An Efficient Algorithm for Increasing Modularity in IoT Based Automation Systems

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Abstract. IoT-based platforms allow for an integrated approach to digital systems. With the increase in complexity of devices and processes in industry and commerce, automation presents itself as a technological panacea in the form of IoT (Internet of Devices) based applications. This paper presents an adaptive, efficient, and affordable system architecture through which modularity in IoT-based automation can be realized. The proposed technique involves an IoT-based platform to coordinate, control, also calibrate microcontrollers connected to various sensors and devices. Using a web page or application as an interface, the system can be configured to operate diversified workloads via distributive control and remote monitoring. The flexible nature of the system allows for a modular approach to parameter design and system integration while allowing dynamic task allocation. Data available through feedback can be used to further streamline and orient tasks in real-time. This allows a single platform to multitask using an adaptive algorithm.

Keywords: Automation; Internet of things; Raspberry Pi; IoT platform; Algorithm; Microcontroller; Relay driver.

1. Introduction
IoT-based platforms allow for an integrated approach. By interconnecting multiple systems into a single picture, synergy in operation and output can be realized. Such a system is self-sufficient, sustainable, and cost-effective. The system owing to its modular nature is adaptive to industrial and domestic applications. On an industrial or even domestic unit, security flaws in prevalent automation systems may be resolved by the usage of logic-based algorithms [1]. An IoT-based platform to provide a template for automation in industrial applications leads to condition also controlled monitoring to growth productivity. This method is advantageous for continuous monitoring of the apparatus, receiving alerts also data accessibility for predictive maintenance [2]. An automated IoT-based system can allow for home automation also energy efficiency at the unit level using innovative modular design processes [3]. This delivers an understanding of the importance of IoT in providing clean distributed energy for sustainable global economic growth [4]. Advanced IoT-based platforms combine remote health monitoring, home automation, and alarm systems sensors to acquire data to store and access through interface access for remote monitoring [5]. The addition of a wireless module allows for functionality to realize a Web of Things node. This allows for a heterogeneous network to interoperate also implements a network stack that allows various IoT systems to be integrated [6]. In analog systems, switching between interconnections is performed using relay and/or rotary switches,
and thus the fails to accommodate for the same. IoT-based biometric security measures leveraging using cloud-based security measures are also possible [7]. For the maintenance of security regarding biometric traits via RPi client to the cloud, crypto graphical algorithms such as RSA, in addition, enhanced AES-256, may be applied. A smart camera network may be used in video surveillance of public spaces, natural habitats, wildfire protection, etc., constructed with off-the-shelf components for modular and low-cost fabrication [8]. An IoT-derived method could allow for a safe and remote monitoring system for machine tools also distribute industry practices between service centers in the manufacturing environment [9]. The utility of IoT is also realized in the agro sector with accurate forecast models and low-cost sensor nodes [10]. In the case of an IoT-capable device like the Raspberry Pi, several sensors can be integrated to monitor various parameters of the system [11]. The implementation of a sensor node as part of an IoT system using Raspberry Pi can be realized to allow for a scalable, do-it-yourself, and interdisciplinary approach to IoT platforms [12]. A software and hardware system can provide feedback via a predesigned interface and provide data on fields [13].

This paper, factoring the above methodologies into consideration, proposes a method to integrate multiple sensors and microcontrollers to a single control unit at a fraction of the cost. By utilizing off-the-shelf components and observations made in analog switching systems, IoT platforms may be multitasked using a basic unit like the Pi on an industrial scale. The motivations to undertake such an enterprise lie in an increasing requirement to simply operational costs and techniques while creating interchangeable units of IoT clusters that require minimal manning to produce optimum outputs.

2. Proposed Working Model
In the case of an IoT-capable device like the Raspberry Pi, a limited number of sensors can be integrated using a standard relay driver. Thus, a concern arises in this regard as to the number of sensors that may be efficiently networked by such a system [14]. Furthermore, programmable input that may be latched using a minimal number of pins is limited to single digits for an off-shelf solution. To mitigate apparent bottlenecks, deconstruction of IoT–relay interfacing is required. The proposed method involved the study of available electromechanical systems that require limited input for maximum output-based solutions. In analog systems, switching between interconnections was conducted using relay and/or rotary switches [15]. A rotary switch, depending on user requirements, may have multiple layers that are interconnected using a common. Connections are effectively 'sandwiched' into a singular platform that allows for a modular, robust, and affordable device in high voltage applications [16]. For the system to be utilized in an IoT setup, the rotary switch must be deconstructed to a format that may be applicable in a digital system. At its root, a rotary switch is a demux unit that allows for switching between settings in a layered format [17]. Thus, while operating the setup, a single setting may be availed. The layered approach reciprocates this to multiple connections at any given time. To mitigate the problems involving pin usage and programmable input of the IoT platform, a latching mechanism is required. An easily available and tested method of using a Peripheral Programmable Interface can be applied to facilitate flexibility and modularity in system design. The device has three ports of eight pins, each requiring an input of eight pins for all three ports. [18] A latched input minimizes the pins and circuit complexity. High voltage applications in industrial zones pose a challenge in IoT platform integration. Safeguards are thus needed to mitigate potential risks to the central unit. A form of galvanic isolation is needed to ensure sustained operation under such conditions can produce consistent output. The approach must be made affordable in line with cost-effectiveness. The components must then be mated with the IoT platform itself to create a modular, efficient but affordable base for sensor networking and automation, scalable as per requirements. The configuration and usage are set by the microcontroller with which user interaction takes place by a web page and/or web application to receive instantaneous feedback.

3. Methodology
The core focus of the paper revolves around IoT or the Internet of things. There are two components to it, the IoT platform itself and the algorithm used to preselect and orient the system operation. The
algorithm known as DeHeBBBi is the driving force behind the automation effort. By using an integrated interface to act in tandem with Pi, the flow diagram Figure 1 may be accentuated.

![Diagram](image)

**Figure 1:** Raspberry Pi – Microcontroller – Sensor

### 3.1 Relay – Interface Module

For the system to be utilized in an IoT setup, the rotary switch must be deconstructed to a format that may be applicable in a digital system. At its root, a rotary switch is a demux unit that allows for switching between settings in a layered format [17]. Thus, while operating the setup, a single setting may be availed. The layered approach reciprocates this to multiple connections at any given time.

Figure 2 is a rotary switch used as a template for the future IoT – relay driver. Due to its analog nature, it must be deconstructed into a format that can be parsed by the microcontroller (Pi) used. Assuming each position of the switch to be a decimal number, an array of numbers equal to the no. of positions that the switch can be slotted into may be constructed as required.

Assume each layer of the wafer switch to be a demux. For e.g., in this case there will be (1+ (2 x (1+1)) or 5 demux(s) used. To determine, the demux is to be used, simply observe the no. of through(s) used in each layer. (1:16) or (1:8) demux may be used. Accordingly, select lines will be 4 or 3 bits, respectively. Demux input can be configured as common in layer(s). To ensure output from the GPIO pins is stored, an 8255-A, a Peripheral Programmable Interface, is used. By manipulating the address bits A0 and A1 of the PPI, PORT A, B, and C can be selected to assign up to 24 bits. The 24 bits are divided into groups of 4 to be used as select lines to the demultiplexer(s), which drive the Darlington transistors. This allows for a basic latched input. The Darlington transistors are adapted to the use of galvanic isolation using optocouplers. The optocouplers prevent back emf from arising due to high voltage applications that may reset or damage the Pi. This allows for additional safety to be integrated into the design. The output drives the relays connected to it. The relays, in turn, power the connectors that link it to other microcontrollers or Wi-Fi/Bluetooth modules. In the PPI, the 24 available pins consisting of PORT A, B, and C can power six demux(s) for 4 bits each. Each 1:16 demux has 16 possible outputs of which one can be controlled at a time as per the select line(s). Figure
3 shows for six demux(s), six outputs may be monitored simultaneously via pulses at regular intervals of a possible $6 \times 16$ or 96 outputs to connected devices. Using only eight output GPIOs of the Pi, 96 or practically 90 outputs (keeping one output in each demux as GND) may be used.

**Figure 2: Rotary Switch**

3.2 Algorithm
To adapt an analog method of input to a digital system, a deconstructed logic in the form of the algorithm is to be used. The algorithm is called as DeHeBBBi (Decimal – Hexadecimal – Binary Byte
– Bit conversion) or 'Debbie.' This will provide for feed lines assigned to the Raspberry Pi GPIO pins. The algorithm called as DeHeBBBi are shown in Figure 6. 'Debbie' is used to orient the driver circuit using the Raspberry Pi. Using a menu interface via the website/web application, the user down selects the configuration of the system. The configuration endows each individual 'switch' (demux) with a decimal position which is converted into a hexadecimal number. The hexadecimal number is then shifted till the last four bytes, i.e., The LSB is obtained. Figure 4 represents Truth Table for Pin Configuration.

| N. | Port Selected (A,B,C)       | Current/Simultaneous Configuration Selected         |
|----|-----------------------------|-----------------------------------------------------|
|    | First 8 Bytes               | Last 8 Bytes                                       | Position Of Demux (s) Selected                      |
|    | (First Demux)               | (Second Demux)                                     |                                                    |
| X  | A  | A’ | A’’ | A’’’ | A’’’’ | 0  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  |
| 1  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 2  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 3  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 4  | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 5  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 6  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 7  | 0  | 1  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 8  | 0  | 1  | 1  | 1  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 9  | 1  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 10 | 1  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 11 | 1  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 12 | 1  | 0  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 13 | 1  | 1  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 14 | 1  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 15 | 1  | 1  | 1  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 16 | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |

Figure 4: Truth Table for Pin Configuration

Figure 5: Reduction of Byte to Bit (Pins)
The LSB is then divided into four individual bytes, which are then converted into bits in Figure 5. The bits are then assigned to the GPIO pins of the Raspberry Pi as input feed for the PPI. At a time, the
configuration of two demultiplexer(s) can be sent. Configurations for the switches can be pre-set in code or user-defined.

4. Results and Discussion
The device logic was tested on the GPIO pins of a Raspberry Pi used in a home automation system in Figure 7. The algorithm was adapted to the newer system and was deemed successful on a limited scale operation. Given the low costs in enabling and adapting such a modular method, future work on the model is promising, especially when an appropriate back-end process is applied. Load selection was allowed using the GUI interface menu that classified clusters as devices. A 5V relay was operated using this method to power LED(s) and domestic applications.

Figure 6: DeHeBBBi Algorithm
Quadrant 1 houses the Pi, and the script was running the setup.
Quadrant 2 houses the relay driver module.
Quadrant 3 houses a 12V supply regulated by an IC7805 transistor.
Quadrant 4 houses the HC-05 Bluetooth Module to interface with a secondary input source.

Quadrant 1 was used as the central node to verify the IoT interfacing with 2. The 8255A PPI was used to operate the relays in this case. 3 and 4 were used as secondary feedback and input, respectively. A GUI interfaces in Figure 8, scripted in python, was used to interact with the Pi. By using a Raspbian OS-derived platform like the VNC Viewer, a mobile phone/laptop may be used.

Figure 7: Experimental Setup

Figure 8: GUI Interface for Pi
5. Conclusion and Future Works

The setup was concentrated on domestic applications that may be set up using a single control node. The modular nature of the device allows for scaling as required by using very few GPIO pins. Thus, ergonomics and efficiency work hand in hand to create IoT systems that are adaptable as per user-defined specifications. Usage of data logging to extract sensor readings and allow for feedback to the interface via user/neural networks may also allow for increased productivity. The open-ended Python script allows for further modifications or expansions as required. Thus, as IoT systems become more complex, this algorithm may be used to simply task and purpose. By presenting a unique and cost-effective method to implement IoT on a large scale, derived applications in domestic and industrial avenues are expansive. Thus, a modular approach can be integrated to automation systems using the ‘Debbie’ algorithm.

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