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Electronics
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ELECTRICAL POWER ENGINEERING

Design of Speedometer and Recording System for Diesel Electric Locomotive

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Abstract— The paper describes design of speed measuring system and display systems are constructed in Myanma Railways. These systems are based on microcontroller, digital logic circuitry, programming as well as the 7-segment LED display. There are two portions in this research work. They are speed sensing system and display system. The type of speedometer used in Myanma Railways is analog clock system. Significant advantages of the proposed system are the modern techniques. So the replacement of suitable and adaptable system is very important application of for Myanma Railways transport operation. This proposed system is a modified design of speed measuring and indicating instrument or speedometer based on electronic methods. A digital readout is also implemented. The design system is intend for long term used, high precision, vibration proof and low power consumption. The microcontroller selection, design and construction of one 7-segment display system and proposed circuits are designed and implemented test and results of the system are described.

Keywords— Speedometer, Recording System, Diesel Electric Locomotive, and 7 segment displays system.

I. INTRODUCTION

In diesel electric locomotive transport, the speedometer is one of the most essential devices which indicates and records the speed of the train during its running time. There are different types of speedometer such as analog, digital, and mechanical systems. The type of speedometer still being used in Myanma Railways is analog system. The analog system is the clock electro-mechanical system. This mechanism is outdated and it is impossible to replace it. So it is important to develop a more suitable and adaptable system in order to replace the existing system used in Myanma Railways transport operation. It is necessary to design and implement a low cost reliable and efficient system.
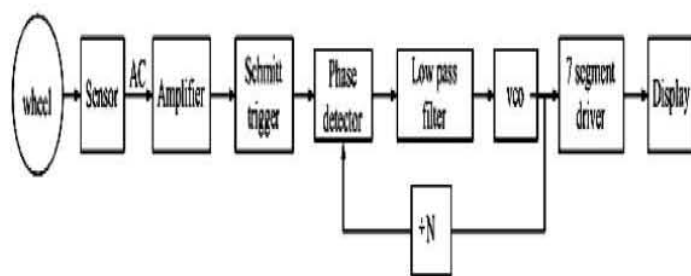
The implement block diagram of speed measurement system is shown in Fig. 1. In this research the magnetic pickup or variable reluctance sensor is used. Sensor output voltage is AC signal and it is about 400mV.This small signal sensor output is needed to amplify. So the amplifying amplifier LM 324 (Low Power Quad Operational Amplifiers) is used in this research. This amplifiers output signals is passed through the Quadruple 2-input NAND Schmitt trigger (HEF 4093 gates).Here, in Schmitt trigger circuit, HEF 4093 is used as a wave and pulse shapers. This Schmitt trigger output is input of the Micro power Phase Locked Loop (PLL CD 4046) and strip chart recorder. Using a phase-locked loop as the basis for the tachometer does a lot to simplify the design of the circuit. The locomotive speed is not constant. The accuracy of the measurement and the stability of the output relies on the design of the loop filter in PLL. The output of a VCO (Voltage- controlled Oscillator) is routed to a phase detector. The phase detector compares the VCO's output with the input frequency of Schmitt trigger. A dividing circuit can be installed between the output of the VCO and the input of the phase detector to make the PLL even more useful. The VCO output can be made equal to the output of Schmitt trigger frequency. The VCO output frequency is displayed in the frequency counter. As a frequency counter, PIC 16F628 is introduced. The display is made equal to the speed of the locomotive in miles/hr and km/hr.

Fig. 2 shows, the R.P.M of wheel is sensed by DC chopper circuit. DC chopper circuit is provided with 24V excitation and its output is variable AC voltage to drive the receiver motor. Mechanism of speedometer is derived by motor and the function of the speedometer is to record and indicate the speed of the locomotive.
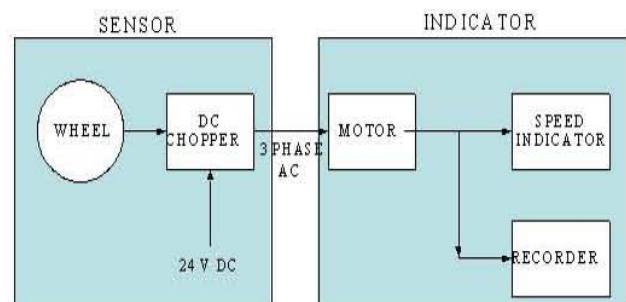

Fig 1. Implement block diagram of speed measurement system.

Fig. 2. Block diagram of Old type speed measurement system.

II. Research Direction

There are two portions in this research project. They are speed sensing system and 7-segment display system. In the speed sensing system the magnetic pickup (or) variable reluctance sensor and gear toothed wheel are included. In this sensing system consists of various sensors that monitor the controllers and other relevant data from the transmitter. There are many types of speed sensors such as variable reluctancesensor, Hall Effect sensor, optical sensor, Doppler radar sensor and magnetoresistive sensor. Among than variable reluctance sensor is more accuracy than other. The variable reluctance sensor type has been proposed. The vehicle speed is measured by a variable reluctance sensor that detects the rotation of a gear toothed wheel on the output shaft of the gearbox. The speed is based on counting the number of pulses output by the vehicle sensor

A. Magnetic Sensor Selection

The internal construction of the typical variable reluctance sensor is a magnet; pole piece and coil are shown in Figure 3. A magnetic field (lines of flux) extends from the magnet, through the pole piece and coil out into the air space at the end of the sensor. The return path of the magnetic field is from the air space to the other end of the magnet. As a ferrous object approaches the tip of the pole piece, the magnetic field increases and then decreases as the object moves away from the pole piece. The snap or the rapid change in the magnetic field induces an AC voltage signal in the coil. With an ideal target and matching sensor, the induced voltage is in the shape of a sine wave. The amplitude of the voltage output is proportional to the speed of the ferrous objects passing the pole piece.

The following information is supplied for assistance in selecting the proper sensors for your particular applications. The sensor output voltage depends on:
1) Surface Speed - speed target passes pole piece
2) Gap - distance between target and pole piece
3) Target Size - geometric relationship of pole piece and target
4) Load Impedance - connected to sensor

The surface speed of a gear depends upon its diameter and RPM. Surface speed is expressed in terms of inches per second (IPS).Please submit your manuscript electronically for review as e-mail attachments. When you submit your initial full paper version, prepare it in two-column format, including figures and tables.
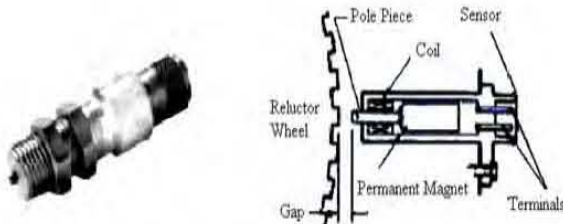

Fig. 3 Internal configurations of typical sensors

There is an optimum pitch (or tooth size) to obtain the highest possible output from a sensor, but this is seldom necessary. Fig. 4 illustrates the relationship of tooth size and spacing for optimum magnetic sensor output. Using a fine tooth gear, relative to a large pole piece diameter sensor, results in a lower generated voltage because the flux also passes into adjacent teeth, resulting in a lower total flux variation. The relationship between pole piece diameter and gear pitch and its effect on the output of a sensor is described in Table A. The load impedance, with relation to the internal impedance of the sensor, dictates the amount of sensor output voltage that will be seen by that load.
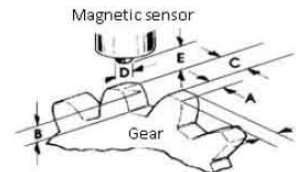

Fig. 4 Sensor output as a function of gear tooth

B. Design of Gear tooth

Diameter of collector cone = 70.2mm = 7.02m

Circumference (c) $= \pi D = \pi \times 70.2 = 220.538$ mm

Teeth top surface (sensor pole piece Diameter) (T) = 4.7 mm

Surface between teeth (S) $= 1.47 \times 4.7 = 6.909$ mm

Number of teeth $= \dfrac{C}{T+S} = \dfrac{220.538}{4.7+6.9} = 19$

C. 7- segment display systems

The digital electronic displays are very important in industry, home and public applications. There are several kinds of display systems constructed by microcontrollers (PICs). The PICs microcontrollers are generally compact construction, small size, low power consumption and suitable price. Display unit such as light Emitting Diode (LED), Liquid Crystal Display (LCD) and Cathode Ray Tube (CRT) can be used as a basic element of a display unit. The LEDs are very light weight, long life expectation and the cheapest cost of the three major display mediums. In this research project 7-segment (LED) display unit propose to be used.
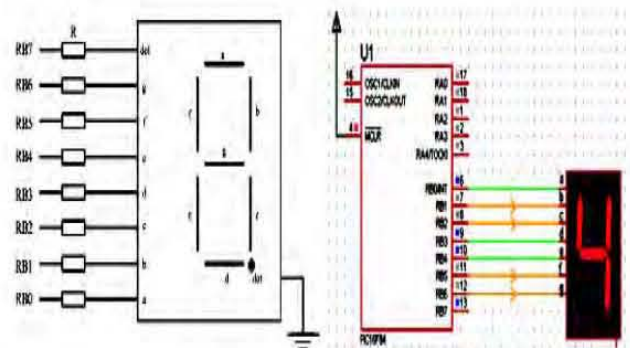

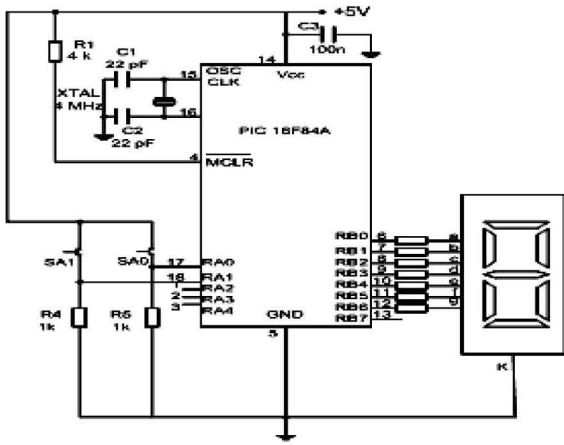Fig. 5 Basic construction of 7-segment display system

Fig. 6 Microcontroller (16F84A) base 7-segment display systems.

D. Implemented Speed Measuring System

To measure the speed of locomotive during travel in mile/hr. In this project speed measuring by using magnetic pickup sensor and display with 4 digit seven-segment LED by using PIC 16F628.It has accuracy for the measuring the speed of locomotive. Fig. 7 shows the schematic diagram of implemented speed measurement circuit.
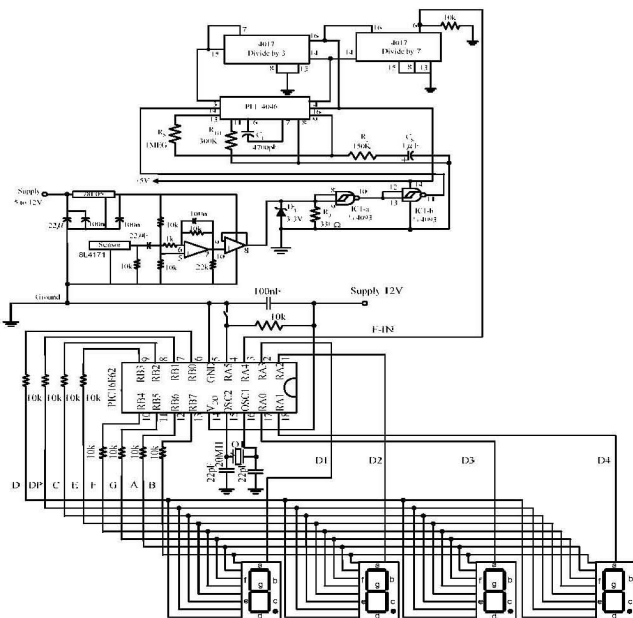

Fig 7 Schematic Diagram of Implemented Speed Measurement Circuit

In this project the magnetic pickup or variable reluctance sensor is used. The amplifying amplifier LM 324 (Low Power Quad Operational Amplifiers), the Quadruple 2-input NAND Schmitt trigger (HEF 4093 gates), the Micro power Phase Locked Loop (PLL CD 4046), decade counter or decoder IC (4017) and frequency counter circuit using PIC 16F628 are used in this project. The implemented circuit diagram is shown in Fig. 7.

III. TEST AND RESULTS

This research work includes the speed sensor using magnetic pickup sensor (or) variable reluctance sensor (VRS). The output signal of a VRS sensor is an AC voltage that varies in amplitude and wave shape as the speed of the monitored device changes, and is usually expressed in peak to peak voltage. One complete waveform (cycle) occurs as each actuator passes the sensing area (pole piece) of the sensor.

A permanent magnet is the heart of a VRS sensor and establishes a fixed magnetic field. An output signal is generated by changing the strength of this field. This is caused by the approach and passing of a ferrous metal target near the sensing area (pole piece). The alternating presence and absence of ferrous metal (gear teeth) varies the reluctance, or "resistance of flow" of the magnetic field, which dynamically changes the magnetic field strength. The change in magnetic field strength induces a current into a coil winding which is attached to the output terminals. If a standard gear is used as an actuator, this output signal would resemble a sine wave if viewed on an oscilloscope. Fig. 8. shows sensor detects the rotation of a gear toothed wheel. The speed is based on counting the number of pulses output by the vehicle sensor.

By using following equation, it can be calculated the output frequency of the collector cone. In this Equation the maximum revolution per minute of collector cone is 800 RPM and the number of teeth on flywheel is 19 teeth. So the magnetic pickup sensor sends 19 pulses which are proportional to one revolution of gear teeth.

Maximum Frequency (Hz)

$$= \frac{\text{Number of Teeth on Flywheel} \times \text{RPM}}{60}$$

$$= \frac{19 \times 800}{60}$$

$$= 253.33 \, \text{Hz}$$

1 revolution = 19 pulses
Locomotive wheel Diameter = 1000mm
By using this equation can be calculated the circumference of wheel.

Circumference of wheel = πD miles/revolution

$$= \frac{\pi \times 1000 \times 0.039}{12 \times 5280}$$

$$= 1.952 \times 10^{-3} \, \text{miles/revolution}$$

$$= 1.952 \times 10^{-3} \times 1 \times 60 \, \text{miles/hr}$$

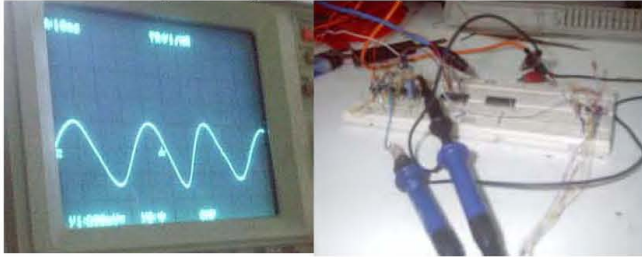Fig. 8 Testing the rotation of gear toothed wheel

Fig. 9 Output waveform of Sensor

Fig. 10 Proposed circuit testing results

Fig. 11 Photo of Motor Drive with Speed Measuring Circuits

By using the variable speed motor drive to rotate the toothed-gear, the display speed and calculated are compared. Figure 11.shows the photos of the test experiment.

TABLE I.
Speed Measurement by using Variable Speed Motor
(0-600 RPM)

Motor (RPM)	Calculation (mile/hr)	Counter Display (mile/hr)	Error (mile/hr)	Error %
60	4.68	4.80	0.116	2.4
150	11.71	11.8	0.090	0.8
210	16.30	16.6	0.300	1.8
300	23.43	23.7	0.280	1.2
360	28.10	28.5	0.400	1.4
420	32.78	33.2	0.420	1.3
480	37.47	38.0	0.530	1.4
540	42.15	42.7	0.550	1.3
600	46.84	47.5	0.660	1.4

The two graphs are drawn on the same scale and compared. It was found that there become some errors between the calculation and counter display when the tested speed reaches above 30 mph.
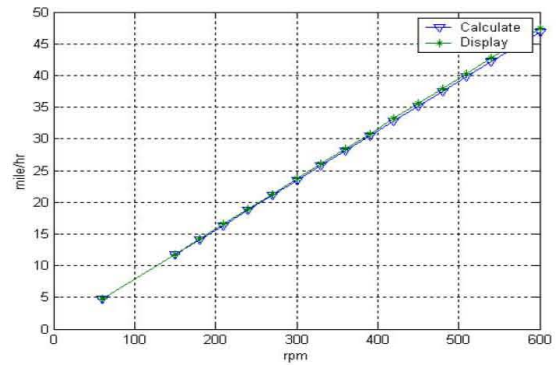

Fig 12.shows the graph of motor RPM Vs counter display (miles/hr).

Table I. Provide the speed measurement results for variable speed range between 0 mph to 50 mph. Figure 12 shows the graph of motor RPM Vs counter display (miles/hr).

IV. CONCLUSION

In conclusion the measurement system is accurate within 1 mile/hr or 1.609 km/hr and the system proved workable from technical point of view. The addition of speed computation circuit and speed tripping sections should be performed so that Myanma Railways can use the speed trip controls on the engine. Some additional hardware and software are required and further research can be considered. The selection and purchase of magnetic sensors is considered more feasible than opto- sensor system due to requirements such as ruggedness, durability and robustness. It is hoped that these additions can be implemented using magnetic sensor amplifiers such as LM 2917/LM2907 integrated circuits. The software requirements can be implemented in PIC or 8051 microcontrollers and some study of engine requirements should be performed before implementation. This will require timing and signal amplified data acquisition tests to be done at Myanma Railways.

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