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# DESIGN AND IMPLEMENTATION OF FUEL FLOW CONTROL UNIT FOR AERO ENGINE

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## ABSTRACT

High speed aircrafts are manufactured for aviation sector, which requires well-equipped and high performance engine, hence various parameters of the engine has to be checked before installing it into an aircraft's. In my project titled "Design and implementation of fuel flow control unit for aero engine" mainly concentrating on the engine parameters such as temperature, pressure, speed and fuel level. If temperature exceeds the threshold limit, it will result in melting up of the engine blades, it may lead engine failure. Hence constant monitoring of this parameter should be done and also deviation from the permissible limit has to be indicated. Aero engine is a typical nonlinear system, and the main fuel control system is the core of the engine control system. Hence we propose this project wherein the fuel control is obtained by controlling the revolution per minute (RPM) of the engine taking into consideration the parameters temperature, pressure and speed. Basically higher rpm means more fuel and hence the control of the rpm should be compatible with the fuel intake. The decision is taken based on the feedback obtained by the gas turbine engine.

**KEYWORDS:** Fuel Flow Control, FPGA, Stepper Motor, PID, PWM

## INTRODUCTION

Aim of this project is to design an Aero Engine Control System for controlling Fuel Flow to the combustion chamber by using Stepper Motor, to control the speed of plane by monitoring critical Exhaust temperature and Compressor pressure. Stepper motor has many advantages then other types of motors, most important is rotates accurate angles or step based on command pulses. The speed of stepper motor can be readily controlled based on the pulse, enable stepping motor to achieve the variable speed synchronous movement of load is directly coupled to drive shaft of motor. For particular application of stepper motor an electromechanical actuator, the stepper motor size is selected and is determined by the nominal operating load range encountered. The stepper motor is capable of receiving the digital signals and is to generate a corresponding angle variation in proportion to total number of pulses, the stepping motor is driven by an open loop without utilizing a feedback mechanism. Therefore, the stepping motor can be easily controlled when stepping motor is driven to achieve a rotational speed within acceptable range. For smooth functioning of engine, it is highly desirable to provide a reliable speed regulation and over speed protection mechanism of engine. The air and fuel ratio, control of the ignition timing, the idle speed of engine, variable valve timings, this all can be controlled by engine control unit. The fuel system is most important sub systems of the aircrafts and engine control unit forms the base for fuel control unit. Digital electronic control unit compares the actual engine speed with demanded speed and then it give back to controller as error signal. The demanded speed is given by Pilot Liver Angle (PLA) and which is transmitted to digital electronic control unit through telemetry.

## The Hardware Sytem

The hardware system includes the sensors, amplifier, analog to digital converter, FPGA and stepper motor driver and stepper motor.

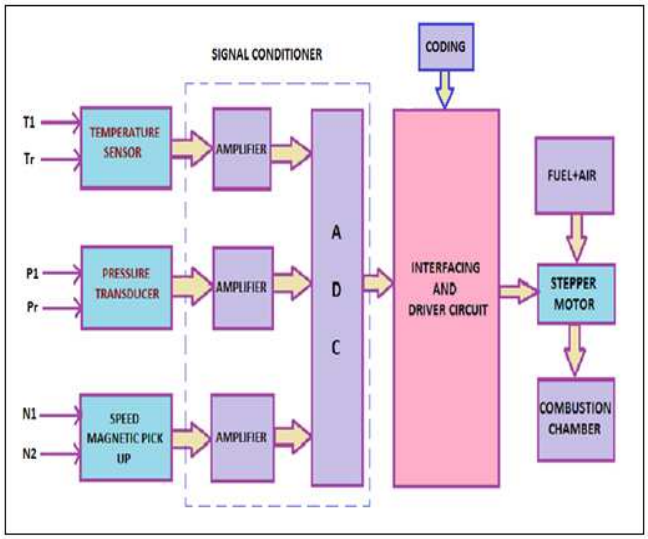


**Figure 1: Block Diagram of Fuel Flow Control Unit**

This hardware system uses sensors, actuator signal conditioner, and controller and driver circuit for stepper motor. The proposed system is a fuel control system in which engine parameters can be varied by controlling the fuel supply to engine. The fuel supplied is varied by driving stepper motor inside the engine whose position dictates the amount of fuel flow into engine and hence the RPM and temperature. Sensors are used to sense the parameters like temperature and pressure. The sensors will sense the temperature, pressure and speed signals of an engine. Later the signals will be applied to the signal conditioner as the output of sensors is generally in mill volts and output in volts is required. The output of the sensors will have some distortion thus it its output is given to the interfacing circuit after proper signal conditioning.

Here Tr and Pr are ambient temperature and pressure respectively. Magnetic Pickup is used to measure the speed of the engine, as the output of Magnetic pickup sensor are voltage signals, Sine to TTL converter is connected to magnetic pick up (speed sensor) in order to convert sine waves to TTL signals. Speed of engine is represented by N1 and N2, which is actual and demand speed in rpm respectively. Here FPGA is used as controller the fuel flow with help of VHDL code by using Xilinx software. The program is implemented in order to run the stepper motor which is useful in controlling the fuel flow of an engine. Since the maximum voltage obtained by Field programmable gate array (FPGA) is 3.3V, to run the stepper motor around 12to28v is required. Therefore, a driver circuit is employed to drive the stepper motor. The driver circuit provides accurate current to drive motor. The output of FPGA is connected to stepper motor Driver circuit.

## Sensors

The temperature, pressure and speed at different altitudes are sensed by the temperature, pressure and speed sensors respectively. Resistance temperature detectors (RTDs) are sensors used to measure temperature by correlating the resistance of the RTD element along with the temperature. It consists of fine coiled wire and is wrapped around a glass core. RTD element is normally quite fragile. The RTD element is usually made by platinum, nickel. This is used normally below 600$^{o}$c.Iy has very high accuracy and repeatability.

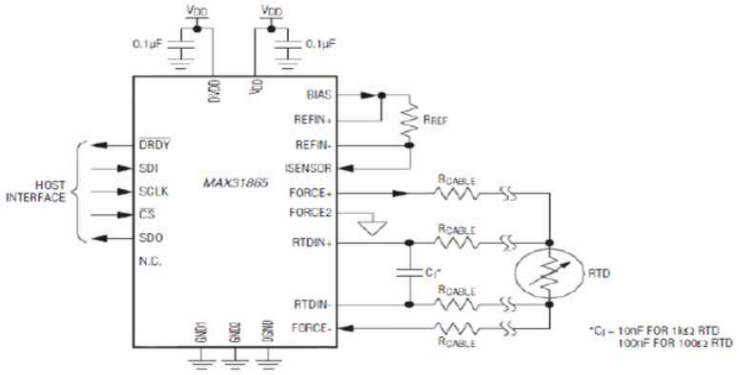


**Figure 2: Circuit Diagram for RTD Measurement**

Thermocouple is temperature-measuring device. It consists of two conductors which are dissimilar and two junctions. Temperature differs from the reference temperature at other parts of the circuit it produces a voltage. Thermocouples do not require any type of external form of excitation and self –powered.

Thermocouples have two junction and repeatable relationship between temperature and voltage. Usually thermocouples are standardized against reference temperature of zero degree Celsius.

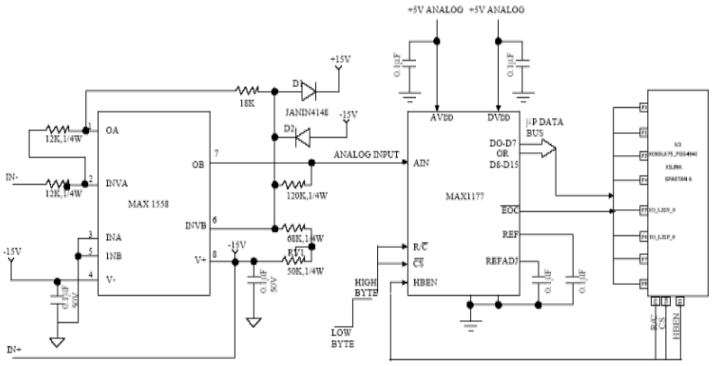


**Figure 3: Circuit Diagram of Thermocouple**

**Pressure Sensor**

A pressure transducer is also called as pressure transmitter that converts pressure into an analog electrical signal. Although there are different types of pressure transducers, the most common using is the strain –gage based transducer. Conversion of pressure into an electrical signal is obtained by physical deformation of strain gages. The strain can produce an electrical resistance change is proportional to the pressure. Strain gauge is defined as sensor whose resistance varies with applied force.

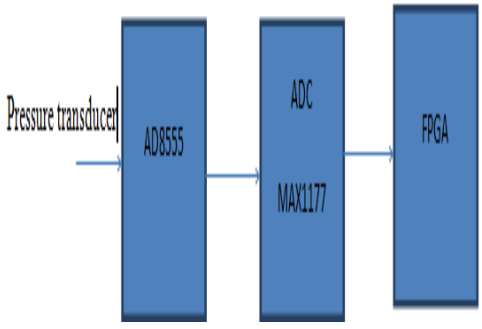


**Figure 4: Interfacing Pressure Transducer with FPGA**

The sensor generates a sine wave for speedometer or controller. The main problem with the magnetic pickup is it will not work with below some threshold minimum speed. The output voltage varies not only in frequency, but it may also in amplitude. Lenz's law demands that both vary. At some low speed, the digital counter cannot sense the passing pulses because the output voltage becomes so low that's way it will not sense. So it does not count them, that's way data errors will occur. To avoid the data error and if we need zero speed detection then the magnetic pickup is replaced by a device is a Hall-effect sensor. The importance of the Hall-effect sensor is it does not rely upon changing the magnetic field (Lenz's law) to produce its output voltage. It senses amplitude and Produces a proportional output voltage.

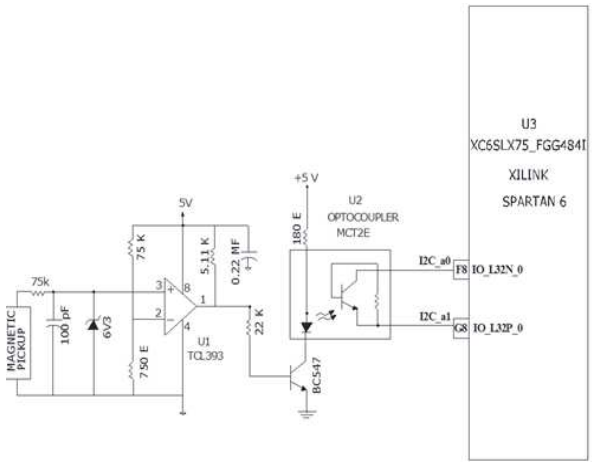


**Figure 5: Circuit Diagram of Speed Measurement**

**Signal Conditioning**

Signal conditioning is helps to meet the requirement or makes helps for the further processing and it include amplification, isolation, filtering, analog to digital conversion for processing after conditioning. To change an incoming signal into the control system the input and output signal conditioners are used. Signal conditioning is most useful stage because some feedback signal is less volt or it will not suits to further stages at that time it will amplify and send it to next stage.

**Driver Circuit for Stepper Motor**

The three phase stepper motor driver circuit is shown in below figure 6, the driver circuit is used because the output from the FPGA is 3.3v or 5v so stepper motor need 24v to rotate so we are using stepper motor driver circuit. And then it is connected to stepper motor.

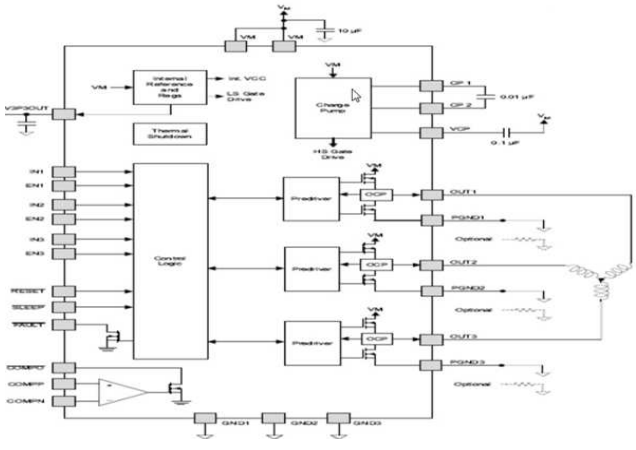

**Figure 6: Three Phase Stepper Motor Driver Circuit**

### Power Converter

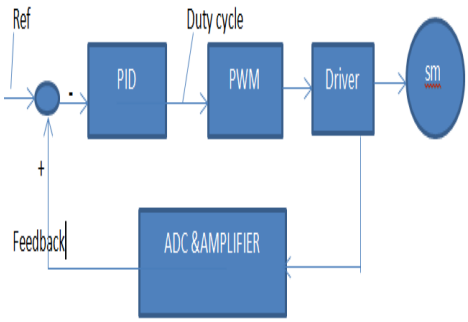


**Figure 7: Block Diagram of a Power Converter**

The power converter includes proportional integral derivative, pulse width modulation, H-bridge circuit, analog to digital converter and amplifier. The H-bridge circuit is used for switching the current into phases of stepper motor. To get the feedback current value for the PID controller the ADC and amplifier are used. To adjust the duty cycle of switching pulse the PID controller will used. PID is most common used in aircrafts before they ars used only proportional integral controller. Pulse-width modulation (PWM) is the modulation technique that controls the pulse width. PWM is used in most common is to inertial loads such as motors. A PID controller is used to adjust the duty cycle of the switching pulses. The PID controller makes error free, it compare the feedback with reference signal then given to PWM.

### Software Design

Xilinx ISE (Integrated Software Environment) is a simulation software tool produced by Xilinx. Is for synthesis and analysis of HDL (Hardware Description Language) designs, enabling the developer to compile their designs, perform timing analysis, examine RTL diagrams, simulate a design's reaction to different stimuli, and configure the target device with the programmer.

### Observations and Results

Throttle Demand that is commanded from Ground Control Panel. It can be varied from 0 to 10 volts, which corresponds to a frequency of 21000 rpm to 30000 rpm. The Demand values and the ambient temperature values are compared and the least value among these demand values is considered as command. Depending upon the command value the stepper motor will rotate. If the higher the RPM and fuel flow is increases and also increases temperature. At different altitudes there is a different reference pressure and temperature. By considering these such parameters we got results. The cam plate is connected to the stepper motor and if RPM increases the angle of stepper motor increases like 30, 45 so valve opens and more fuel flow and increases speed.

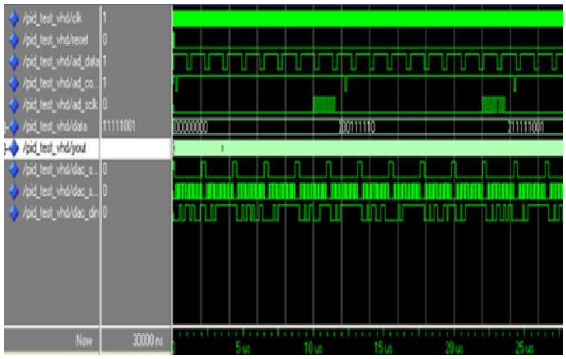

**Figure 8: Simulation Wave Form of PID**

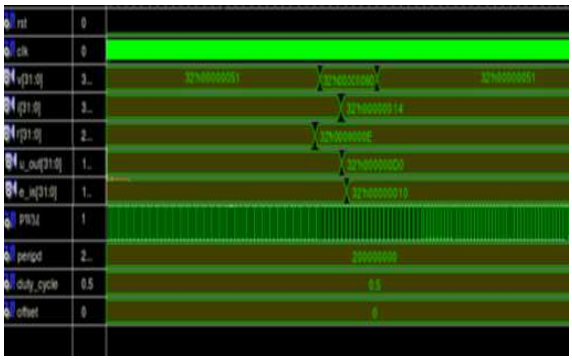

**Figure 9: Simulation Wave Form of PWM**

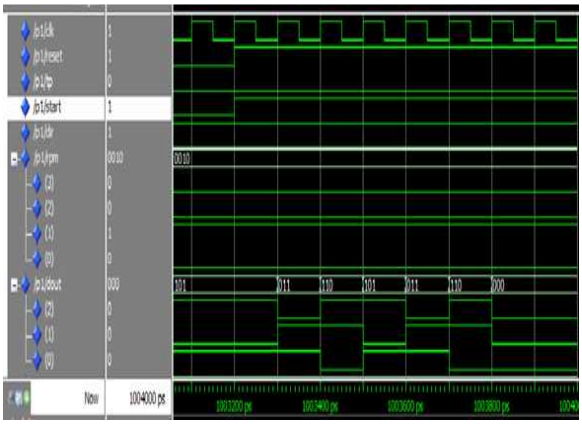

**Figure 10: Simulation Wave Form of Stepper Motor**

## CONCLUSIONS

The proposed project named “aero engine fuel control” focuses on the control of the fuel flow with respect to the engine speed. Modern engines are typically controlled using a Full Authority Digital Engine Control (FADEC) system. Various sensors and actuators interfaces to the ECU using a mixture of analog, discrete and digital interfaces. The decision on what amount of fuel has to be injected into the engine is taken based on the feedback obtained from the gas turbine engine whose temperature, pressure are again measured using the sensors. The limiters i.e. the maximum temperature and pressure beyond which the aircraft wouldn’t withstand, when given as the feedback, the fuel flow will reduce regardless of the speed with which the aircraft is moving. The possibility of lowering the cost of fuel control systems for gas turbine engines is high and the main areas of research have also been determined regarding this. In general, the modern electric/ electronic technology will be employed since there is no doubt that such systems will prevail in the future.

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