Harmonics reduction of a noisy optical speed sensor signal of DC Motor Drive using LabVIEW

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Abstract-This paper presents an active signal filter design to achieve the harmonic control function for speed sensing signal which directly determine the overall performance of a DC motor drive. Presence of harmonics in speed sensing signals causes the system to be unstable. An algorithm is implemented to sense pulse pattern per revolution for harmonic detection and compensation are presented. Existing algorithms usually need a large amount of computation, and the compensation effect of specified order harmonic is also limited. DC side capacitor voltage at sudden change of load is affected by the algorithm as well. This paper proposes a new algorithm for harmonic detection and compensation in which a band-pass filter with frequency of nth harmonic is designed in fundamental frequency to extract random harmonic signals. The effectiveness filter circuit and of this new algorithm are verified by experimental results using LabVIEW.

Keywords: speed sensor, optical encoder , ADC, IR LED, LabVIEW.

Introduction-

Recently power electronics devices are used in large-scale application and the amount of various nonlinear loads has been increased rapidly. In electric drives waveform distortion and harmonic problem is becoming more and more serious; hence the research and application of harmonic control devices have become a hot research topic [1–3]. The main filter for this purpose is a passive power filter (PPF) and removes harmonic or prevents harmonic spreading by adding extra impedance branches to a system.

Generally digital speed input reference is provided to the DC motor speed controller to control the speed of motor. The speed sensor signal is discussed in this paper. That digital input is provided to through analog to digital (A/D) converter. The control circuit has been implemented digitally using LabVIEW.

Hardware Circuit of Speed sensor

The speed sensor circuit uses an IR sensor device which works by reflecting infrared light and detecting the reflecting with a photo transistor that is tuned to the same frequency of light. The circuit diagram of the speed sensor circuit is shown in Fig 1(a). The LED is mounted ahead of the photo-transistor, where the emitted light from the LED directly shine into the photo-transistor. Appropriate values of resistances are in series with both the LED and photo-transistor to limit the current. A metal strip was attached to the motor shaft. When the strip passes between the LED and IR sensor, a square wave pulse signal was obtained at the output of the transistor BC 548. The infrared LED and phototransistor are contained in plastic moulded package and placed below the motor shaft. As the metal strip passes through the gap, the emitter light beam becomes interrupted and the sensor output shifts from a closed state to an open state. When the IR receiver receives infrared, it will generate voltage at its pin. The generated voltage is in the range of 0V to 5V. The voltage will drop to zero if there is no infrared received. The comparator will compare the output voltage of the IR receiver with an input voltage through a resistor. The comparator able to compare both input voltage and generate either 0V or 5V. The speed sensor circuit has been developed using the principle of optical encoder which is shown in Fig.1 (b).

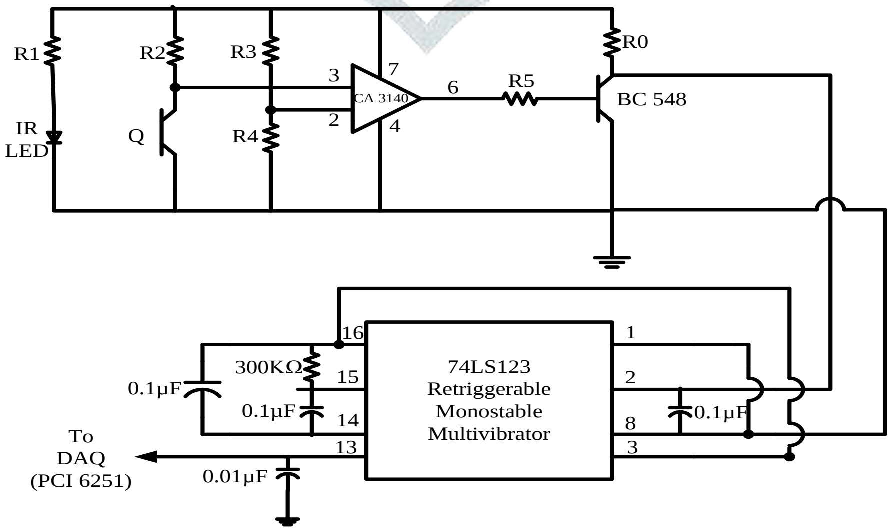


Fig 1(a) Circuit diagram of speed sensor circuit (R1=470Ω, R2=100KΩ, R3=R4=10KΩ, R0=3.3KΩ).

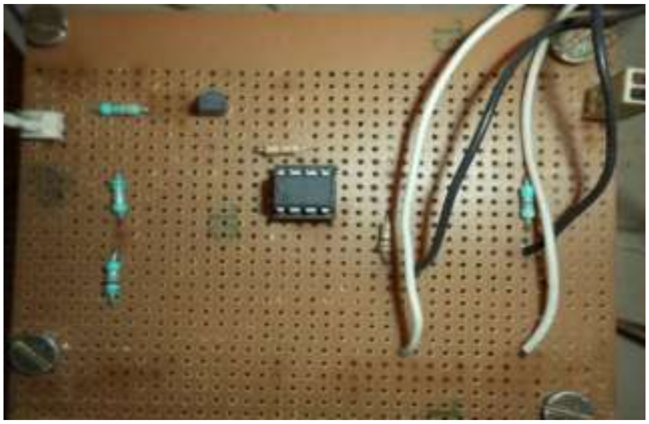


Fig 1(b) Hardware development of speed sensor circuit (CA 3140 is a 4.5MHz BiMOS Op-Amp with MOSFET input and bipolar output).

Use of Lab VIEW with DAQ in Hardware

For this experiment which combines measurements, automation and control, virtual instrumentation (VI) platform has been used. Virtual instrumentation is defined as the combination of measurement and control hardware and application software with industry-standard computer technology to create user-defined instrumentation systems. This platform provides the combination of measurement and control hardware and application software with industry standard computer technology to create user defined instrumentation system. It also provides the flexibility to modify the system to meet unpredictable needs. The modular property of VI makes it easy to add new functionality. LabVIEW contains a comprehensive set of tools for acquiring, analyzing, displaying, and storing data, as well as tools to help troubleshoot failures in scheme and code program. LabVIEW is a graphical programming environment, which can be used to built data acquisition and instrument control application. LabVlEW has been used successfully for many years in test and measurement applications due to the ease of graphical programming and its wide array of functionality for interfacing directly to instruments, sensors and actuators. This connectivity to I/O has also enabled LabVIEW to be used for control applications. When control and measurement capabilities are integrated into a single development platform, the engineering effort to program the automation task is greatly reduced. If the task needs to be altered in the future to accommodate a new part or technology, the associated re-engineering effort is at so greatly reduced.

The LabVIEW software is composed with two main elements that are front panel and block diagram respectively. Front panel is a graphical user interface that is used to display data and control parameter, and block diagram implements user defined program.

accommodate a new part or technology, the associated re-engineering effort is at so greatly reduced.

Peripheral Component Interconnect (PCI-6251).

Typical PCI card.

- 16-bit Resolution(ADC)
- Sampling rate

Maximum
1.25 MS/s single channel,
1.00 MS/s multi-channel

Fig 2. PCI 6251 Card

All of the input (measured) and output (generated) signals are connected with the National Instrument data acquisition card (DAQ). This card is controlled by LabVIEW (VI) software. Fig.2 shows the typical PCI 6251 card used for this application. The measured waveforms of speed and current are plotted on the labVIEW front panel in real time. Fig. 3 shows the different signal communication system using DAQ. The circuit connection for communication between sensor and computer is shown in Fig. 3.

Procedure to use LabVIEW with DAQ software.

Fundamental task of a DAQ system is to measure and generate real-world physical signals

- Data acquisition (DAQ)
- Connecting Signals
- Simple DAQ application

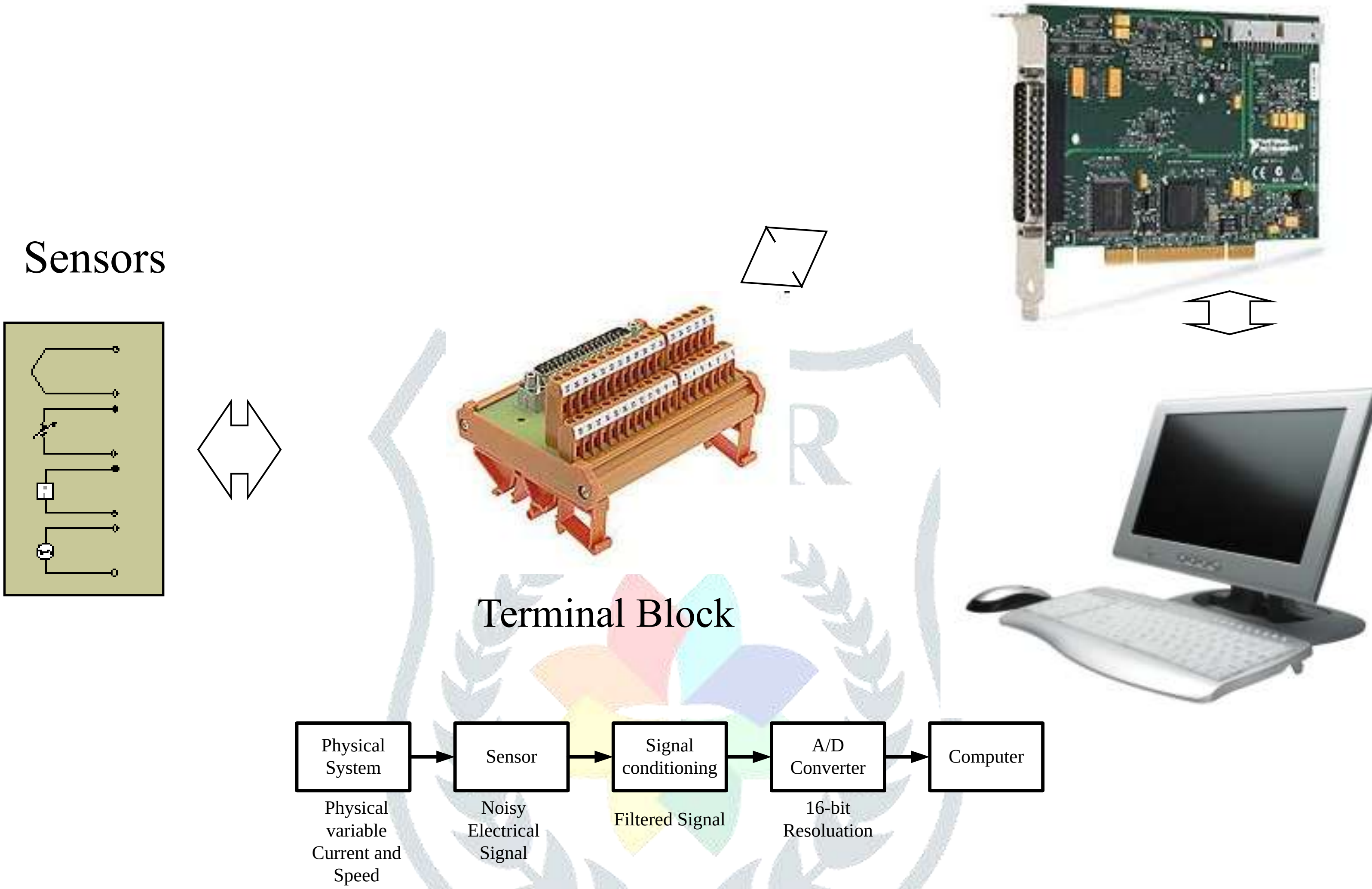


Fig 3 Communication between sensors and computer.

Data Acquisition

Data acquisition and control hardware generally performs one or more of the following functions such as Analog input, Analog output, Digital input, Digital output and Counter/timer functions.

The nature of the Analog Signal depends on the parameters such as

- Single or Differential input
- Range
- Resolution
- Sampling rate
- Accuracy
- Noise

Signal Conditioning

- Signal conditioning circuits improve the quality of signals generated by transducers before they are converted into digital signals by the PC's data-acquisition hardware.
- Examples of signal conditioning are signal scaling, amplification, linearization, cold-junction compensation, filtering, attenuation, excitation, common-mode rejection, and so on.

Speed measurement using LabVIEW.

For measuring the speed accurately which is essential for closed loop operation several tests has been conducted in the laboratory. Fig. 4 shows the implementation of the closed loop speed controller with speed estimation in LabVIEW environment.

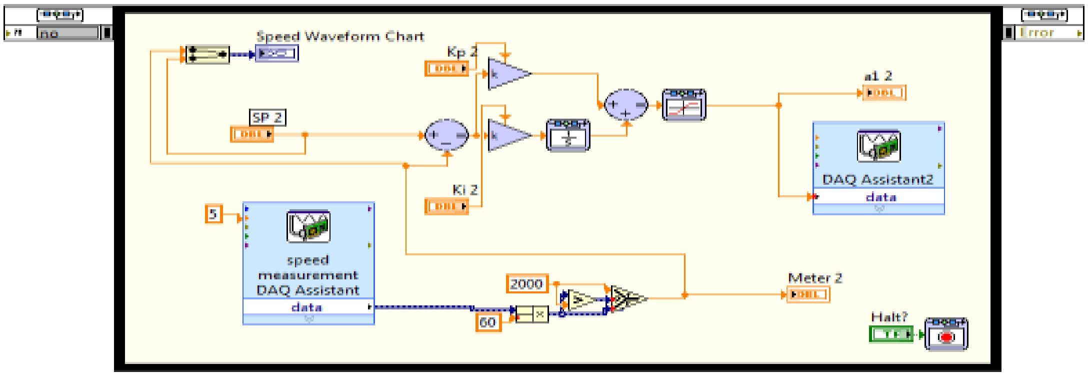


Fig 4 Implementation of the closed loop speed controller with speed estimation in LabVIEW.

Flow chart of the speed estimation algorithm

Once the signal is acquired from the speed sensor circuit, the speed estimation is accomplished by LabVIEW by incorporating the following algorithm. This is shown in the flow chart shown in Fig. 5. Here X is the number of pluses per second which is output of the speed sensor circuit.

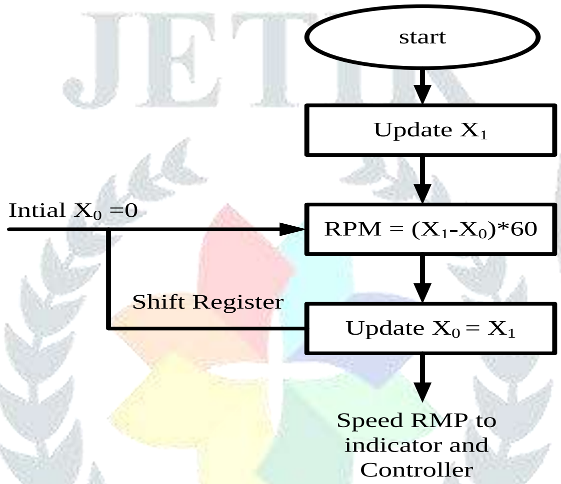


Fig 5. Flow chart of the speed estimation algorithm.

Issues of speed estimation in LabVIEW.

There are some issues regarding the speed estimation which are discussed in this section. The value of estimated speed suddenly changes to a large value when the LabVIEW program starts. Fig. 7 shows the output signal of the sensor circuit which contains noise. There was variation of estimated speed value when the motor runs at high speeds. The estimated speed looks like a noisy signal. The jumping value of estimated speed causes the control system to be impossible to control the motor speed. In order to estimate accurate speed of the motor a filter circuit has been developed for the encoder signal which is shown in Fig. 6. The filtered signals are shown in Fig. 8.

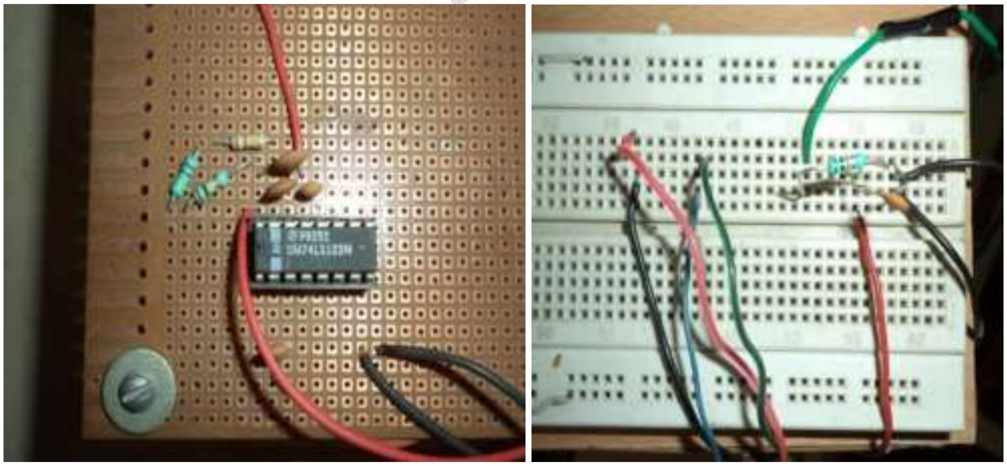
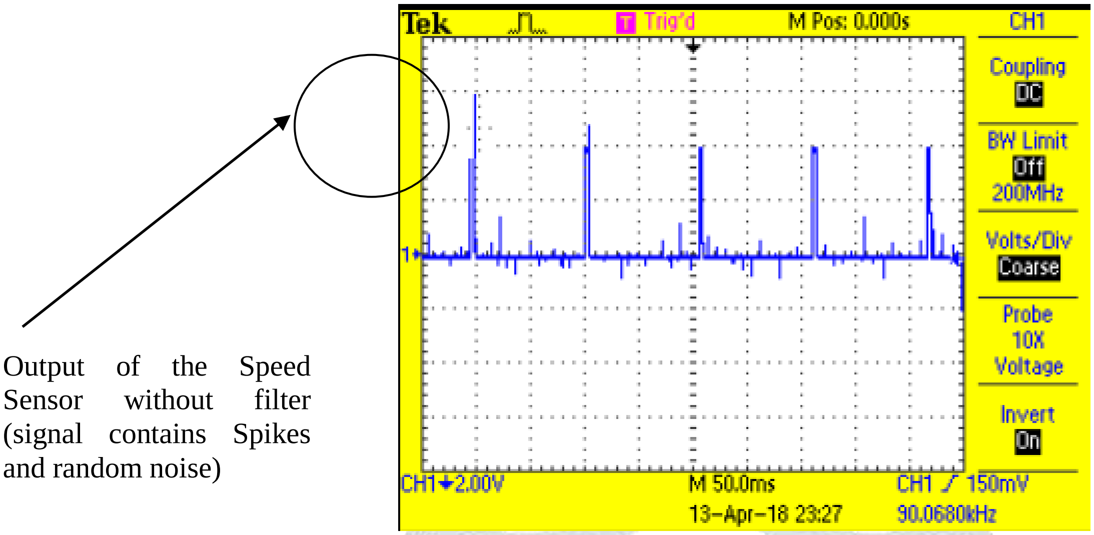


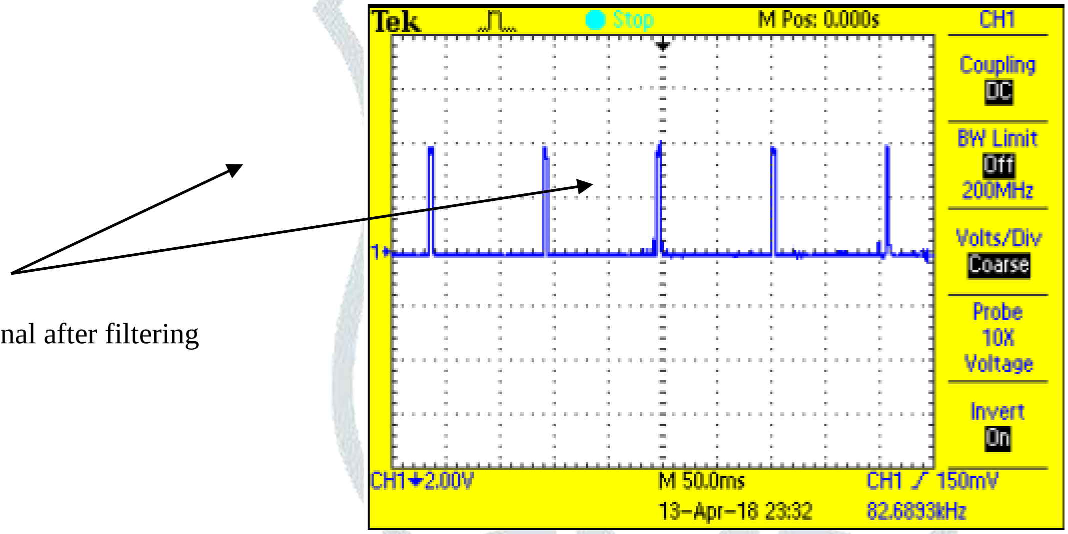
Fig 6 (c) The signals of the speed sensor circuit are passed through a retriggerable monostable multivibrator (74LS 123) and low pass filter (R-C) circuit



Coupling DC
BW Limit Off 200MHz
Volts/Div Coarse
Probe 10X Voltage
Invert On

Output of the Speed Sensor without filter (signal contains Spikes and random noise)

Fig 7. Output signals of the speed sensor without filter.



Coupling DC
BW Limit Off 200MHz
Volts/Div Coarse
Probe 10X Voltage
Invert On

Signal after filtering

Fig 8. Output signals of the speed sensor with filter.

Fig. 9 shows the measurement of speed at the rated speed of the motor. The converter output voltages are shown for motor speed of 1500 rpm and 400 rpm respectively in Fig 10. Fig 11.shows DC Bus voltage of 180 volts at Motor Speed of 1500 rpm and 50 volts at Motor Speed of 400 rpm respectively.

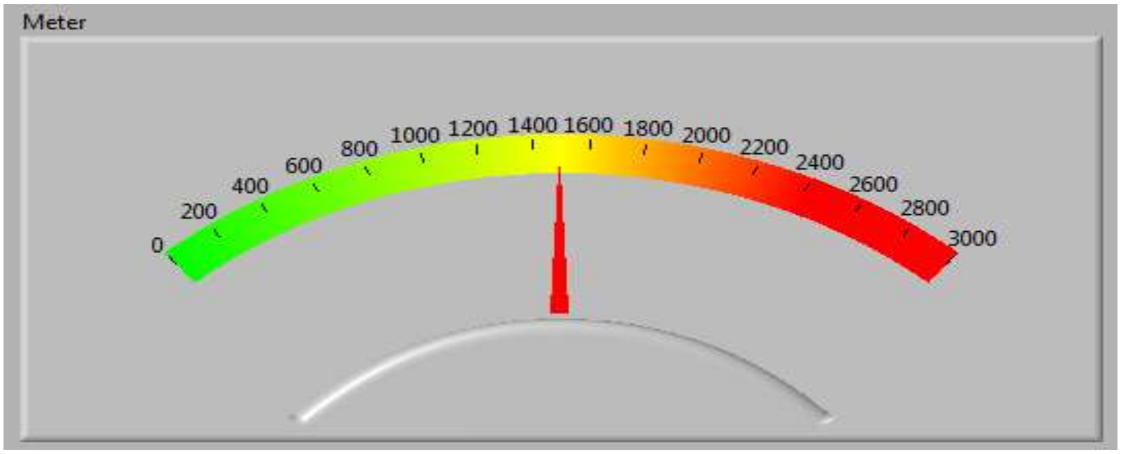


Fig 10 Front Panel showing the motor speed at 1500 rpm.

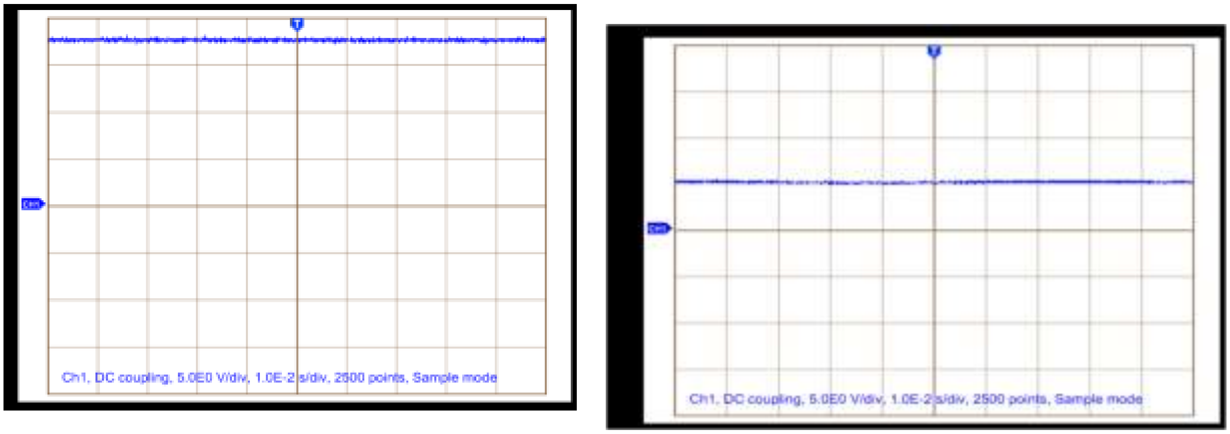


Fig 11. DC Bus Voltage (180 volts) at Motor Speed of 1500 rpm and 50 volts at Motor Speed of 400 rpm respectively.

CONCLUSION

In this paper a speed sensing circuit is developed and the analog output signal contains harmonics which is undesirable for closed loop control of electric drives. to overcome this problem a filter circuit is proposed along with a algorithm to minimise the harmonics which is implemented in LabVIEW. This technique is used to control the speed of the motor. The output of the speed sensor is pulses per revolution and then it is converted to RPM form. The detail speed sensing circuit and algorithm are presented in this paper. The experimental results are presented and show satisfactory results. The same technique can be used in similar application.

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