Electronic Frequency Controller

Thesis

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Abstract

The project was performed with universal electronics which is based in Karachi Pakistan at PRD Lab. Due to the energy crises the industry is switching to alternative power generators. The main issue with the maintenance of the generator is the constant failure of the controller which has to be imported, the purpose of this project is to make a cheap efficient Electronic Frequency Controller (EFC) that can be used in almost all kinds of generators. The work was tested on Multisim and then soldered together. To make it functional the frequency generation was converted to voltage which was connected to the controller. The controller was joined with the actuator and the actuator opens the amount of fuel needed to run the generator so that there is a smooth constant voltage. If we have high frequency from the input like a heavy machinery is operational then the actuator will widen its opening and when the frequency is low the actuator will open appropriately. The presentation was a successful one but due to time deadline few minor adjustment could be made to make it more effective as discussed later.
Problem statement

The issue here we are addressing is a Electronic Frequency Controller (EFC) that is functional to all kinds of power generators that can be used and implemented at a cheaper cost, normally these controllers gets broken due to their tough environment and the amount of load put on these controllers so therefore they have to be replaced. Sometime there affect is so much that it can burn or destroy the whole generator so it is of utmost importance to make a quality and workable controller. Usually these controllers cost a lot and most of them are to be imported from their manufactures which also cost a lot. So our prime objective was to make a good quality controller that can be made and then used in almost all kind of different generators.
Chapter 1

1.1 Introduction

The present day situation in Pakistan, energy sector faces significant challenges especially in electricity generation where all the household and the industry are run in one way or the another using generators. All these power generating equipments use different systems to give a constant current flow, hence to answer this issue we made an Electronic Frequency Controller EFC[1]. This Electronic frequency controller can help maintain constant output frequency using specific criteria. The special thing about this controller is that it is universal and therefore could be used in almost any kind of generator. A constant RPM is a challenging task where the system needs a steady flow of frequency to operate, any change in load will then have a direct effect on the current generated by the generator, if the load is high then the frequency will decrease and vice versa so a constant RPM is of utmost importance.

There are numerous ways and techniques to maintain and run the EFC but since we wanted to work in almost any kind of system, therefore it is completely different from the other controllers. An important drawback affecting most of the processing systems is the high temperature where these controllers work in, since the controllers work with generators where there is high temperature this might damage our controller with overheating. Any error in input have a dangerous and harmful effect on the system performance, even sometimes hazardous for the generator so keeping this in mind we also constantly monitor our controller so that the output from the controller does not affect the generator or in some cases it can cause huge damage to industry and household appliances. Inaccurate detection of the error can cause serious problems such as degradation of recognition performance and deterioration of output. It is therefore highly desirable to develop a robust and reliable EFC method. The solution to one of the significant problems are to use Fail-safe controller.

1.2 Application of Electronic Frequency

There are many fundamental and practical examples where this Electronic Frequency Controller can be used in the industry.
Below are some examples:

- Conveyor belt
- Plug-in and hybrid electric components
- Variable speed air compressor
Chapter 2

2.1 Overview of the Project

This is a general take out on the project. Detail explanation will be presented with complete analysis in later Chapters.

Revolutions Per Minute [2] (RPM) is sensed by Magnetic Pickup Unit [3] (MPU) which gives AC voltage that is directly proportional to RPM. This signal will go further into our next step which will provide signal conditioning, later we convert frequency to voltage provided the help we got from our IC555[4]. We needed Current buffering which in turn provides a smooth DC output.

We used a comparator[5] which drives our PNP transistor [6] which at the end of our controller gives the input to the actuator. Increasing current to the actuator [7] increases the fuel to the engine which in the end result tunes our frequency.

The MPU gets the signal which is joined by the Controller and the resulting output runs the actuator depending on the frequency.

Fig.1 A Block diagram of the system.
2.2 Factors affecting the controller

There are certain factors that can degrade the performance of the systems, these are discussed here.

- MPU
- Load Effect
- Fuel response
- Set point
- Actuator

Magnetic Pickup Unit (MPU)

Revolutions Per Minute (RPM) is the measure of the frequency for the rotation. It is the number of turns completed in one minute around a fixed axis. It is used as a measure of rotational speed of a mechanical component where when Magnetic pick-up sensor is mounted to the axle or a disc.

In either of the application, the device senses a change in the magnetic field caused by a metal protrusion on a rotating shaft. The sensor generates a sine wave for transmission to the controller.

![Magnetic Pickup Unit Diagram](image)

Fig.2 A general figure of MPU is shown
Load Effect

We can deduce for the load effect on a generator by stating that the torque is proportional to the amperage supplied by the generator[8] that is for a constant magnetic field generator, which means it is the electrical current. Amperage is proportional to torque. Voltage is proportional to angular velocity of the generator shaft.

In other words the angular inertial of the generator resists a change in angular velocity, but it will still slow down or speed up if the two forces angular forces are imbalanced. If the generator is islanded and you add the load to it, the speed would obviously go down and the controller would infuse in higher quantity of fuel to bring back the turbine speed to the normal operating speed.

Fuel response

The main characteristic of your controller is to determine the load it has been put on in a given time hence the fuel injection system pumps in the fuel into an internal combustion system[9].

To determine the amount of fuel required is directly proportional to the air intake. All modern systems use a mass airflow sensor to send this information to the control unit. Data representing the amount of power output desired to run the controller smoothly is used by the control unit to calculate the amount of fuel required.

Set point

A set point stations enable the current flowing to be manually tuned from the process area hence allowing an operator to easily adjust a controller set point or an actuator position. We can say that set point is the target or the desired value for the variable system[10].

A system is in constant motion and different factors involved can lead to different variable from its set point therefore error-controlled regulation is used from the feedback to return the system to its normal position. The controller calculates the error which is the difference between a measured process variable and a desired set point. The controller minimizes the error by adjusting the manipulated variable process. The responsiveness controller controls the error, the point which the controller exceeds the set point and the system oscillation. An excessive movement in the output is visible when a system is subjected to an increase instantaneous step-error, such as set point change.
Actuator

An actuator controls the moving or in our case opening or closing of the fuel shaft inside the fuel pump that is run by a motor. The actuator converts electrical energy to mechanical torque and work simultaneously with the load or frequency applied.
Chapter 3

3.1 The system methodology

The system has following parts

1 Signal Conditioning
2 Frequency to Voltage Converter
3 L.P Filter
4 Controller
5 Actuator

Each of the part is explained in detail below

3.2 Signal conditioning

The AC voltage that comes from the Magnetic pickup (MPU) is changed from a sine wave into a square wave. The wave coming from MPU was a sine wave and since we passed it to a digital inverter so therefore it changes to a square wave. In return we also have a benefit of having the square wave that is when further at pin 2 of IC555 the square wave triggers better then sine wave at IC555.

If we get any external noise in our system that is discarded from using the IC 40106 inverter[11], although almost any kind of digital gate can be used.
From the oscilloscope we can see an example of a sine wave into a square wave, see Fig 3 and Fig 4.

Fig 3 Example of sine wave at the oscilloscope.

Fig. 4 Example of square wave at the oscilloscope.
3.3 **Frequency to voltage convertor**

The frequency from the MPU was converted into square wave due to invertors and then we applied it on IC 555. It works as a mono stable multi vibrator which is with every passing time it get a trigger which then generates a pulse at the output, if the number of the trigger increase or in other word the frequency increases then the pulse will generate more at the output. At the output the RMS(root mean square)[12] voltage will increase and vice versa. In our circuit the power supply in between 0V and 7V so if the frequency is high we will get 7v and if the frequency is low we will get 0V for a longer period hence the RMS output voltage will decrease. The RMS voltage is not a smooth DC which is why further on we passes it through invertors to get a smooth DC.

The analogue voltage is proportional to the frequency i.e. if the frequency is high the resulting voltage will also increase [13]. This conversion is performed by 555IC. This procedure will be shown in next chapter.

![IC555 general layout](image)

**Fig.5 IC555 general layout.**

3.4 **Low pass filter**

The DC voltage which we want to have is a smooth one but the output from the frequency to voltage convertor is not a smooth one. To make sure we have a smooth DC we pass it twice through two low pass filters. It is been performed by two invertors and one Resistor-Capacitor (RC Filter) [14].

When frequencies are lower than a certain cut-off frequency and constrict with frequencies higher than the cut-off frequency it is a L.P filter[15]. To understand more it is the opposite of a high-pass filter, Low-pass filters gives a smoother form of a signals.
Since our project is based on low-pass RC filter for voltage signals, high frequencies in the input signal are constricted, but the low pass filter has little constriction from the cut-off frequency which is sensed by its RC time constant. A perfect low pass filter eliminates all the frequencies above the cut-off frequency while the lower remain unchanged, its frequency response is a rectangular function.

Below is the example of an RC filter where we use two invertors and one Resistor-Capacitor (RC Filter)

Fig. 6 An RC filter from the system using MultiSim, a detail explanation is shown in later chapter.

![RC Filter Diagram](image)

Fig. 7 A general example of a L.P RC filter.
3.5 Controller

The resulting output from the operational amplifier for the proportional gain where it joins the CA3130 at pin number 2. The frequency to voltage conversion goes into the controller, here we have two inputs coming into the controller one is the analogue input while the other is our set-point. This controller is actually from an Operational amplifier[16]. This output would then go into the driver. The OP amp cannot directly drive the actuator since it needs too much ampere current to run an actuator so to fix this issue we feed it into the driver which works as an amplifier. This driver runs the actuator, which in turn controls the speed of the engine.

![Diagram of controller system]

Fig.8 The controller with respect to the input and the actuator connected to the generator to give a stable output.

The controller is used to remove any voltage or frequency error, therefore at any given time the system can fluctuate and give inappropriate data to the actuator and the whole system.

The speed of the engine is again feedback through the MPU and the whole process keeps on going.

3.6 Fail safe

A Fail-safe[17] is one that, in the event of failure, responds in a way that will make sure the damage is limited within the system or beyond.

The output from our Fail-safe goes into the driver and switches off when necessary. In any failure where the controller is getting a wrong data the Fail-safe will make sure that any wrong input won’t effect the whole system and hence it will take control and switch off the system. The Fail-safe makes sure the system runs smoothly and in the correct order. In the case of any failure in the controller where the controller is generating any false output our fail-safe automatically enabled and the system will shutdown to a halt. The function of our Fail-safe is to make sure the loss of signal. In our Fail-safe we are using an operational amplifier which is
a comparator. A comparator compares two voltages or currents and outputs a digital signal indicating the larger one. Our Fail-safe works parallel to our system.

Fig.9 Example of a comparator.

Take the example,

In the case of the MPU stops working and is sending no signal, our controller will process it as the input frequency is too low and our output from the controller will reach its maximum which in turns runs our actuator, this can cause a major accident. This is one of the reason why there is a strong need to work on this project to rectify this problem.
Chapter 4

Signal conditioning circuit

4.1 Signal conditioning process

Magnetic pickup or MPUs are located near the flywheel of our generator. The passing of the gear teeth in front of the MPU tip (pole) generates a voltage and frequency. The strength of the signal is determined with the gear teeth as to which the sensor can read the signal. Since our desired input frequency should be around 1k-5k Hz and we do not want any high frequency to pass through therefore,

The Rate per second (RPS)

with 1500 RPM (Revolution per minute)

100 teeth's in our fly wheel

RPS=RPM/60

1500/60 gives us 25 RPS

25*100=2500 Hz

Therefore we get 2.5KHz frequency from our MPU

Keeping in mind our controller is functional between 1 kHz to 5 kHz.

The first inverter(as shown in the below Fig.10,11 and later chapter shown in detail with respect to the overall asyatem) joined with a 301kΩ resistor and a capacitor of 0.0001μF which are filtering the signal, furthermore the two more invertors make the feedback positive along with a resistor adjoin them that removes the noise.
Our circuit operates at 7 volt and because of that the resultant sine wave should be around peak to peak 7 volts so that our logic is maintained throughout the EFC.

4.2 Precaution

One key value feature of the EFC is that even at very low voltage levels our circuit will operate and sense it. This is due to self-biasing [18] which we have used.

Self biasing is a method that requires only two resistors to bias the transistor. The biasing voltage is from the voltage drop from the load, So if the load current increases there will be a larger voltage drop. Same will happen as the opposite reaction will occur where the transistors current becomes less. This method of biasing is called self-biasing with the transistors stability using the feedback.
Another key feature of signal conditioning [19] is its functionality even at low or high frequencies, that is

If we connect our Gate with the input that is the MPU and we get a high voltage (say 80 volts) then expected it can damage our gate but since our 100kΩ resistor is arranged in series it gives appropriate resistance and protect the gate from high voltage in abnormal circumstances. If we have high input our resistor could get damaged but the whole gate and the circuit will be safe from any unexpected inputs.

The terminal of the MPU is grounded and the other terminal is helping to generate a signal. The 10kΩ resistor works as a load and a capacitor of 0.01μF its function is to have AC coupling which is to reject the DC component of the signal.

The other terminal from the MPU is connected to a 100kΩ resistor. The function is to protect the gate and the circuit from any high inputs. If there is too much voltage from the MPU this resistor would provide the appropriate resistance and won't let the later part of the NOT gate to be damaged. The Not gate used here is IC4069.

The parallel NOT gate [20] at pin 6 and 7 which later be connected to our IC ,301kΩ resistor and a capacitor makes up our signal conditioning. This Output is again coupled by a 33.2kΩ resistor and the input is going to another NOT gate.

![Signal conditioning in Multisim National instruments](image)

There are two more NOT gates which have 5,4,3 and 2 pin number for our IC ,This works as a buffer where the output is coming from 100kΩ. The resultant output from the capacitor is
going to the pin-2 of our IC. This particular capacitor is again performing coupling and the function of it is that our signal conditioning circuit is coupled from frequency to voltage convertor at the input of frequency to voltage convertor.

Resultant at the IC555 (Frequency to voltage convertor)

When our generator is first initiated and switched ON we have very low voltage and while the circuit has to sense it, our input frequency at signal conditioning should not be influenced by the voltage[21].

Fig.13 Our signal conditioning circuit with result
Fig. 14 At oscilloscope
Chapter 5

5.1 Frequency to Voltage Converter

IC 555

The 555 IC is a chip used in a variety of timer, pulse generator, and oscillator applications. The standard IC555 have 8 pins each having specific purpose as explained below.

Fig.15 IC 555 Texas Instrument
The general application are as follow.

- Precision Timing
- Pulse Generator
- Sequential Timing
- Time Delay Generation
- Pulse Width Modulation
- Pulse Position Modulation
- Linear Ramp Generator

Pin functions

- Pin 1 Ground reference voltage.
- Pin 2 Responsible for switching from set to reset.
- Pin 3 Output driven waveform
- Pin 4 Applying negative pulse to disable or reset the timer.
- Pin 5 Controlling the threshold and trigger levels. It determines the pulse width of the output
- Pin 6 Here comparing the voltage applied to the terminal
- Pin 7 Between the phase, open collector output which discharges a capacitor between intervals
- Pin 8 Supply voltage

5.2 Low pass-filter

When frequencies are lower than a certain cut-off frequency and constrict with frequencies higher than the cut-off frequency it is a L.P filter. To understand more it is the opposite of a high-pass filter, Low-pass filters gives a smoother form of a signals.

Since our project is based on low-pass RC filter for voltage signals, high frequencies in the input signal are constrict , but the low pass filter has little constrict from the cut-off frequency which is sensed by its RC time constant. A perfect low pass filter eliminates all the frequencies above the cut-off frequency while the lower remain unchanged, its frequency response is a rectangular function.

To apply when, designing or constructing one has to use convolution or Laplace to get the right order filter.
5.3 RC circuit

An electric circuit which is run by a voltage or current source is an RC filter. It is composed of resistors and capacitors. It acts as a passive filters. Its function is to filter the signal by blocking certain frequencies. The three basic circuit components the resistor (R), the capacitor (C), and the inductor (L) they can make up into an RC, RL, LC ,RLC circuit.

Since our circuit uses a low pass filter we uses an RC which is a resistor and a capacitor for our pulses filtration.

5.4 Mono-stable Multi Vibrator

It is a Sequential regenerating circuits and is used in timing applications. It uses square wave to display its output. Monostable Multivibrators [22] produces very short pulse or a much longer rectangular shaped waveform.

5.5 The Convertor frequency to voltage

From the Signal conditioning we continue forward and implement one diode and a 100kΩ resistor from the capacitor. When we couple these with our capacitor it helps to have a clipper and clamper qualities. Where our diode is protecting our IC555 from any accident .We get input as square wave at Pin 2 which is basically giving it a trigger as mentioned earlier about each individual pin function. At Pin 3 we get the output which have constant width because it is in a (Mono-stable Multi Vibrator). At pin 6 and 7 a resistor 100kΩ and a capacitor helps us to have RC time constant and this helps to determine our output pulse.

This mono-stable multi-vibrator is acting in this circuit in a manner when a pulse comes at the input it gives a pulse at the output, where at the input if the frequency is higher the pulses will generate at a rapid speed and hence vice versa. These same pulses will go pass pin 3 and the same NOT gate, these pulses will pass the next two NOT gates here still we have the Pulsating DC[23].

At the next junction where we have 51.1kΩ resistor and 0.224μF(224 means 0.22μF) capacitor, these two work as RC filter which is mentioned above in detail. The same procedure is followed for resistor 49.9kΩ and the capacitor 0.223μF(223 means 0.022μF) which again work as an RC filter.

The reason behind having these two RC filter is to purify those pulses that is now we have no more Pulsating DC and instead at the next junction we have a smooth DC which will be the OP-amp input.
Fig.16 Our Frequency to voltage convertor
Chapter 6

6.1 Fail safe

A fail-safe is one that, in the event of failure, responds in a way that will make sure the damage is limited within the system or beyond. Here in this circuit it takes input from the controller output which is analogue.

The output from our Fail-safe goes into the driver and disables it when necessary, which is when the circuit is activated the driver will be disabled by the fail-safe. The fail safe make sure the system runs smoothly and in the correct order. In the case of any failure in the controller or the controller is generating the false output our fail-safe will automatically be enabled and the engine will shutdown to a halt. The function of our Fail-safe is to make sure the loss of signal. In our Fail-safe we are using an operational amplifier which is a comparator. A comparator compares two voltages or currents and outputs a digital signal indicating the larger one\cite{24}. Our Fail-safe works parallel to our system.

6.2 Methodology

We start by receiving the inputs at our Dual OP am TLC27M2 \cite{25}. First from our Low pass filter and second from the fixed voltage from using the voltage divider. Using 100k\(\Omega\) resistor and 634\(\Omega\) resistor where one is at the pull up resistor at the OP amp. A 750k\(\Omega\) resistor is used which is further grounded, the function to it is if we don't have this resistor will keep on charging the capacitor 223\(\mu\)F(again the same mistake). To have a discharge path we add this resistor.

![Fig.17 voltage-divider](image-url)
The reason using the voltage divider is that if the input from our Low pass filter is less or more then the voltage divider, using that the OP amp output will switch accordingly.

This means if the input at the OP amp is high our driver will switch off and hence the actuator. In one case it can go be grounded or in other it can follow the Vcc.

6.3 Test

To test and make sure it works correctly, we give power supply while there is no signal from the MPU our output voltage at the actuator will be 0.

When our generator is started at the very initial time say (t=1) we built up some voltage, this will go all along and some voltage will be measured at the end of the L.P filter. In unforeseen circumstances our OP am will be disabled and its output will be 0. On the other hand the other OP amp used at the controller will try to run the system(This will be explained in the next chapter).

In other case if the generator is running and the input from the MPU goes to 0 our controller will try to have a maximum output but right at that moment our Fail safe OP amp output will go high.

To understand it any failure at the MPU can cause to have maximum current and voltage at the actuator therefore we use this Fail-safe to protect our system.

6.4 Output

The output from our OP amp will go pass a diode and will be the input of the driver. In the case of our OP amp output being 0 this diode will be reverse biased and the signal at the driver input will be maintained and due to that the OP amp wont drowned it.

For understanding if the input is 1 the output will pass on 1 but if there is 0 at the input it won't forced it. The voltage at the controller will remain.
Fig. 18 Fail-safe with signal conditioning and IC555 adjoined.
Chapter 7

7.1 Controller

The input from our L.P filter connects with the amplifier where along with the feedback not only include the resistance but also have the capacitor i.e. it gives capacitance. This part of the controller is the differentiator. The negative terminal of the OP am terminal gets it feedback from a grounded capacitor of 1μF and resistor of 10kΩ further more the negative terminal also have a variable resistor of 1MΩ and to this is a parallel capacitor of 109μF that is helping to negate any high frequency response.

7.2 Process

This signal we get from our L.P filter works hand in hand with the controller where the output of the previous L.P filter becomes the input of this OP amp. The OP-amp amplifies it and produces a gain at the output where to sum it up we get a Differentiator Op Amp [26].

![Differentiator Op Amp](image)

The variable provides Stability where it does not have any Generator Hunting[27]. To stabilise it our differentiator gain is tuned at this junction.

In the next part our output is connected to a variable resistor of 200kΩ and another 10kΩ resistor in series. To avoid having any resistance of 0Ω we gave a fixed 10kΩ resistor and 200kΩ variable resistor. This particular variable has a minimum of 10kΩ and maximum of 200kΩ resistance. This works as a proportional where it works as a Proportional Gain.

The later part becomes the input for another CA3130 OP am[28].
At CA3130 one input we get from Differentiator while the other we are getting from the variable resistance that is frequency adjustment which is our Set-point.

The variable that is helping to archive a set point is made to be connected from one part that is connected to a potentiometer. This potentiometer is made up of where one end is grounded through resistors and the other part has a supply through a combination of resistor, this provides a fixed voltage to our OP-amp.

The comparator is working where this OP-amp is comparing but the output of our CA3130 is having its feedback through a capacitor. As this OP-amp is comparing its function here in the circuit it is also have its function as an integrator. The time constant is dependent on the capacitor and feedback resistance. This part is called integrator. A stable time constant for the Integrator is very crucial to archive therefore we have added a capacitor of 0.27μF and a resistor of 200kΩ. The time constant is depended on both these components, so if our system in spite of adjusting stability and gain constant is not stable we can tune and change the capacitance value as accordance to what the system needs to be stable.

### 7.3 Controller to driver

In the next part, the output of the controller passes through a 51.1kΩ resistor where it is an input for an Darlington pnp-transistor MJ11015 [29]. It works as a power amplifier. To function it properly the smaller transistor 2N2222[30] is driving the bigger transistor where it further drives the actuator. It further goes to a collector where it goes to another transistor here it is connected to a diode. This part is further connected to the positive end of the actuator.

Since the current passing through the actuator is not constant and every single time the voltage fluctuates because of the feedback, we added a 0.01μF capacitor which works as a filter so that high frequency noises does not come to the OP amp input.

The three components here work as an amplifier. The interesting thing is that the position of the actuator depends on the pass through current. If the current is high the actuator will open more and vice versa.

Our system is made to look and function easy therefore the CA 3130 is situated where output current from CA 3130 is injected to the actuator. The negative terminal of the actuator is grounded through a very small resistor of 0.05kΩ. This means any current passing through the actuator will also pass through this weak resistor and therefore accordingly there will be proportional drop of voltage on this resistor too.
Continuous process

The signal from the resistor will go to transistor 2N2222 where it amplifies and goes to MJ11015, which drives the actuator. The current supplied to the actuator also passes through 0.05Ω resistor. The voltage across the resistor is sensed and amplified by op-amp and fed back to the driver op-amp.

This means that we sense the current passing through the actuator but the current is dependent on CA3130 output voltage. We can also derive that the output from CA3130 is the one that function and controls the transistor where the OP amp is depended on CA3130 OP amp.

Fig.20 EFC made in the lab using Multisim National instruments
Fig 21

Channel A (yellow): Input signal from signal generator

Channel C (pink): Input to IC555 timer (after filtration)

Channel B (blue): Output from IC555

Channel D (green): Desired response from the controller, a DC Output
7.4 Experimental result in the lab

Fig.22 Input signal from signal generator.

The result shown in Fig.22 represents the signal taken from the MPU to test the frequency generated from it.

Fig.23 Output from IC555

The Fig 23 represents the result at the oscilloscope when tested at the IC555, the following test shows that it was working alright with respect to the IC555.
Fig. 24 Input to IC555 timer (after filtration)

Fig 24 represents the result from a pulse generation which is determined by the R-C network, connected externally to the 555 timer. 555 monostable circuit stopped after a preset time waiting for the next trigger pulse to start over again. The 555 Oscillator is another type of relaxation oscillator for generating stabilized square wave output waveforms, generating highly accurate free running waveforms whose output frequency can be adjusted by means of an externally connected RC tank circuit consisting of just two resistors and a capacitor. The Monostable circuit produces a single output one-shot pulse when triggered[31].
Fig. 25 Smooth DC at the actuator

Fig. 25 represents the smooth DC with no noise; the reading was collected right before the input DC was joined with the actuator.
Fig. 26 With the change in frequency we find a change in smooth DC which is, when normal frequency

Fig. 26 represents when we have low frequency from the signal generator, the following result show change in DC, the same result is compared with Fig. 24 down below where the frequency is higher.

Fig. 27 when we increased the frequency

Fig. 27 represents when the frequency is increased from the input signal generator we find change in DC.
We can also check the difference of voltage on the Multimeter

Fig.28 with high frequency the voltage is 3.592V

To test our voltage at the Multimeter we connected it with the controller and change the frequency from signal generator, here we have a normal voltage.

Fig.29 with low frequency the voltage is 0.629V
When we lower the frequency the voltage changes as shown in the Multimeter.

Fig.30 Bulb lights up with the input frequency

With the change in frequency our bulb light up accordingly.

Fig.31 Bulb dims with the input frequency

When there is a change from the input signal generator it shows the bulbs gets dim hence when our controller is operating we get a normal smooth DC but when its turned off we see some fluctuation of DC.
7.4 **Universal actuator usage**

We could have said by not bringing current to the feedback but simply having CA3130 works independently where if the output from CA3130 is increasing we could have increased the voltage at the actuator but we did not followed that path because different actuator have different current consumption that is why we have a $0.05 \Omega$ resistor at the negative terminal of the actuator. Hence we follow this path so that we can determine the current of the actuator.

For example if the value of the resistor is further lowered more current will pass through the actuator.

We can also adjust the resistor at the actuator. This means if we lower the value of the resistor more current will pass through the actuator on the other hand if one uses an actuator which has high consumption level of the current we can tune it and we can increase the value of the resistor.

This is because the resistor determines the current consumption of the actuator.
Chapter 8

8.1 Generator type

Our purpose of this project is to implement a fully functional system in a workable or practical environment therefore before design and implementation we had to analyze the type of generators and the fuel response.

Our controller is workable in almost all the kinds of generators which are mainly divided into AC and DC generators but before we work through that we had to make it possible that it works both in gas and diesel generators. Since gas is quiet cheap and abundant in Pakistan therefore it is our priority to run it on gas generators.

The gas generators are weak compare to their counterpart since diesel generator is more powerful and the fuel has more power to run it. The fuel consumption is almost half of what is need in a gas generator. During the time of power failure when there is access load on the generator the response is much better for the diesel generator rather than the gas generator.

8.2 Issues

Stability

We came across many key problems but there were few that stand out, such as like in the diesel generator the stability criteria is quiet different to the gas one and that was the reason why the variable adjustment wasn't able to come in our control. In the case of the Op amp 3130 which has some capacitor at the feedback we sometime have to change the values to adjust and find a stable point. In the similar case when we have hunting and have tried to tune with the gain and stability then sometimes we have to adjust the capacitance of these capacitors.
8.3 Improvements

Frequency meter

The project covers quite a vast topics hence we worked to achieve a functional and workable controller but to further enhance and improve the working and functionality we can add a frequency meter.

Over speed

The basic tool to make sure no harm is done to our system is that we use fail-safe but to further improve we can add Over-speed safety that is when the RPM is higher then normal our system can trip so to protect it we can use Over-speed safety.

Starting fuel, Ramp-up time and Minimum fuel /Maximum fuel

There is no provision of these to control Starting fuel, Ramp-up time and Minimum fuel, Maximum fuel i.e. they are not in our hands to control it and therefore we cannot adjust it. In the case when the speed of the engine goes down our actuator can keep on opening so to rectify the short coming we can put a limit to actuator that would not allow fuel flow until a certain limit the same could be done for minimum fuel like in the case when a system can suddenly goes to a halt.

For Ramp-up time our system tries immediately to achieve rated Reveloution per minute RPM, to solve this problem we can adjust an approximate of time between 3 to 5 seconds to slowly achieve its peak.
Fig. 32 EFC implementation first attempt of soldering (front side)

Fig. 33 Final attempt of soldering (front side)
Fig. 34 Final EFC implementation
Fig. 35 Our controller from the back side.
Conclusion

The project which we embarked on was quite successful and we had quite a bit of learning about the system. It was fully functional and since it had programmable Gain/stability which we can tune depending on the type of generator. The response was quite a successful one and on the other hand the load performance was the one which we were aiming for from the start of our project. One vital thing that we wished and achieved was that there was almost no over-shoot.
References


