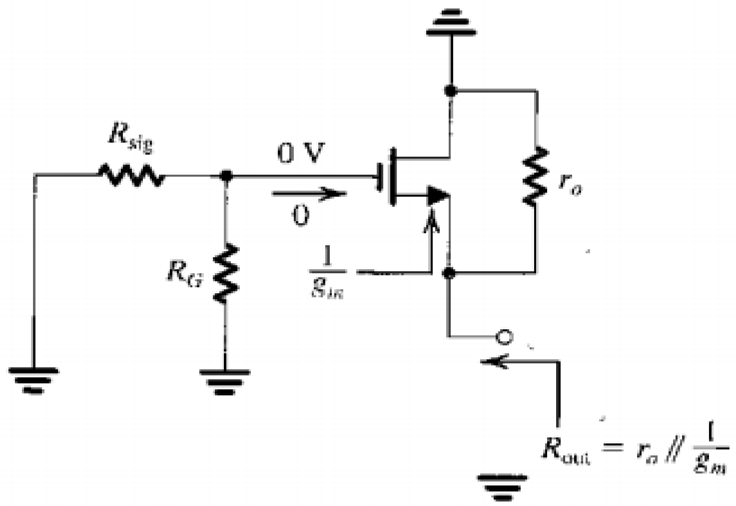
V_{DD}
C_{C1}
R_{sig}
C_{C2}
v_{sig}
v_i
R_G
v_o
I
R_L
R_{in}
$-V_{SS}$
R_{out}



D
i
R_{sig}
0
G
r_o
v_{sig}
v_i
R_G
i
$\frac{1}{g_m}$
$R_{in} = R_G$
S
v_o
R_L



R_{sig}
0
r_o
$\frac{1}{g_m}$
v_{sig}
v_i
R_G
v_o
R_L
$R_{in} = R_G$



R_{sig}
0 V
0
r_o
R_G
$\frac{1}{g_m}$
$R_{out} = r_o \,//\, \frac{1}{g_m}$

Appendix D:

Thunder Series – High Voltage DC/DC Converter

Features

- Unipolar outputs from 500 to 5000VDC either Pos or Neg Polarity
- Miniature Size – Low Profile
- High Efficiency
- High Reliability/Long life
- Short Circuit/Over Current Protection
- Low output ripple
- Regulated - No minimum load Required
- Wide environmental range
- Custom Designs Available (*consult with factory*)

AM Power Systems' Thunder broad line of miniature, high voltage dc-dc converters offer regulated high voltage output directly proportional to the input voltage. The Thunder series is encapsulated in high thermal conductivity epoxy resin for use in harsh environmental environments. These single output devices are available in a variety of input and output voltages.

Electrical Specifications

- Output Regulation.......Proportional
- Short Circuit Protection..........Yes
- Output Voltage Tolerance.........5%
- Output Power ....1W to 2W

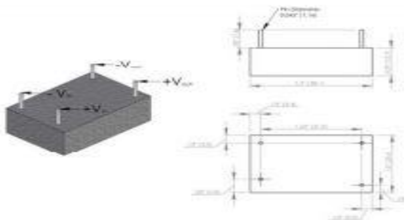
General Specifications

- Dimensions (typ)...27 x 40 x 15mm
- Weight................................29g
- Environmental*........-10° to +60°C
  ** Expanded Op Temps available*

Typical Applications

- Electroactive Polymers
- Piezo Devices
- Atomic Force Microscopes
- Medical Imaging & Electronics
- Electrophoresis
- Chromatography Optics
- Avalanche Photodiodes
- Sustaining Ion Pumps
- PMT Mass Spectrometry
- Ordonance Triggers
- Electrostatic Chucks

Case Size 'A' Shown



Thunder Series – High Voltage DC/DC Converter

	Input Specifications			Output Specifications		
Model Number	**Voltage**	**No Load Current**	**Full Load Current**	**Voltage**	**Maximum Current**	**Ripple* (typical)**
AM-0505N & P	0-5 VDC	50 mA	400mA	500 VDC	2 mA	±2%
AM-1005	0-5 VDC	50 mA	400mA	1000 VDC	1.0 mA	±2%
AM-1505	0-5 VDC	50 mA	400mA	1500 VDC	670 µA	±2%
AM-2003P	0-3 VDC	50 mA	400mA	2000 VDC	500 µA	±2%
AM-2003N	0-3 VDC	50 mA	400mA	2500 VDC	400 µA	±2%
AM-2005	0-5 VDC	50 mA	400mA	2000 VDC	500 µA	±2%
AM-2505	0-5 VDC	50 mA	400mA	2500 VDC	400 µA	±2%
AM-3005	0-5 VDC	50 mA	400mA	3000 VDC	333 µA	±2%
AM-3505	0-5 VDC	50 mA	400mA	3500 VDC	286 µA	±2%
AM-4005	0-5 VDC	50 mA	400mA	4000 VDC	250 µA	±2%
AM-4505	0-5 VDC	50 mA	400mA	4500 VDC	222 µA	±2%
AM-5005	0-5 VDC	50 mA	400mA	5000 VDC	200 µA	±2%
AM-0512	0-12 VDC	25 mA	280 mA	500 VDC	4 mA	±2%
AM-1012	0-12 VDC	25 mA	280 mA	1000 VDC	2 mA	±2%
AM-1512	0-12 VDC	25 mA	280 mA	1500 VDC	1.3 mA	±2%
AM-2012	0-12 VDC	25 mA	280 mA	2000 VDC	1.0 mA	±2%
AM-2512	0-12 VDC	25 mA	280 mA	2500 VDC	800 µA	±2%
AM-3012	0-12 VDC	25 mA	280 mA	3000 VDC	667 µA	±2%
AM-3512	0-12 VDC	25 mA	280 mA	3500 VDC	570 µA	±2%
AM-4012	0-12 VDC	25 mA	280 mA	4000 VDC	500 µA	±2%
AM-4512	0-12 VDC	25 mA	280 mA	4500 VDC	444 µA	±2%
AM-5012	0-12 VDC	25 mA	280 mA	5000 VDC	400 µA	±2%
AM-0524	0-24 VDC	15 mA	139 mA	500 VDC	4 mA	±2%
AM-1024	0-24 VDC	15 mA	139 mA	1000 VDC	2 mA	±2%
AM-1524	0-24 VDC	15 mA	139 mA	1500 VDC	1.3 mA	±2%
AM-2024	0-24 VDC	15 mA	139 mA	2000 VDC	1.0 mA	±2%
AM-2524	0-24 VDC	15 mA	139 mA	2500 VDC	800 µA	±2%
AM-3024	0-24 VDC	15 mA	139 mA	3000 VDC	667 µA	±2%
AM-3524	0-24 VDC	15 mA	139 mA	3500 VDC	570 µA	±2%
AM-4024	0-24 VDC	15 mA	139 mA	4000 VDC	500 µA	±2%
AM-4524	0-24 VDC	15 mA	139 mA	4500 VDC	444 µA	±2%
AM-5024	0-24 VDC	15 mA	139 mA	5000 VDC	400 µA	±2%

** Note: If required, ripple can be reduced even further with external capacitor*