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# Wireless Automation of an Electrical Drive using Bluetooth

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## Abstract

Industrial automation in the present day requires effective feedback-oriented mechanisms which can control as well as monitor electrical, electronic and mechanical systems. Traditionally, feedback based automation systems utilize wired communication interfaces to control parameters and monitor responses. Wireless means have decided advantages over wired means, such as elimination of physical interfacing wires, compactness, highly mobile usage facilities and ease of installation which save labor costs. Wireless operation can be facilitated by user-friendly interfaces which can be implemented by using software. Such user interfaces provide for control facilities as well as feedback reading facilities to and from the appliances.

**Keywords**: Electrical drive, Bluetooth module, microcontroller, Android application, user interface, serial communication.

## Introduction

Motion control is essential in a huge number of industrial and residential applications such as automobiles, aircraft, oil refineries, power plants etc. Electrical drives, which employ electric motors, are vital systems used for motion control. Functioning of an electrical drive is often time-critical and safety-critical, which makes effective closed-loop feedback provisions an absolute necessity. Control is generally established using wired interfaces. However wired connections have limitations: they are laborious to install, ease of access is sometimes circumscribed and they depend greatly on physical surroundings. Interruption in their operation caused by environmental factors may prove expensive to detect and repair.

The project aims to develop a system which replaces the wired connection between an electrical drive and the control terminal by a sophisticated wireless connection, while providing a user interface that facilitates convenient operation, control and supervision of the drive with minimal efforts on the user's part. This system would overcome significant drawbacks of wired interfaces, i.e. there would be no interruption of operation owing to physical damage and wireless Bluetooth technology would enable easier access to the device where physical wires and connections may be difficult to install. The system could be considered a primary step in the arena of wireless embedded control and automation of industrial appliances.

## Literature Review

Automation requires time critical and safety critical closed loop feedback mechanisms to ensure efficient and safe operation. Advantages of using Bluetooth and a microcontroller based system lie greatly in the ease of development and installation of a convenient mobile user interface which is implemented using Android. This is due to the availability of Bluetooth APIs (Application Programming Interfaces) in Android SDK(Software Development Kit) [11]. Further, the use of Bluetooth allows highly mobile access from different locations over different distance ranges. The following table classifies Bluetooth according to ranges [10]:

**TABLE I**
**BLUETOOTH CLASSIFICATION [10]**

| Bluetooth Class | Maximum Permissible Power | Typical Range |
|---|---|---|
| Class 1 | 20dBm | ~100 m |
| Class 2 | 4dBm | ~10 m |
| Class 3 | 0dBm | ~1 m |

The Bluetooth module is therefore chosen according to requirement, based on the class.

Microcontroller based systems provide for effective ways to transmit and receive data using serial communication. Since the microcontroller is a processing and controlling unit of the system, it must feature a

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powerful CPU, with preference to RISC (Reduced Instruction Set Computing) architecture. It must work by consuming minimal DC power and current.Advantages of employing a microcontroller instead of a Programmable Logic Controller (PLC) are: the availability of on-chip resources [5] and the ability to program the controller in embedded C, a powerful and flexible coding language. The choice of MSP430G2553 is justified owing to ultra-low-power consumption of 230 µA at 1 MHz, 2.2V in active mode [5].

## Technology Used

In this section the technology used in the design of the system is discussed.

***A. Bluetooth***

Bluetooth is a wireless standard for data exchange over short distances, which creates personal area networks (PANs) with high security level, which is an essential factor in this system. Bluetooth is managed by the Special Interest Group (SIG).

Bluetooth operates in the range of 2400-2483.5 MHz, guard bands included, which falls in the globally unlicensed short range RF band [10]. Bluetooth uses radio technology called frequency-hopping spread spectrum wherein the transmitted data are divided into packets and each packet is transmitted on one of the 79 designated channels. Since the introduction of Bluetooth 2.0 + EDR, π/4- DQPSK (Differentially Encoded Quadrature Phase Shift Keying) and 8-DPSK (Differential Phase Shift Keying) modulation is used between compatible devices, instead of the original GFSK(Gaussian Frequency Shift Keying). Bluetooth is a packet-based protocol [10].

**TABLE II**
**BLUETOOTH VERSION DATA RATES [10]**

| Bluetooth Version | Data Rate |
|---|---|
| Version 1.2 | 1 Mbit/s |
| Version 2.0+ EDR | 3 Mbit/s |
| Version 3.0+ HS | 24 Mbit/s |

Bluetooth Version 4.0 (called Bluetooth Smart) has been adopted on June 30, 2010.It includes Classic Bluetooth, Bluetooth high speed and Bluetooth low energy protocols. Bluetooth high speed is based on Wi-Fi, and Classic Bluetooth consists of legacy Bluetooth protocols. [10].

***B. Universal Asynchronous Receiver/Transmitter (UART)***

UART is actually a piece of computer hardware. It is generally incorporated into Integrated Circuits (ICs)and used for serial communication over serial ports of peripheral devices and the controller or processor. UART transmits data bits in a sequential manner from byte frame. At the destination or receiver, UART reassembles the data bits, again sequentially, to form data bytes. The underlying principle is the use of a shift register to convert data to and from serial and parallel forms.

UART communication forms an integral and critical part of communication used by this system.

***C. Android***

Developed by Android Incorporated, supported and later bought by Google, Android is an open-source software stack that includes the operating system based on Linux kernel, middleware, and key mobile applications, along with a set of API (Application Programming Interface) libraries for writing applications that can shape the look, feel, and function of the devices on which they run. It has been mainly designed for mobile devices such as smartphones and tablet computers which use touch-screen operation [1].

Android is open source and Google releases the code under the Apache License. Being open source, the software may be freely used, modified and distributed by developers. Android applications are primarily written in a customized version of the Java programming language [2].

The key elements of Android are a powerful software stack, consisting of a Linux kernel and a collection of C/C++ libraries; and the Dalvik Virtual Machine (DVM). Android uses DVM as its own customized Virtual Machine designed to ensure efficient running of multiple instances on a single device [1].

This system incorporates Android to develop a User Interface which provides convenient features to control and monitor the electrical drive.

## System Structure

This section discusses the general block diagram and the components used by the system.

***A. Block Diagram and Components***

Fig. 1 shows a generalized block diagram of the system.

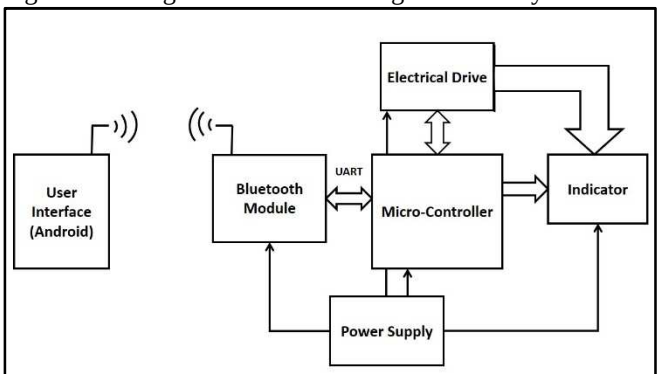


**Fig. 1 Block Diagram**

*1) User Interface:* This is developed as an Android-based application. The code is developed in Java and

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XML to create buttons, string entries and displays [11]. This application is installed on an Android mobile phone or tablet. The application uses Bluetooth hardware present in the Android phone and communicates with the Bluetooth module present at the drive-end. It provides a user interface for a number of functions:

- Switching the motor ON/OFF
- Setting priming speed.
- Setting different values of speed and duration of running. This will be set in a number of sequential steps with different settings. An override option will also be available.
- Displaying feedback to monitor parameters and detect faults.

*2) Bluetooth module:* This is used to enable Bluetooth communication with the User Interface. A Bluetooth module equipped with UART is preferred to facilitate serial communication. The proposed system incorporates the WT11 Bluetooth module by Bluegiga Technologies [6]. This module has inbuilt powerful iWRAP firmware [7] which enables users to access Bluetooth functionality with simple ASCII commands delivered over a serial interface.

*3) Microcontroller:* This is the processing and controlling unit of the system. This system uses the ultra-low-power MSP430G2553 device by Texas Instruments [4]. The microcontroller employs a Universal Serial Communication Interface (USCI) which, in the asynchronous mode connects the controller to the external system via TXD and RXD pins [4]. The UART mode features of the controller include 7 or 8 bit data with odd, even and non-parity; and independent transmit and receive shift registers. These features are essential in the system to process communication received or transmitted at the Bluetooth module. The controller generates TTL signals.

*4) Electrical Drive:* This is the primary component employed for motion control [3]. The drive consists of independent DC power source, power modulator block, DC motor, load (which is a pump), a sensing block unit and a controller unit. The drive in our system employs a brushless DC motor. The microcontroller controls the input to the drive's power modulator according to feedback received from the sensing unit regarding speed and temperature. The temperature is monitored by the sensing unit using anInsulated Gate Bipolar Transistor (IGBT) sensor.

*5) Power Supply:*All the blocks in the implemented system requires a $V_{CC}$ supply voltage of 3.3V. This is obtained by implementing a block which takes in a power source of 12V and regulates it to output 3.3V, which is then supplied to different parts of the system. The 12V input is obtained from an adapter which is powered from the mains supply.

This power supply block can be bypassed if a regulated voltage of 3.3Vis available directly using other sources. The circuit diagram of the implemented power supply block is shown in Fig. 2. The regulator used here is LD1117V33.

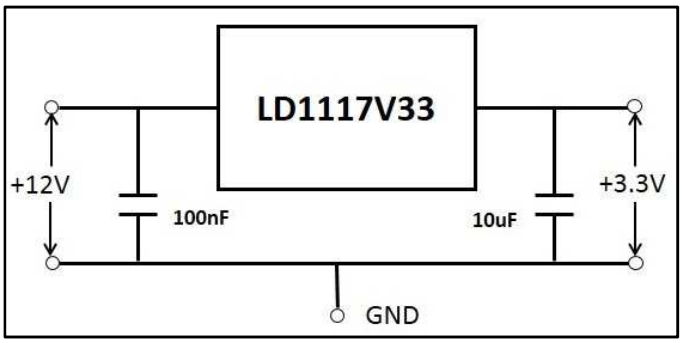


**Fig. 2 Power Supply – Implemented Circuit**

*6) Indication:* The indication block takes input from the controller, the power supply block and the sensing unit of the electrical drive. The indication is implemented as a simple array of LEDs and an LCD screento provide visual feedback about the functioning of each of the three blocks.

***B. Working***

The user interface is an Android application with facilities to control and monitor various parameters. When the application is switched on, it scans the vicinity for Bluetooth devices and detects the Bluetooth module incorporated into the receiver of the system. A wireless connection is thus established. The interface is provided with easy-to-use buttons for switching the motor ON or OFF. The user avails of an option list to set speed and duration of running. The initial priming speed can be set by selecting an appropriate value from another list of options. The speed is set in rpm. These control signals are processed by the controller which generates corresponding TTL signals as response, thus controlling the drive. The drive has sensors for speed and temperature, the output of which is fed back to the controller. The controller in turn processes the feedback and communicates via UART to the Bluetooth module. The Bluetooth module then transmits the feedback to the user interface, which enables monitoring of the drive.

## Results

Implementation is in progress at the Integrated Engineering Services (IES) Department, Larsen & Toubro Ltd, Powai. Till date, the work has yielded the following results:

*A. Power Supply Output*

Output of LD1117V33: +3.3V

*B. Bluetooth Module Testing*

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WT11 Bluetooth module is configured for a baud rate of 9600 bits/second. It has been tested by successfully interfacing it to a PC using the RS232 serial cable. The working is observed on the Windows HyperTerminal by sending AT commands.

*C. Android Application Development*

The Android application to detect remote online Bluetooth devices is developed using Android SDK on the Eclipse IDE and tested on an Android mobile phone. Currently the application is in progress and has been developed to scan for online devices. The following screen shots demonstrate the working:

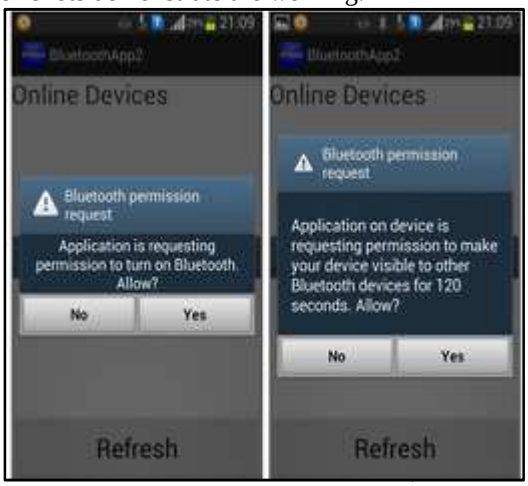


**Fig. 3 Android Application start-up screen**

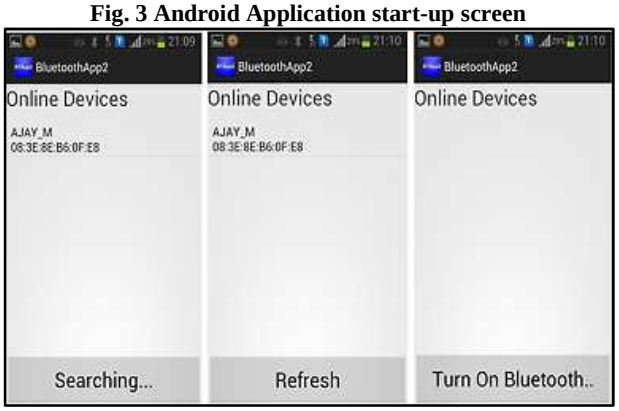


**Fig. 4 Android Application search-mode screen**

## Conclusion

The system once fully functional will enable wireless control and monitoring of the parameters of an electrical drive. The system will enhance automation and reduce the need for human effort, particularly by setting the motor speed in steps which execute sequentially. Thereby, a user will only need to configure these settings one time. In the event of on-spot changes being rendered necessary, the user can avail of an override option.

This is a foundation step into the domain of wireless control and automation. Future scope of wireless automation includes usage of flexible networks of microcontroller based systems to control and monitor a bank of electrical appliances in industrial and residential arenas. These networks would not be restricted to Bluetooth but would also use Wireless Fidelity (Wi-Fi), Radio Frequency Identification (RFID) and Zigbee etc.

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