UPPSALA UNIVERSITET

"May The Candy Be With You" Project Report

Programming Embedded Systems, 2018

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1.Introduction

“May the Candy be with you”, a continuation to our previous project “Sweet Shot”, is an electronic system that is designed and implemented to control the movements of a cannon that shoots candy using an electronic glove. The system is wireless and operates using ATmega328p microcontroller units. The idea is to create a wireless peripheral input device that can be used for various applications that detects two-dimensional motion relative to the surface.

2.Implementation

The system consists of two modules: primary and secondary module. The primary module is set up on a glove that the user wears to control the movements of the cannon. It consists of an accelerometer and a flex sensor. The accelerometer is used to detect the movements in the X and Y axis. The flex sensor is used to send a signal to trigger the cannon to shoot when the glove is being clenched. These data are being set to the secondary module, the cannon.

The secondary module is the cannon which consists of two stepper motors and solenoid. The Stepper motors help to change the direction of the cannon on the X and Y axis while the solenoid is utilized as the trigger of the cannon.

The user has control over the actions of the cannon and can control it fully till our restricted limits.

3.Design

The “May the Candy be with you” circuit was built on two main sections i.e. the Glove and the Cannon. Firstly, the Glove consists of an Atmega328P MCU, flex sensor, ADXL345 accelerometer, nRF24L01+, Voltage regulator and a few LEDs for display. Meanwhile, the Cannon is connected to two Stepper motors for movement, a Solenoid, Switches, Voltage Regulators and nRF24L01+.

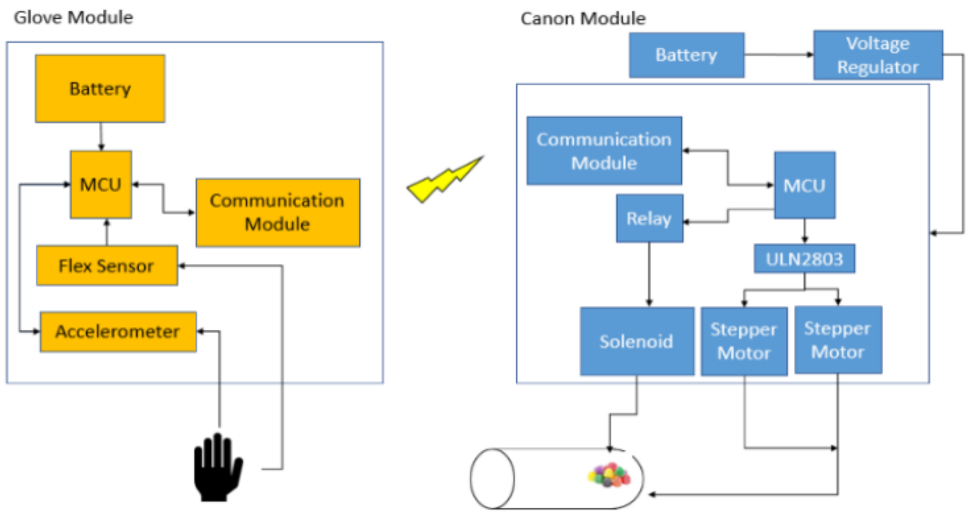


Figure 1. Block Diagram of the Entire System

In the primary system (Glove), the connections are wired as seen below in Figure 1. the MCU is getting powered up directly from an external battery , which is the main Vcc of the primary module. But the ADXL345 and the nRF24L01+ modules demand lesser voltage than the main Vcc i.e. only 3.3 V, so a voltage regulator L78L33 is added to the circuit. The nRF24L01+ is also connected to the MCU by a Serial Peripheral Interface (SPI) bus and it will function as a transmitter module that the secondary module (Cannon) will receive. Serial Peripheral Interface (SPI) is an interface bus commonly used to send data between microcontrollers and small peripherals such as shift registers, sensors, and SD cards. It uses separate clock and data lines, along with a select line to choose the device you wish to talk to like in Figure 2.

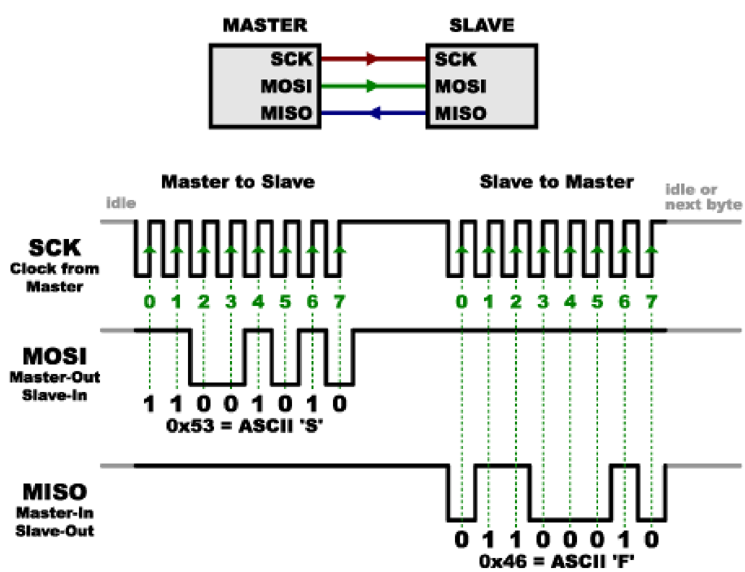


Figure 2. Operation of SPI Protocol

The accelerometer i.e. ADXL345 is connected to the MCU by I2C interface, with SDA and SCL. The I2C (Inter-integrated Circuit Protocol) is a protocol intended to allow multiple "slave" digital integrated circuits ("chips") to communicate with one or more "master" chips like in Figure 3. Like the SPI, it is only intended for short distance communications within a single device. Like Asynchronous Serial Interfaces (such as RS-232 or UARTs), it only requires two signal wires to exchange information. The I2C bus drivers are "open drain" so they can pull the corresponding signal line low but cannot drive it high. Thus, we need to connect pull-up resistors like 4.7KΩ to each signal line, to restore the signal to high when no device is asserting it low.

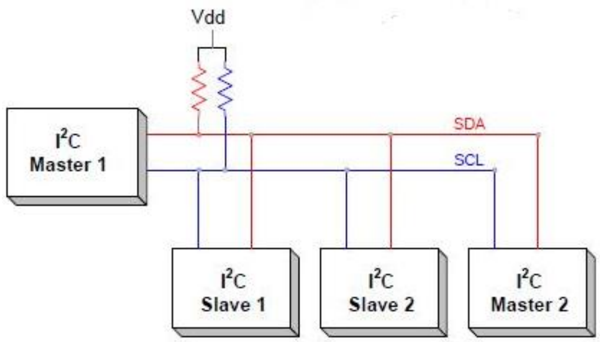


Figure 3. Operation of I²C Protocol

We then have 3 LEDs for status display that are also connected to the MCU using GPIOs with 220Ω resistors. This system is entirely powered by three 1.5V AA batteries to get 4.5V power.

Moving to the secondary system i.e. Cannon, the connections are wired as seen above in Figure 1. The mechanism of receiving the signal from the primary system (Glove) and moving the cannon in 4 directions as well as shooting the cannon are implemented here. The nRF24L01+ module will function as the receiver between systems which is also connected through a SPI interface. The servo motors are connected to the GPIO pins of the MCU. Though, the stepper motors are controlled by the MCU's GPIO pins, the MCU cannot supply sufficient current to control the poles of the stepper motors. Thus, we use a high-voltage, high-current Darlington transistor array i.e. ULN2803A to control the supply to these modules. The solenoid is connected to the MCU via a 5V relay which has a load of max 30V. We require the relay because the solenoid require more than 12V which cannot be supplied by the MCU GPIO to trigger the solenoid. This entire system is being powered by two 9V Alkaline Batteries which gives us 18V. The MCU and the stepper motors require 5V thus we add a voltage regulator L78S05 which regulates 18v to 5V. Since the nRF24L01+ requires 3.3V, we use another voltage regulator L78L33 to regulate 5V to 3.3V. The solenoid uses the system's power supply via the 5V relay.

Project Hardware

The two circuits of the connected systems of the primary system and secondary system are shown in Figure 4. and Figure 5. respectively, it indicates the connection between the hardware parts.

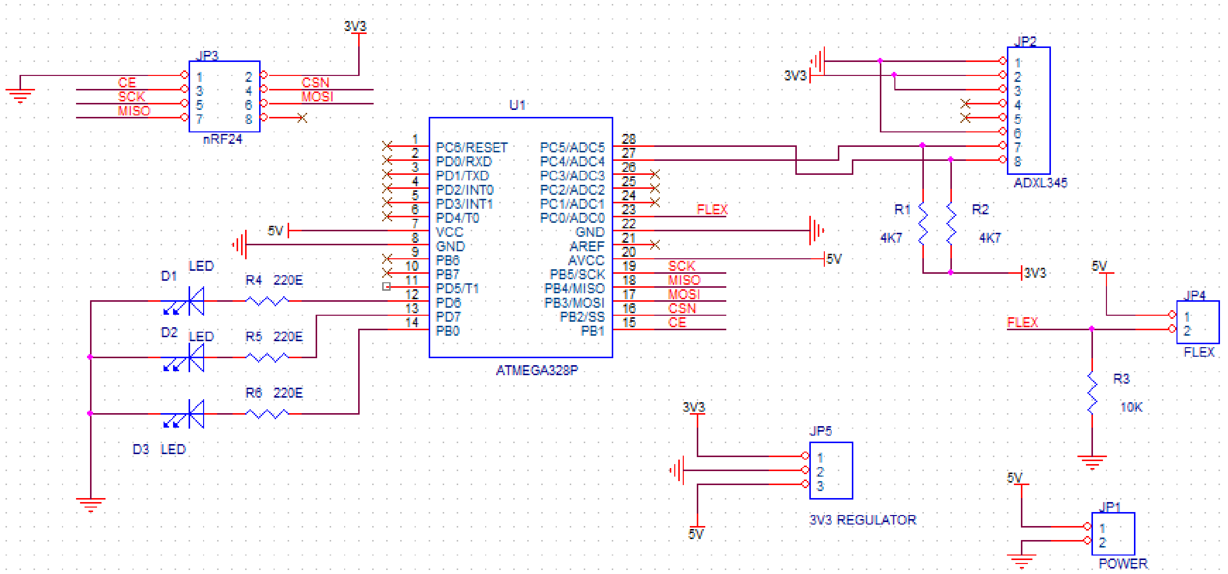


Figure 4. Schematics of Glove

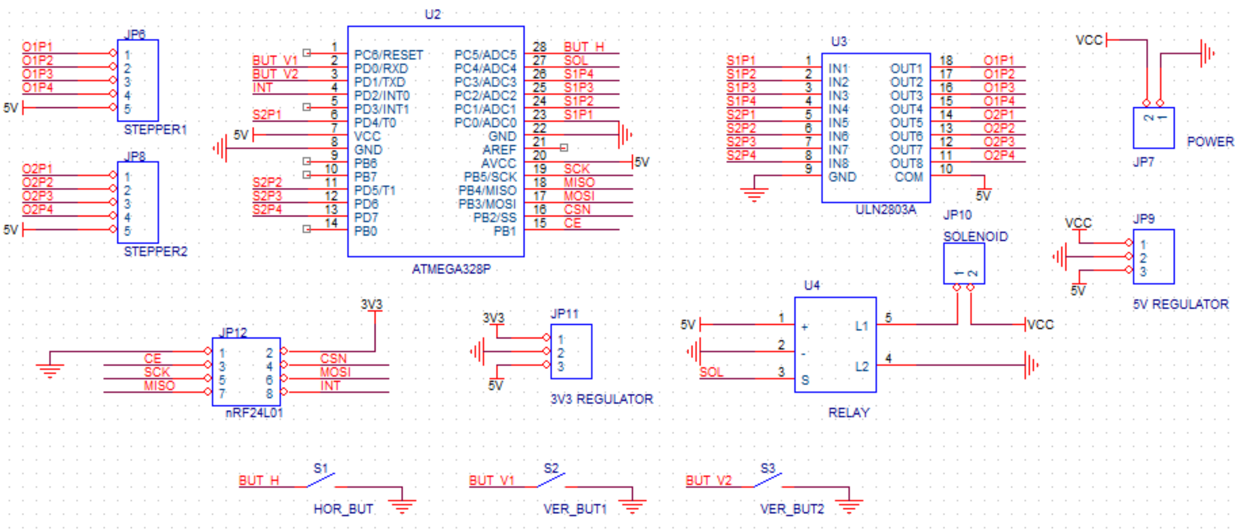


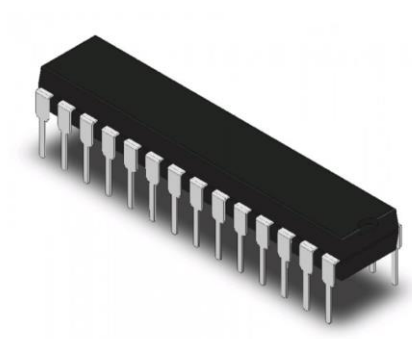
Figure 5. Schematics of Cannon

The exact used hardware parts are listed below, in addition to the essential features that is useful in the project.

The MCU: ATmega328p

The ATmega328p is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. [1]

- Advanced RISC Architecture
- Two 8-bit Timer/Counters with Separate Prescaler and Compare Mode
- Six PWM Channels
- 6-channel 10-bit ADC in PDIP Package
- Two Master/Slave SPI Serial Interface
- Interrupt and Wake-up on Pin Change
- 23 Programmable I/O Lines
- Operating Voltage 1.8 - 5.5V



nRF24L01+

The Nordic nRF24L01+ integrates a complete 2.4GHz RF transceiver, RF synthesizer, and baseband logic including the Enhanced ShockBurst™ hardware protocol accelerator supporting a high-speed SPI interface for the application controller. [2]

The Nordic nRF24L01+ is a highly integrated, ultra-low power (ULP) 2Mbps RF transceiver IC for the 2.4GHz ISM (Industrial, Scientific and Medical) band. With peak RX/TX currents lower than 14mA, a sub µA power down mode, advanced power management, and a 1.9 to 3.6V supply range, the nRF24L01+ provides a true ULP solution enabling months to years of battery life from coin cell or AA/AAA batteries.

Accelerometer ADXL345

The ADXL345 is a small, thin, low power, 3-axis accelerometer with high resolution (13-bit) measurement at up to ±16*g*. Digital output data is formatted as 16-bit twos complement and is accessible through either a SPI (3- or 4-wire) or I^2C digital interface.

- Ultralow power: as low as 23 μA in measurement mode and 0.1 μA in standby mode at V_S = 2.5 V (typical)
- Power consumption scales automatically with bandwidth
- User-selectable resolution
- Fixed 10-bit resolution
- Full resolution, where resolution increases with *g* range, up to 13-bit resolution at ±16 *g* (maintaining 4 mg/LSB scale factors in all *g* ranges)

Stepper motor 28BYJ-48

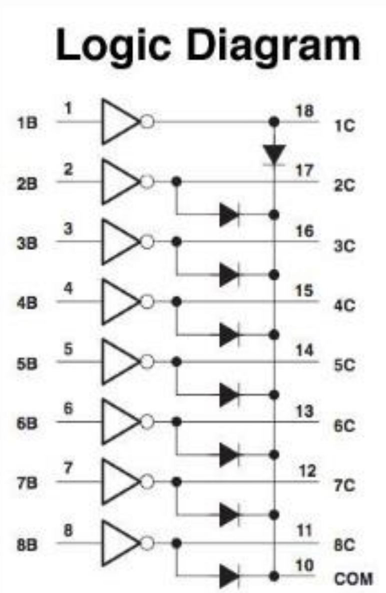
The 28BYJ-48 is a small stepper motor suitable for a large range of applications that operates at 5V. It contains 4 phases.[4]

Transistor Array ULN2803

The ULN2003A device is a high-voltage, high-current Darlington transistor arrays. Each consists of seven NPN Darlington pairs that feature high-voltage outputs with common-cathode clamp diodes for switching inductive loads.[6]

Main specifications:

- 500 mA rated collector current (single output)
- 50 V output (there is a version that supports 100 V output)
- Includes output fly back diodes.
- Inputs compatible with TTL and 5-V CMOS logic.



36V Push-Pull Solenoid

Solenoids are a great way to induce linear motion for pushing, pulling or controlling switches and levers. According to the datasheet this solenoid is rated for 36V, but they work like a charm at 12V. With a throw of 10mm these solenoids are great for all kinds of motion applications such as actuating door latches, automating percussion instruments. At 12 volts these Solenoids draw 650mA, while at 36 volts they draw 1.85A.

Voltage regulator L78L33

The L78Lxx series of three-terminal positive regulators employ internal current limiting and thermal shutdown, making them essentially indestructible. If adequate heat-sink is provided, they can deliver up to 100 mA output current.

- Integrated circuit type voltage stabilizer
- Kind of voltage regulator LDO, fixed
- Output voltage 3.3V
- Output current 0.1A

Voltage regulator L78S05

The L78S series of three-terminal positive regulators provide local on-card regulation, eliminating the distribution problems associated with single point regulation. If adequate heat-sink is provided, they can deliver up to 2 A output current.

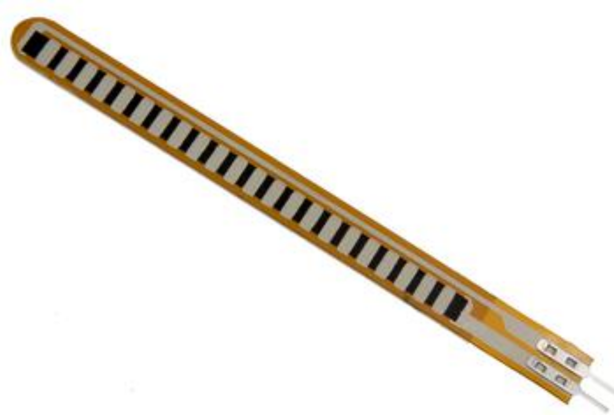
- Integrated circuit type voltage stabilizer
- Kind of voltage regulator LDO, fixed
- Output voltage 5V
- Output current 2A

Flex sensor (2.2'')

A simple flex sensor 2.2" in length. As the sensor is flexed, the resistance across the sensor increases.

The resistance of the flex sensor changes when the metal pads are on the outside of the bend (text on inside of bend).

- Angle displacement measurement
- Bends and flexes physically with motion device
- Simple construction
- Low profile

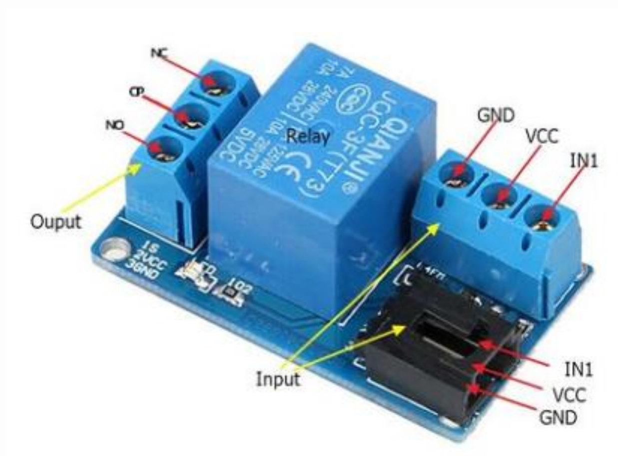


SPST switches

A single-pole, single-throw (SPST) switch is as simple as it gets. It's got one output and one input. The switch will either be closed or completely disconnected. SPSTs are perfect for on-off switching. They're also a very common form of momentary switches.

5V Relay with 30VDC load

The module is uses SRD relay module to control high-voltage electrical devices. (maximum 250V).It can be used in interactive projects and can also be used to control the lighting, electrical and other equipment can be controlled directly by a wide range of microcontrollers and can be controlled through the digital IO port, such as solenoid valves, lamps, motors and other high current or high voltage devices.



Project Software

The Code implementation is divided as previously mentioned into two main systems, and each has a separate code.

Primary module

- **Headers**
  - As the nRF24L01+ module uses SPI interface to communicate with the MCU, we utilize a simple library to initialize and implement the communication between two different nRF24L01+ modules as *nrf24l01.c*.
  - We have added the *adxl345.c* library to initialize and to read the adxl345 accelerometer.
  - We have added i2c interface library i.e. *i2cmaster.h* for the MCU we are using to communicate with adxl345.

- **Main Function**
  - Initializes the nRF24L01+ to Tx mode to transmit data to the destination address
  - Flex sensor is configured for ADC mode
  - Accelerometer is initialized as well.
  - Event flag is declared which updates based on the kind of data that is supposed to be transmitted.
  - In the main loop, we check for any flex or accelerometer activity through the Boolean functions flexControl() and accelActivity().
  - We read the ADC value and the flexControl() function checks if it is less than the given threshold value. If it is then the flag is updated to value true.
  - The accelActivity() function reads the X and Y axis values and normalizes the value for our convenience. Then the two values are compared with the four specified thresholds for each direction (forward, backward, right, left). If any value is true, then the event flag is updated.

Secondary Module

- **Headers**
  - As the nRF24L01+ module uses SPI interface to communicate with the MCU, we utilize a simple library to initialize and implement the communication between two different nRF24L01+ modules as *nrf24l01.c.*
  - A library is created to initialize and control the stepper motors as *systemsecon.c*.

➔ **Main Function**
- Enable the interrupts.
- Calls the functions to initialize the stepper motor and solenoid to the respective pins.
- Initializes the nRF24L01+ to Rx mode to receive data from the source address.
- Main while loop begins and checks for any data being received to enable the flag in the interrupt.
- Based on the message received, a function is called which changes the angle of the respective stepper motor for a couple of steps or the solenoid is switched on & off within few milliseconds.
- There are three switches which act as reference positions for the stepper motors to stop when they reach that position regardless of the message received.

➔ **Process system**
- There are 5 different types of messages that the system can recognize.
    - AL – Vertical Stepper motor moves Upwards.
    - BL – Vertical Stepper motor moves Downwards.
    - CL – Horizontal Stepper motor moves Left.
    - DL – Horizontal Stepper motor moves Right.
    - EL – Triggers the Cannon to shoot.

4.References

1. ATmega328P - 8-bit AVR Microcontrollers - Microcontrollers and Processors. (n.d.). Retrieved from https://www.microchip.com/wwwproducts/en/ATmega328P
2. Flex Sensor Interfacing with AVR Microcontroller (ATmega8): Circuit Diagram & Code Explanation. (n.d.). Retrieved from https://circuitdigest.com/microcontroller-projects/flex-sensor-interfacing-with-atmega8
3. I2C - learn.sparkfun.com. (n.d.). Retrieved from https://learn.sparkfun.com/tutorials/i2c
4. Optimized High Speed NRF24L01+ Driver Class Documentation: Optimized High-Speed Driver for nRF24L01(+) 2.4GHz Wireless Transceiver. (n.d.). Retrieved from http://tmrh20.github.io/RF24/index.html
5. Serial Peripheral Interface (SPI) - learn.sparkfun.com. (n.d.). Retrieved from https://learn.sparkfun.com/tutorials/serial-peripheral-interface-spi
6. Stepper Motor Interfacing with Atmega32. (n.d.). Retrieved from http://www.electronicwings.com/avr-atmega/stepper-motor-interfacing-with-atmega32