DESIGN AND IMPLEMENTATION OF DC MOTOR SPEED CONTROL BY ARMATURE VOLTAGE VARIATION USING WIRELESS TECHNOLOGY

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ABSTRACT

This paper presents a scheme for the speed control of a dc motor by changing its armature voltage using wireless technology. Here the remote node consists of two RF transceivers, along with signal conditioning circuits. The motor speed is sensed by an encoder, and feedback signal is transmitted wirelessly to the Base Station equipped with another RF transceiver module. The required control action is taken by the Base Station PC and again transmitted wirelessly to the remote node. This work does not need any WSN platform and remote nodes do not require additional processor hardware.

Keywords: Application Programming Interface, API data frame, Encoder, RF transceiver, Xbee, Zigbee

I. INTRODUCTION

A Wireless Sensor Network (WSN) is a collection of a large number of smart sensor nodes, consisting of radio frequency (RF) transceivers, sensors, micro-controllers and power sources – thereby imparting computational and communication capabilities along-with sensing functions to them. Advances in wireless sensor networking technology have led to the development of low cost, low power WSNs which are being increasingly used in diverse application areas not only for sensing and data acquisition but also for controlling end devices [1], [2].

A general WSN protocol consists of the application layer, transport layer, network layer, data link layer, physical layer, power management plane, mobility management plane and the task management plane. Currently two standard technologies are available for WSN : ZigBee and Bluetooth. Both operate within the Industrial Scientific and Medical (ISM) band of 2.4 GHz, which provides license free operations, huge spectrum allocation and worldwide compatibility [3].

In this work wireless technology has been used to control the speed of a dc motor at the desired value by changing the armature voltage. The remote node consists of two RF transceiver devices, digital to analog converter, and some signal conditioning circuits. Here a single remote node has been used for both sensing and actuation but with separate RF transceivers. The control algorithm resides in the Base Station PC. The control output generated there is transmitted in coded form by the RF transceiver to the Remote node. The control signal received at the Remote node is suitably processed to effect change of speed.

II. WIRELESS TECHNOLOGY

Wireless technology is based on RF data transmission and ZigBee is a standard RF communication protocol for low-power, wireless mesh networking and XBee is a brand of radio that supports a variety of communication protocols, including ZigBee, 802.15.4, and WiFi, among others. ZigBee defines three different device types: coordinator, router, and end device having different functions and privileges. Each zigbee network is defined with a unique PAN identifier (PAN ID) which is common among all devices of the same network. ZigBee devices are either preconfigured with a PAN ID to join, or they can discover nearby networks and select a PAN ID to join. XBee modules support 16 operating channels in the 2.4 GHz frequency band.

Data transmission in Zigbee can be either unicast or broadcast. Unicast transmissions are sent from one source device to another destination device. Broadcast transmissions are intended to be propagated throughout the entire network such that all nodes receive the transmission. Xbee module has two communication modes - Transparent mode and API mode. In transparent mode, The data received by the DIN pin is transmitted via antenna, and the data received via antenna is sent out through the DOUT pin [4].

The module configuration parameters are configured using the AT command mode interface. API (Applicatio Programming Interface) extends the level to which a host application can interact with the networking capabilities of the module. API mode transfers data in formatted frame. The data needs to be formatted according to the frame type as per the requirement of the application. There are different types of frame such as ‘ AT Command’ type, Transmit

Request type, ‘Explicit Addressing Frame’ type, ‘Remote AT command’ type and many more. In this work for sending the control signal to the remote device ‘Remote AT command frame ‘ type is used provided the IO sampling rate for the RF modules are properly set. For getting the present value of 16 bit network address of the RF modules ‘Transmit Request frame‘ type is used.

III. DATA TRANSMISSION USING API

API data frame comprises of Start Delimiter, Length, Frame Data and Checksum. API framed data starts with ‘Start Delimiter’ as 0x7E, ‘Length’ indicates the number of bytes of data being sent. It is divided in 2 bytes (MSB & LSB) for the length over 255 bytes. The ‘Frame Data’ is made up of ‘API Identifier’ and ‘cmdData’. The first one specifies the selected frame type and the last one comprises of ‘Frame ID’, ‘Destination Address’, ‘Options’ and ‘RF Data’. The ‘Frame ID’ identifies the UART data frame for the host to match with a subsequent response. If it is zero, no response is requested. There are 64 bit ‘Destination Address’ as well as 16 bit ‘Destination Address’. The first one just represents the serial number of the destination XBee module and the second one indicates the destination network address. Both of these if not known can be represented by FFFE for broadcasting to all devices including sleepy devices. By giving right byte value to the ‘options’ special functions can be allowed. Next is the RF data for transmission. The ‘Checksum’ is calculated by subtracting the sum of the byte values after ‘Length’ upto ‘Checksum’ from FF [5].

IV. SYSTEM DESIGN

The major hardware components include XBee Series2 IC, DAC 0808, LM 317, F/V Converter, I/V Converter, Speed sensor, DC motor (12 V, 0.1 A, 30 rpm), power supplies. The circuit developed is shown in Fig 1.

The Xbee Series 2 IC is a microchip from Ember Networks and requires 3.3V power supply for its working and has a whip antenna for RF transmission. Its indoor range of communication is 30m whereas outdoor range is 90m. In this work three XBee series2 modules have been used, one as a coordinator (base station) and other two as end device one for sensing and and the other for actuation, henceforth referred to as Sensing XBee and Actuation XBee respectively.

The XBee USB Adapter provides a serial interface using the FTDI USB serial interface chip (FT232RL) and virtual COM port drivers to emulate a serial COM port. This interface has been used to send/receive serial data between the PC and the coordinator XBee for communication and configuration.

For configuring the XBee modules as coordinator or end device, XCTU software of Digi International is required. The baud rate (9600) setting for communication, PAN ID verification, channel synchronization, destination address setting for both the coordinator and end device are done through this software. Loop back testing ensures that the two XBee modules communicate with each other properly and at the configured Baud Rate. The control algorithm has been implemented in C++.

Remote Node

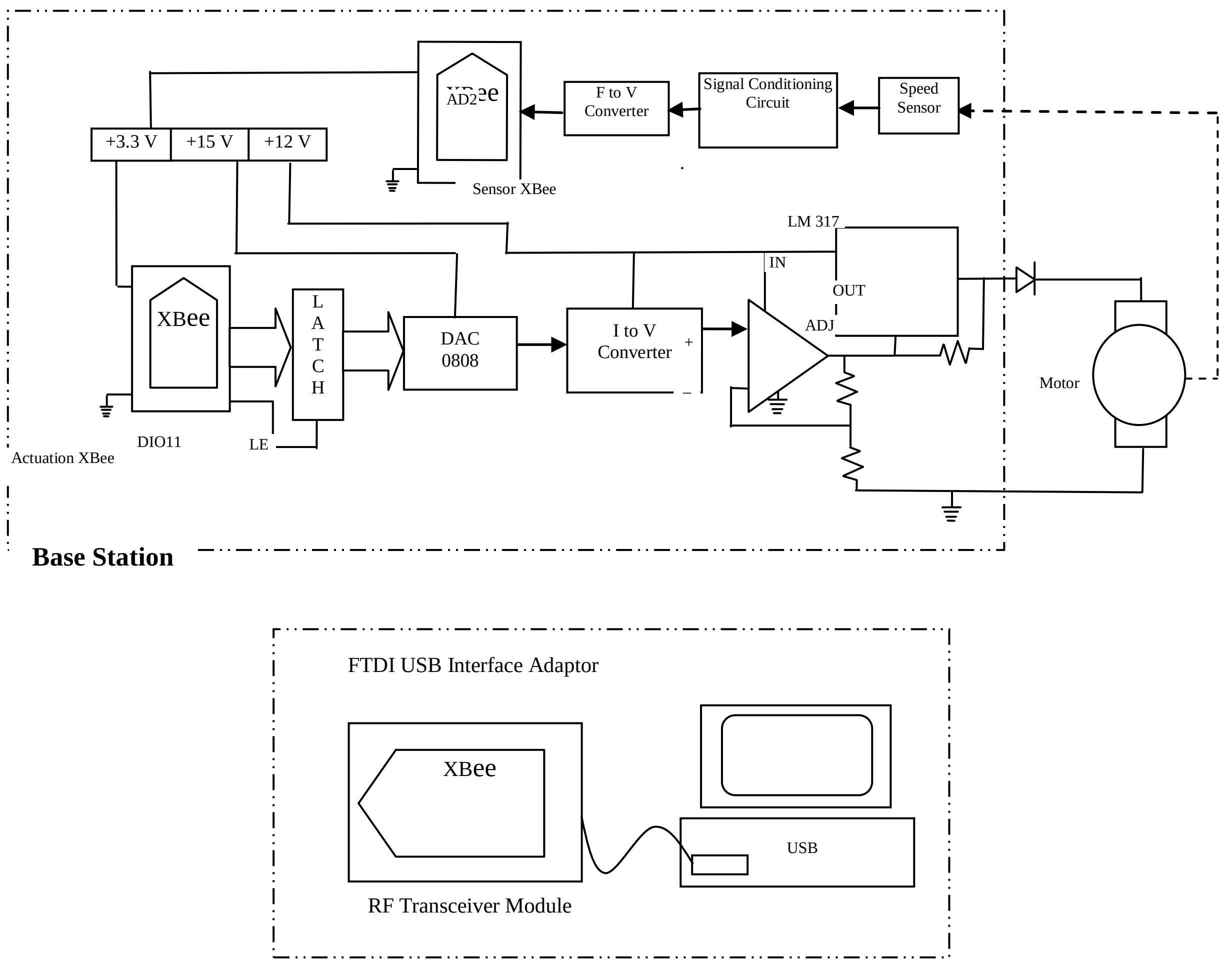

Fig 1 : System Architecture

V. CONTROL METHODOLOGY

The configuration of the Remote Node XBee(s) is done with the XCTU software. Both the Xbee chips are configured as End Devices to function in the API mode. The AD2 input (ADC enabled) of the Sensor XBee has been used to acquire the motor speed signal (pin 18) and the IO sampling rate is set at one second. The DIO pins of the Actuation Xbee are configured as digital outputs. Once configured both the XBee chips are allowed to join the network so that they have the same operating PAN ID. To ensure this the Join Notification and Channel Verification must be enabled for both the Xbee chips.

The sampling rate enables periodic sampling and once the value is set the sensor signal is sampled and transmitted once in every sampling period. This configuration is done by setting parameter IR of the Sensor Node XBee to the appropriate hex value of the desired sampling period in milliseconds. The sensor data is transmitted by the Xbee in API format (API frame type 92 : IO Data Sample Rx Indicator) with the data coded in "Samples" variable (2 bytes) part of the frame. The analog value at the AD2 input pin is converted to 10-bit digital value by the internal ADC of the XBee chip. The maximum analog voltage that can be sensed being 1.2 V, the circuit components have been duly designed to match this requirement.

The control signal is sent from the base station to the Actuation Node Xbee in API format (API frame type 17 : Remote AT Command), for which the 16 bit network address (MY) of the Xbee chip is required. This information can be obtained from the Xbee chip immediately after it has joined the network by sending a Transmit Request (API frame type 10) to it. The Xbee responds by sending a Remote Command Response (API frame type 97) which contains its MY. The output of the control algorithm is converted to a digital 8-bit data which must be mapped onto the eight DIO pins of the Actuation Node Xbee. Two ASCII characters identify the DIO pin and the parameter value decides whether that pin is to be made high or low. (Refer Table 1). A ninth line, DIO11 has been used to enable the output of the octal latch as required, thus eliminating the need for any additional processor.

The signal processing circuits convert the digital data to the necessary analog signal for use by the actuator.

Table 1 : Data Coding in API frame type 17

DIO pin	AT Command in ASCII	HEX Value for the AT command		AT Command Data (HEX) to make		Used for
				Pin low	Pin high	
DIO0	D0	44	30	04	05	Control signal
DIO1	D1	44	31	04	05	
DIO2	D2	44	32	04	05	
DIO3	D3	44	33	04	05	
DIO4	D4	44	34	04	05	
DIO5	D5	44	35	04	05	
DIO6	D6	44	36	04	05	
DIO7	D7	44	37	04	05	
DIO11	P1	50	31	04	05	Hand-shaking

The analog-to-digital conversion of the analog value inside the XBee is an important factor in control accuracy. This being a 10-bit conversion, each bit represents a voltage of 1.172 mv, which corresponds to 0.03 rpm. This translates to a calculated accuracy of ± 0.1 % or better.

VI. RESULTS

The variation of speed with varying armature voltage is shown in Table 2. The data shown is the average of multiple runs. The results indicate conformance with the voltage - rpm characteristics of the motor (Fig 2).

Table 2: Experimental Observations

Voltage across the motor terminals (Volt)	No. of Rotations	Time Taken (Sec)	R.P.M
2	10	86.22	6.96
4	10	56.04	10.71
6	10	43.11	13.92
8	10	36.75	16.33
10	10	25.23	23.78
12	10	24.54	24.45

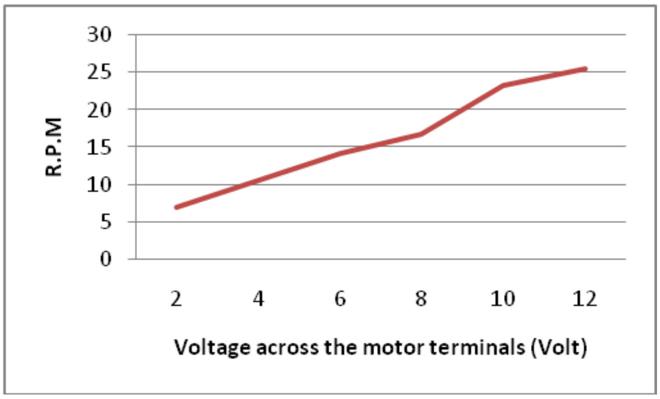

Fig 2 : Voltage – Rpm Motor Characteristics

VII. CONCLUSION

In this work the speed control of the dc motor has been implemented in closed loop. The motor used was a 12 Vdc Motor but this scheme can be applied to higher rated motors simply by increasing the power handling capability of the associated devices. The wireless methodology adopted can be seamlessly used to control other types of final control elements as well. By taking advantage of the processing features of the RF transceiver, the necessity of a micro-controller has been done away with – thereby substantially reducing the power requirements of the Remote Node. Moreover, advanced control algorithms can be easily implemented in the Base Station PC. Hence this work can be considered as a stepping stone to build robust but low cost schemes for wireless control of end devices in feedback loops.

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