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DEVELOPMENT OF TURBOCHARGER CONTROL SYSTEM FOR WANKEL ENGINE

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ABSTRACT– *The paper deals with the aspect of Development of Turbocharger Control Unit for Unmanned Aerial Vehicle which is running with Wankel Engine. The main aim of the work is to compensate the intake Pressure drop at high altitude as this engine is operated there. This is done by controlling the boost pressure of turbo charger, Waste gate is used to control the amount of exhaust gases directed to the turbine wheel of the turbocharger. A closed loop turbocharger control system to control waste gate in response to the pressure at inlet manifold is developed and tested in engine. The best suited Inlet Manifold pressure is found using real time engine testing and from that the set point is found for every engine speed. Using that as a set point intake pressure, pressure is controlled using MC9S12B128 microcontroller. This Controlling of waste gate will allow the engine not to lose its efficiency even at high altitude.*

KEYWORDS: *Wankel Engine, Turbocharger, Waste Gate, Boost Pressure, PI Controller,Pulse Width Modulation.*

I. INTRODUCTION

The Turbo Charger is integrated with the Wankel engine which is petrol operated engine. As this engine is used in an UAV which flies at higher altitude, the pressure drop will be more over there which in turn affect the boost pressure of the wankel engine. In this project, the best suited intake manifold pressure is found using engine testing's and that is kept as a set pressure for intake manifold and tried to maintain the best value at every RPM's of the engine. It will be useful when the engine is running at high altitudes of more than 10000 ft, where the atmospheric pressure is half as in the ground level. The Waste gate in the turbo charger is used here to control the boost pressure in the intake manifold.

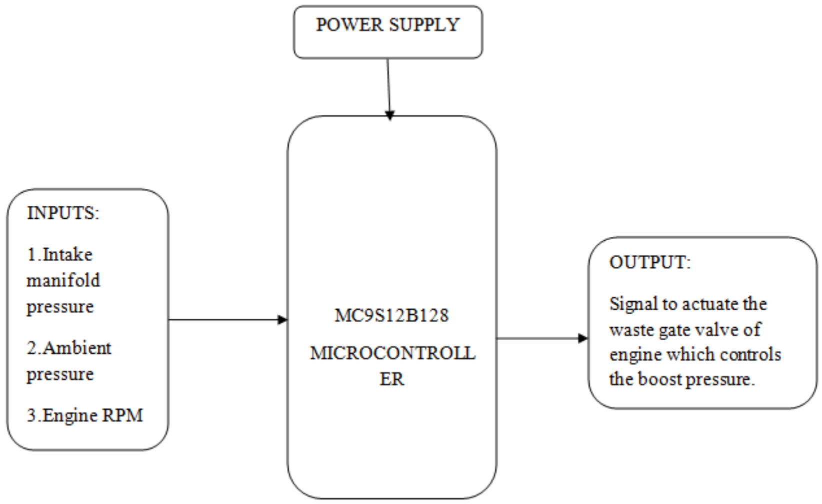
The Unmanned Aerial Vehicle (UAV) is primarily tasked with intelligence gathering over enemy territory and also for reconnaissance, training, surveillance, target designation, artillery fire correction, and damage assessment. The Engine used in this UAV is developed indigenously by Vehicles Research and Development Establishment which is a Wankel engine.

The Wankel engine is a type of IC engine uses an Eccentric rotary design to convert pressure into a rotating motion instead of using reciprocating pistons. Its four stroke cycle takes place in a space between the inside of an oval-like epitrochoid-shaped housing and a rotor that is similar in shape to a Reuleaux triangle but with sides that are somewhat flatter. The very compact Wankel engine delivers smooth high-rpm power. It is commonly called a rotary engine.

II. OVERALL SYSTEM

The set point value of boost pressure of the Wankel engine is determined for various speeds (RPM) of the engine. The inlet manifold pressure of the engine is acquired to the microcontroller as input and is added to the ambient pressure at every instant for the engine speed (RPM). At higher altitudes, the pressure drop will be more which in turn affects the efficiency of the wankel engine. We can process the acquired inputs at every instant to keep the boost pressure at efficient point according to the set point table. This can be achieved by giving signal output to the actuator of wastegate valve which controls the boost pressure as when it should open/close and how much it should open/close which will generally be a 5V supply.

This processing is done using the Microcontroller MCS912B128 which is attached to the Starter Kit ZK-S12-A.



Overall Block Diagram

III. MC9S12B128 MICROCONTROLLER

Designed for automotive multiplexing applications, members of the MC9S12B-Family of 16 bit Flash-based microcontrollers are fully pin compatible and enable users to choose between different memory and peripheral options for scalable designs. All MC9S12B-Family members are composed of standard on-chip peripherals including a 16-bit central processing unit (CPU12), up to 256K bytes of Flash EEPROM, 8K bytes of RAM, 2K bytes of EEPROM, two asynchronous serial communications interfaces (SCI), serial peripheral interface (SPI), an input capture/output compare timer (TIM), 16-channel, 10-bit analog-to-digital converter (ADC), an 8-channel pulse-width modulator (PWM), one CAN 2.0 A, B software compatible module (MSCAN12) and an Inter-IC Bus. System resource mapping, clock generation, interrupt control and bus interfacing are managed by the lite integration module (LIM). The MC9S12B-Family has full 16-bit data paths throughout, however, the external bus can operate in an 8-bit narrow mode so single 8-bit wide memory can be interfaced for lower cost systems. The inclusion of a PLL circuit allows power consumption and performance to be adjusted to suit operational requirements. In addition to the I/O ports available in each module, up to 22 I/O ports are available with Wake-Up capability from STOP or WAIT mode.

IV. PI CONTROLLER

A PI controller calculates an "error" value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting the process control inputs. The PI controller calculation (algorithm) involves two separate constant parameters, and is accordingly sometimes called **two-term control**: the proportional and integral, denoted *P*, *I*.

Heuristically, these values can be interpreted in terms of time: *P* depends on the *present* error, *I* on the accumulation of *past* errors based on current rate of change. The weighted sum of these two actions is used to adjust the process via a control element such as the position of a control valve.

The PI control scheme is named after its three correcting terms, whose sum constitutes the manipulated variable (MV). The proportional and integral terms are summed to calculate the output of the PI controller. Defining u(t) as the controller output, the final form of the PI algorithm is:

$$U(t) = MV(t) = K_p e(t) + K_i \int_0^t e\,(T)\,dT$$

Where

K_p: Proportional gain, a tuning parameter

K_i : Integral gain, a tuning parameter

e = Error = SP – PV

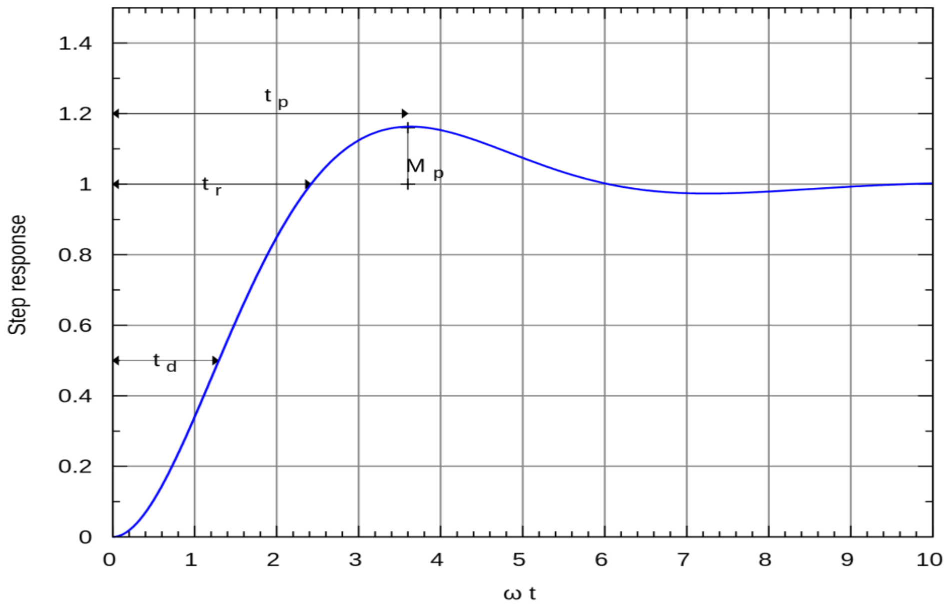
t = Time or instantaneous time (the present)

T: Variable of integration; takes on values from time 0 to the present t.

Plot of PV vs time, for three values of Kp (Ki and Kd held constant)The proportional term produces an output value that is proportional to the current error value. The proportional response can be adjusted by multiplying the error by a constant *Kp*, called the proportional gain constant.

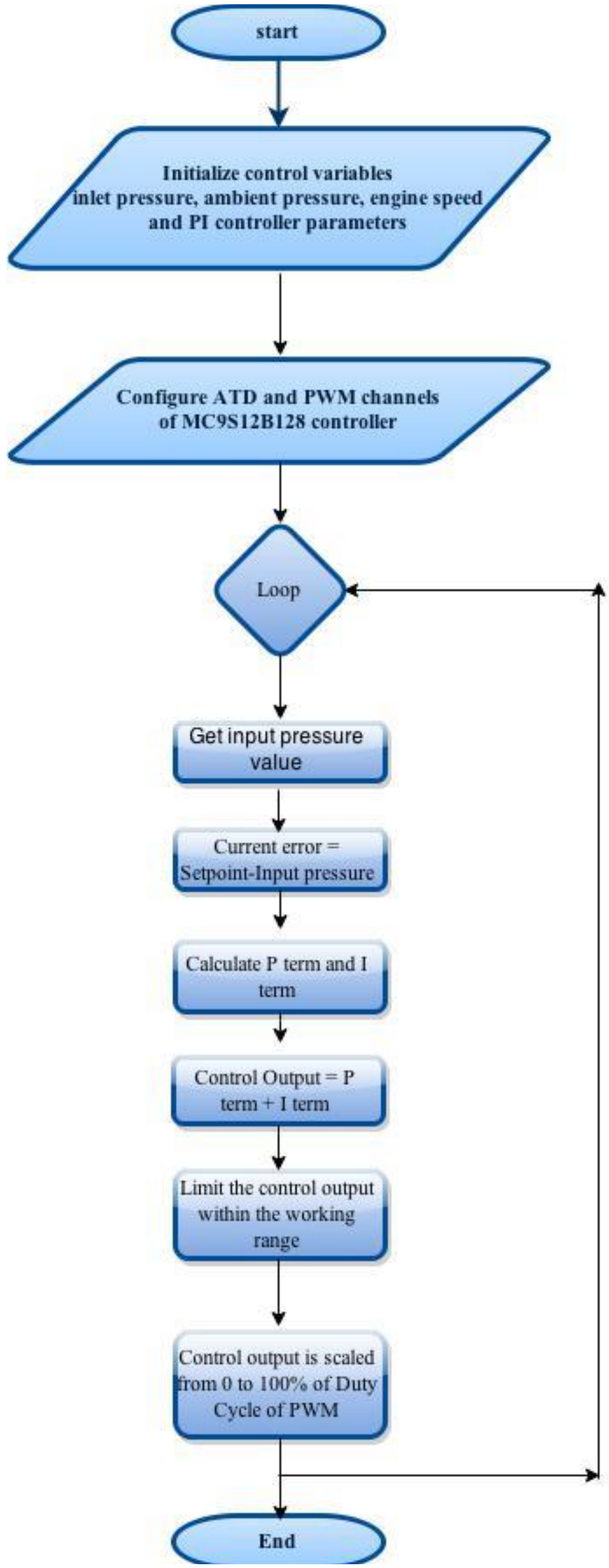
$$P_{out} = K_p e(t)$$

A high proportional gain results in a large change in the output for a given change in the error. If the proportional gain is too high, the system can become unstable. In contrast, a small gain results in a small output response to a large input error, and a less responsive or less sensitive controller. If the proportional gain is too low, the control action may be too small when responding to system disturbances..



Transient response characteristics of PI controller

V. FLOW CHART


start
Initialize control variables
inlet pressure, ambient pressure, engine speed
and PI controller parameters
Configure ATD and PWM channels
of MC9S12B128 controller
Loop
Get input pressure
value
Current error =
Setpoint-Input pressure
Calculate P term and I
term
Control Output = P
term + I term
Limit the control output
within the working
range
Control output is scaled
from 0 to 100% of Duty
Cycle of PWM
End

VI. RESULTS

The PI controller has to be tuned to determine the exact value of proportional and integral gain constants in order to make the controller work effectively with a fast response. Here we implement the trial and error method of tuning. In this method, the value of integral gain constant is kept zero and when the system is in steady mode, a disturbance is given as step input. Then the value of proportional gain constant is increased slowly till it attains a periodic oscillation. The value of k_p for which the system responses very fast is noted. If the system's response time with respect to the actuator movement is more, we can tune the integral part of the controller also. But in our case, the proportional part itself is fast enough to give the required output. So tuning of proportional part itself is sufficient in response.

S.NO	TEST CASE	OBSERVATION
1	Error = 5 m bar. (positive error) Ex. 950-945(Set point-Actual)	When the error gets positive, the boost pressure value gets lesser than set point value. This in turn closes the waste gate valve to increase the pressure and reach the set point.
2	Error = -5 m bar. (negative error) Ex. 950-955(Set point-Actual)	When the error gets negative, the boost pressure value gets higher than set point value. This in turn opens the waste gate valve to decrease the pressure and reach the set point.
3	Error = 0 m bar. (zero error) Ex. 950-950(Set point-Actual)	When the error gets zero, the boost pressure value gets same as set point value. This in turn keeps the waste gate valve to remain in its position as to maintain the set point.

Response of PI controller with respect to different types of error

When the system is tuned with different $k_p$values and k_i=0 for same error value, the response time happened was as follows.

S. No	K_P	Initial Error (m bar)	Settling Time (sec)	Steady State Error (m bar)
1.	0.2	5	>180	3
2.	0.4	5	>60	3
3.	0.5	5	15	3
4.	1.0	5	8	2
5.	2.0	5	5	2
6.	3.0	5	4	2
7.	**3.2**	**5**	**2**	**2**
8.	4	5	2	4

Response of PI controller with respect to different k_p values and k_i=0

When the system is tuned with k_p= 3.2 and for different values of k_i for same error value, the response time that happened was as follows.

S. No	K_i	Initial Error (m bar)	Settling Time (sec)	Steady State Error (m bar)
1.	0	5	2	2
2.	0.0001	5	2	1
3.	**0.00001**	**5**	**2**	**0**

Response of PI controller with respect to different k_i values and k_p= 3.2

From the above table, we observed that the system was responding very fast with the $k_p$value of 3.2 and $k_i$value of 0.00001 when tested with several RPMs, the system was responding well with this value with no oscillations. Here the value of K_p is altered through the potentiometer in the starter kit and k_i is altered through function generator. This potentiometer is capable of giving 0 to 5V analog input which is scaled from 0 to 255 through ATD converter which is available in the starter kit and is used in the program in the range of 0 to 10 and the function generator is scaled from 0-5V to 0-0.0001.

The PI controller is tuned for its effectiveness by changing only the value of k_p with change in the intake pressure value. The output of the PWM and the change in input from the pressure sensor are taken into the oscilloscope by scaling them to appropriate level.

This picture below shows the response of PI controller when there is a change in the set point value of the intake pressure. The dark blue wave represents the change in intake pressure (channel 1) which in turn changes the set point at different engine rpms. Accordingly the PWM's duty cycle is varied to give different output to maintain the respective set point values which in turn are the pulses visible in the picture (channel 2). This duty cycle value of PWM is given by the PI controller's output.

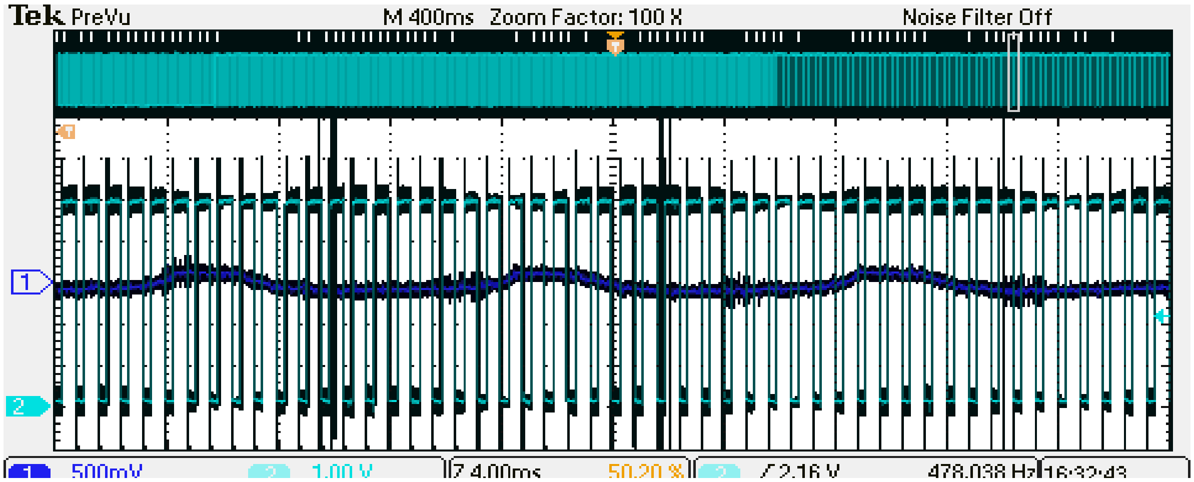


Fig-12.1 Response of PI Controller with change in set point

VII. CONCLUSION

The main contribution of this paper is to control the boost pressure of the turbocharger unit of the wankel engine when it works in higher altitudes and it is done successfully by real time testing with the engine. It also safeguards the home and makes it more secure and safe.

The future investigation can be done to test the whole setup at different altitudes whereas the setup is tested at ground level over here.

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