DyckCo Wireless Remotely Controlled Home System Technical Report

Prepared for: John Popyuk, Communications Instructor
Electronics Engineering Technology Instructors

Prepared by: Trevor Cook
Dustin Dyck

Date: April 16, 2007

Letter of Request

Palliser Campus
xxx
Moose Jaw, Saskatchewan

January 12, 2007

DyckCo
xxx
Moose Jaw, Saskatchewan

Dear DyckCo:

As per our discussions, we request you design and build a prototype for a simplex wireless remote control with encryption to control the entry of a person into a home, in addition to turning on a light in the home. The main areas of the project will consist of:

- Research
- Component Identification
- Schematic Design
- Programming
- Prototype Design
- PCB creation
- Prototype Testing
- Presentation

The user will be able to specify which device they wish to operate via button presses on the wireless remote. The Door Lock will be capable of being locked and unlocked. The door opener will also be capable of closing the door. The light will be capable of being turned on or off. A prototype of this device is to be constructed and demonstrated on April 13, 2007. A technical report consisting of no less than 3000 words is to be completed by April 16, 2007.

Information on the project may be obtained from knowledge gained from your Electronics Engineering Technology classes, and instructors of said classes, text books, libraries, the internet, and wherever else you can acquire the necessary information. Feel free to contact any of your instructors for all the help they are able to give.

Good luck on the simplex wireless remote control with encryption system. I look forward to your presentation of the prototype and fully reading your report.

Sincerely,

Electronics Engineering Technology Instructors
Palliser Campus

Letter of Transmittal

xxx
Moose Jaw, Saskatchewan

April 16, 2007

Palliser Campus
xxx
Moose Jaw, Saskatchewan

Dear Electronics Engineering Technology Instructors:

As requested, we have completed researching and designing a prototype wireless remote control with encryption system, however we have changed it to a duplex system from the requested simplex system. We respectfully submit our written report to accompany our working prototype. An outline of our results is as follows:

1. The remote control uses duplex communication and Keeloq encryption to control 3 devices.
2. The three devices are: A door lock, a door opener, and a light power control.
3. The devices receive the signal, process it, behave appropriately, and send a signal back to the remote to acknowledge the signal was processed and responded to.

Our report can be used by an Electronics Technologist to build our system, and it could be modified so additional devices could be added. It could be used anywhere a wireless remote controlled system would be useful to trigger a device from a distance.

If there are any questions or concerns, feel free to contact us at (306) 694-4600 or by email: dyckco@gmail.com

Sincerely,

Trevor Cook and Dustin Dyck
DyckCo

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Executive Summary

When you are coming home with a load of groceries wouldn't it be nice to have some help opening the door? We have designed and implemented a prototype of the ***DyckCo*** Wireless Remotely Controlled Home System to solve this problem. This system enables you to unlock and open your front door as well as turn on a light inside your house.

We chose to use the PIC family of microcontrollers in order to control our devices. The transmitters and receivers were designed by R.F. Solutions to operate at 433.92 MHz. They operate very easily with the RF600 series of encoders and decoders also designed by R.F. Solutions. These encoders and decoders work very easily together and can be connected directly to the PIC microcontroller. We decided to control an electromagnet, a power interrupter, and a motor in our system.

The ***DyckCo*** Remote Control interprets a series of button presses and sends out the required data to an encoder. This encoder sends the signal through the transmitter to the antenna which in turn transmits the signal. After the signal is received by the appropriate device, the device is triggered. The device then transmits a signal back to the remote saying it has done its job. The decoder located on the remote then decodes the signal and sends it back to the PIC. The PIC then lights up the desired LED indicating that the device has done its job.

The ***DyckCo*** Voltage Controller can be used to interrupt power to a device. In our design it will interrupt a light. The circuit receives a signal from the ***DyckCo*** Remote Control. The decoder then decodes the signal and transmits it to the PIC located in this circuit. The PIC then runs a subroutine causing a relay state to be changed. This enables the light to come on or go off, depending on the last state of the relay.

The ***DyckCo*** Door Lock Controller is used to control the lock or unlock function of the electromagnetic deadbolt. The circuit receives a signal from the ***DyckCo*** Remote Control. The decoder then decodes the signal and transmits it to the PIC located in this circuit. The PIC then runs a subroutine causing a relay state to be changed. This enables the lock to be either locked or unlocked, depending on the last state of the relay.

The ***DyckCo*** Door Motor Controller can be used to power the motor that will open or close the front door. The circuit receives a signal from the remote. The decoder then decodes the signal and transmits it to the PIC located in this circuit. The PIC then

runs a subroutine causing an H-Bridge to become active in one direction. This enables the motor to turn clockwise or counter clock wise depending on the direction required.

The programming for the PIC was done using the C programming language. Components that could be used with the programming software and equipment supplied by SIAST were selected for ease of use.

Problems were encountered during the research and development of this design. Serial communication and our transmitters and receivers was investigated. In order to use the serial communication SPI, the design would need to have three I/O pins from the transmitter and receiver. Only one pin on each could be used, making this technique useless for our purposes. The solution found was acquiring the R.F. Solutions RF600 series of encoders and decoders. They communicate directly with I/O pins on the PIC, making functionality easy.

When a relay was introduced into the circuit it caused the voltage from the PIC output pins to drop from the 5 volts required by the relay to trigger to 1.7 volts. This voltage would not be sufficient to trigger the relay. To solve this problem, a transistor was used to raise the current to the relay so that the 5 volts required for the relay was available.

In order to open and close the front door the motor needed to be able to turn in both directions. To make this happen, the output of the PIC had to go to an H-Bridge circuit which would allow control of the direction the motor spins.

Future implementations for this system include making use of surface mount technology to make the remote smaller in physical size. Implementing the use of pre-made electromagnetic locks, a battery backup system, and introducing sleep mode for the remote are additional changes that could be made to the system. In the future, implementing a system with enough remotes for everyone in the family could be accomplished with more decoders and encoders. For a more advanced system, more control over the command signal could be implemented with the user of other encryption ICs..

The ***DyckCo*** Wireless Remotely Controlled Home System would make life more manageable when coming home carrying a lot of groceries. This system is easy to use, easy to install, and would replace the third arm that evolution has been slow to develop.

Introduction

Background and Purpose

When you are coming home with a load of groceries and do not have a third arm to open the door wouldn't it be nice to have some help? How does pushing a button that unlocks and opens your front door for you sound? Most business people do their grocery shopping in the evenings, so also having a button to turn the lights on in your house would be convenient. We have built three wireless devices which respond to commands from a remote control. They unlock and open the front door, turn the lights on, and the design has the capability to be expanded to control multiple other devices as designed or modified by an Electronics Technologist.

The problem is evolution. Doors were invented to keep the environment, and unwanted guests, out however; they also do a good job of keeping us out too. Trying to juggle groceries and open your front door at the same time never seems to work too well. The door always seems to win because the groceries end up on the floor. Adding the dark of night into the equation and you have a disaster waiting to happen. There is a need for a wireless remote door and lighting system that can alleviate this problem that plagues most Canadians.

The main reason we built the system is convenience. People, who are elderly, have disabilities, muscle and back problems, or are just tired of fighting with their front door require a solution to this problem.

Intended Readers

This report is written for members of the department of Electronics Engineering Technology at Palliser SIAST Campus. It is written towards people who have an interest in electronics, or have the education equivalent of a diploma or higher.

Data Sources

We used the microchip.com website and the rfsolutions.co.uk website extensively. These sites include spec sheets for all of their components, as well as typical application circuits.

Other sources we referred to were:

- Class notes for designing power supplies
- Spec sheets for other components
- PCB Creation documentation available online at http://programs.siast.sk.ca/comptek/pcb/pcb_making.html

Scope

This report is designed to take the reader through the design and implementation of a wireless remotely controlled home system. It will cover the positive aspects of our design, and some limitations of our implementation.

Limitations

This report will not advise the reader on how to fix the devices we created, or how to troubleshoot the design. This is covered in the ***DyckCo*** Wireless Remotely Controlled Home System Technical Manual, which can be found after the report in this binding.

Physical Design and Construction

Component Selection

Microcontroller

This project uses a Microchip PIC16F877A microcontroller. This component is a 40-Pin PDIP package, with 5 I/O ports, uses SPI and I^2C, has 256 bytes of internal EEPROM. (PIC16F87X) We chose to use the same microcontroller for all devices since this would make the programming and circuit design easier and more standardized. Our remote control requires the largest number of I/O pins, needing 6 input and 6 output pins. This microcontroller has more I/O pins than required, other features that we do not need, and the 40-pin PDIP package has a large footprint. We chose this microcontroller because the usage of it was being taught in our 5th semester COMP class, and we decided that this class would help us learn how to program and use this microcontroller in our design. We chose the PDIP package because it is of the form we can program using the available PICStart Plus programmer supplied by SIAST.

Transmitter

This project uses the R.F. Solutions AM Hybrid transmitter module AM-RT4-433. This module provides a complete RF transmitter which can be used to transmit data at up to 4kHz from any standard CMOS/TTL source. It is designed to operate with a supply voltage of 2-14V at an RF frequency of 433.92MHz. They have an ideal transmit range up to 70 meters. The modules are compatible with R.F. Solutions range of AM receivers. These transmitters are also designed to work with the RF600E Keeloq encoder, produced by R.F. Solutions. (DS013)

Receivers

There are two RF Transmitters in use in this system. The R.F. Solutions range of AM Super-regenerative receiver modules are compact hybrid RF receivers which can be used to capture undecoded data from any AM transmitter. They produce a CMOS/TTL output, and require connections to power and antenna only. (DS014)

The AM-HRR30-433 is a miniature AM super-regenerative receiver. The AM-HRR3-433 is an AM super-regenerative receiver. Both of these devices were produced by R.F. Solutions. They use a supply voltage of 5V and operate at an RF frequency of 433.92MHz. They have an optimal receiving range up to 50m. They are manufactured to be compatible with the AM Transmitters (AM-RT4/5-433) produced by R.F. Solutions. These receivers are also designed to work with the RF600D Keeloq decoder, produced by R.F. Solutions.

Encoder

The R.F. Solutions Keeloq RF Encoder uses the highly secure Microchip Keeloq Code Hopping Protocol to encrypt an eight character message into an encoded signal of 67 bits. The RF600E uses a source voltage between 2 to 6.6V, with automatic battery level monitoring, and 'Manchester' modulation. It recognizes the pressing of up to four buttons. The encrypted or hopping code portion of the transmission will change every time a button is pressed, even if the same button is pushed again. The eight character message sent consists of seven ASCII characters from 0 through 9 and A through F representing the serial number of the encoder. The last digit is an ASCII character in the range of *A* to *O* or *a* to *o*, representing which button was pressed. This ASCII character is in capital letters if the battery of the encoding device is good, and is in small letters if a low battery is detected in the encoding device. (DS600)

Decoder

The RF600D has the capability to learn up to 7 unique RF600E encoders. With the addition of an EEPROM memory device, this is increased to 48 encoders.
The RF600D is connected to the output of a receiver, and when a valid message is received, it decodes the encrypted signal. When the message is decrypted, the serial number of the sending encoder is checked, and if the decoder is programmed to listen to that encoder, the button press information transmit is processed and sent to the output. The digital outputs may be configured as latching or momentary action setting the reaction time to the command received. (DS600)

Relay

The relay is a 5V dual coil latching relay that has a maximum current rating of 5A, 235VAC or 5A, 30VDC. The dual coil type is a set/reset coil. One set of pins sets the latch to allow the voltage to pass through to the device connected to the relay. The other set of pins are for the reset coil, and are used to disconnect the voltage from the device connected to the relay.

Electromagnet

The door lock mechanism uses two electromagnets powered with 5V and 2A.

Motor

The motor for the door opener operates with +/-5V and 250mA.

Antennas

¼ Wave Whip Stub Antenna made by R.F. Solutions and is tuned to the frequency of 433.92MHz.

Component Usage For Each Device

DyckCo Remote Control

The PIC takes input from buttons pressed by the user on PORTC, then processes which button was pressed and produces an output on PORTD which is sent to the encoder. The encoder creates an encrypted signal which is sent to the transmitter. The transmitter then transmits the signal through the antenna. After the signal is transmitted, the PIC waits for a signal to be received from the device attempting to be controlled. When the signal comes in from the antenna, it is passed to the decoder, decrypted, and then passed to an input on PORTC on the PIC. This input is processed by the PIC and the output is sent from PORTD and then the appropriate LED is turned on to notify the user of which device has responded.

DyckCo Voltage Controller

The receiver gets a signal from the antenna, and then passes the signal to the decoder. The decoder decrypts the message, and if the decoder is programmed to listen to the encoder that sent the message, the button press is processed and the output is sent to the PIC. The PIC takes signal from the decoder on PORTC and processes the input. If this PIC is supposed to respond to that input, it sends output on PORTD triggering the Relay to either set it or reset it depending on its current state. The PIC then sends an output on PORTD to the input of the encoder, which encrypts the signal and sends it out to the input of the transmitter which sends the signal through the antenna.

Dyc4Co Door Motor Controller

The receiver gets a signal from the antenna, and then passes the signal to the decoder. The decoder decrypts the message. If the decoder is programmed to listen to the encoder that sent the message, the button press is processed and the output is sent to the PIC. If the encoder is unknown to the decoder the message is discarded. The PIC takes signal from the decoder on PORTC and processes the input. The PIC sends output on PORTD triggering one side of the H-Bridge to turn the motor in the appropriate direction. The PIC then sends an output on PORTD to the input of the encoder. The encoder encrypts the signal and sends it to the input of the transmitter. The transmitter sends the signal through the antenna.

Dyc4Co Door Lock Controller

The receiver gets a signal from the antenna, and then passes it to the decoder. The decoder decrypts the message. If the decoder is programmed to listen to the encoder that sent the message, the button press is processed and the output is sent to the PIC. If the encoder is unknown to the decoder the message is discarded. The PIC takes signal from the decoder on PORTC and processes the input. The PIC sends output on PORTD triggering the relay to either set it or reset it depending on its current state. The door is then either unlocked, or relocked. The PIC then sends an output on PORTD to the input of the encoder. The encoder encrypts the signal and sends it to the input of the transmitter. The transmitter sends the signal through the antenna.

Programming Language and Programmer Used

The C programming language was chosen for the code for this system. The CSCC C compiler was used to create files to be transferred into the microcontroller's memory. The MPLab Integrated Development Environment was used to transfer files into the microcontroller's memory through the PicStart Plus PIC Microcontroller Programmer made by Microchip.com, since the PIC16F877A microcontroller is fully supported.

Programming Procedures and Descriptions

Remote Control Code

Main Procedure

Inside of an infinite loop, this procedure waits for a button press on the three inputs on PORTC coming from the buttons on the remote.

If button 1 is pressed, go to the Button1 procedure.

If button 2 is pressed, go to the Button2 procedure.

If button 3 is pressed, go to the Button3 procedure.

If one of the buttons were pressed, call the Receive procedure.

Button1 Procedure

Turn button 1 output high for 3 seconds to send the command to the Voltage Controller to trigger.

Button2 Procedure

Turn button 2 output high for 3 seconds to send the command to the Door Lock Controller to trigger.

Button3 Procedure

Turn button 3 output high for 3 seconds to send the command to the Door Motor Controller.

Receive Procedure

If the Voltage Controller responded, turn on the red LED for 2 seconds as the acknowledgement notification to the user.

If the Door Lock Controller responded, turn on the orange LED for 2 seconds as the acknowledgement notification to the user.

If the Door Motor Controller responded, turn on the green LED for 2 seconds as the acknowledgement notification to the user.

Wait for 5 seconds before getting new input from the user.

Voltage Controller Code

Main Procedure

Inside an infinite loop, wait for input on pin C0. If a signal is received, either set the relay by calling the Turnon procedure, or reset the relay by calling the Turnoff procedure, depending on the relay's current state.

Call the Transmit procedure.

Turnon Procedure

Turn the reset coil low, turn the set coil high. Turn on the red LED for 1 second as an acknowledgement notification.

Turn the set coil low.

Turnoff Procedure

Turn the set coil low, turn the reset coil high. Turn on the red LED for 1 second as an acknowledgement notification.

Turn the reset coil low.

Transmit Procedure

Transmit button 1 press for 5 seconds back to remote.

Wait 2 seconds extra until accepting new input.

Door Lock Controller

Main Procedure

Inside an infinite loop, wait for input on pin C1. If a signal is received, either set the relays by calling the Doorunlocked procedure to unlock the door, or reset the relays by calling the Doorlocked procedure to lock the door, depending on the lock's current state.

Call the Transmit procedure.

Doorunlocked Procedure

Turn the reset coil low; turn the set coil high on both electromagnets. Turn on the orange LED for 1 second as an acknowledgement notification.

Turn the set coils low.

Doorlocked Procedure

Turn the set coil low, turn the reset coil high on both electromagnets. Turn on the orange LED for 1 second as an acknowledgement notification.

Turn the reset coils low.

Transmit Procedure

Transmit button 2 press for 5 seconds back to remote.

Wait 2 seconds extra until accepting new input.

Door Motor Controller

Main Procedure

Inside an infinite loop, wait for input on pin C1. If a signal is received, either trigger one side of the H-Bridge by calling the turnopen procedure to open the door, or trigger the other side of the H-Bridge by calling the turnclose procedure to close the door, depending on the door's current state.

Call the Transmit procedure.

Turnopen Procedure

Turn high one pin input to the H-Bridge, and set the other pin low, to turn the motor counter-clockwise to open the door.

Turn on the red LED for 1 second as an acknowledgement notification.

Turn the pins low.

Turnclose Procedure

Turn high one pin input to the H-Bridge, and set the other pin low, to turn the motor clockwise to open the door.

Turn on the red LED for 1 second as an acknowledgement notification.

Turn the pins low.

Transmit Procedure

Transmit button 3 press for 5 seconds back to remote.

Wait 2 seconds extra until accepting new input.

See Appendix A for the flowcharts for the programming for each device.

Problems Encountered, Solutions Found

Serial Communication

Encryption is required for secure communication. With SPI, communication needs to be synchronized before messages can be transmitted or received between Microcontrollers. However signals cannot be decrypted without a signal first being synchronized. Whether a signal is a synchronizing signal or a data message cannot be determined until after a signal is synchronized and decrypted.

SPI is made for bi-directional communication in-circuit through “3-wire”. “3-wire” is set up by three pins on each microcontroller. One pin is a clock pin used for synchronization and the other two pins are used for transmission or receiving. The receivers and transmitters connected to each microcontroller have only one pin for communication, so they cannot control which of the three pins on the PIC they are trying to communicate with. Therefore SPI will not work for our wireless system.

Our solution to not use the serial pins of the microcontroller is to use the RF600 series Keeloq ICs from R.F. Solutions. These ICs handle synchronization, encryption/decryption, and message determination internally, and communicate with the microcontroller directly. They are extremely user-friendly, but the encoders and decoders can only exchange messages consisting of which of the 4 buttons were pressed. It also communicates which encoder pushed the button.

Relay Voltage Divider

When the G6BK-1114P relay was connected into our Voltage Controller circuit directly to the output PORTD of the microcontroller, a voltage divider was created. The output pin of the microcontroller measured 1.7V instead of the 5V required to trigger the relay. This resulted in the inability of the set/reset coils of the relay to latch or de-latch the relay.

After consulting with Rob, our Networking instructor, we used a BJT as a buffer, as shown below in Figure R-1. This allowed us to get the full 5V from the microcontroller's output pins to trigger the set/reset coils of the relay so we could latch the relay and turn the light on in our system.

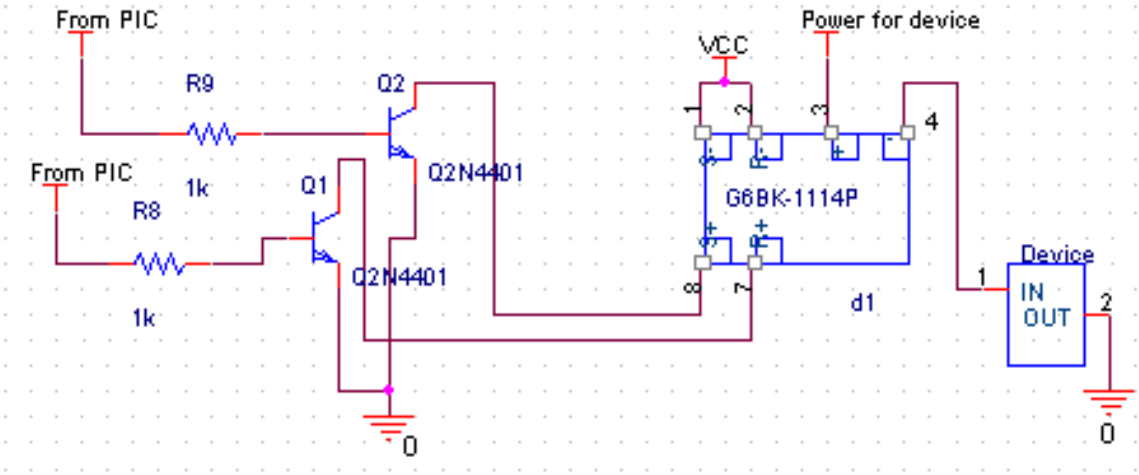

Figure R-1 - BJT Buffer for Relay Schematic

Voltage Inverter for Motor

The motor for this system requires at least 5V to operate. The leads on the motor require opposite polarity inputs to the motor for it to turn. We tried a voltage inverter from Microchip.com, but it could handle 100mA while our motor required 250mA.

After consulting with Bob, our Control Systems instructor, we decided to use an H-Bridge to provide the inputs to the motor, as shown below in Figure R-2. As one side of the H-Bridge is triggered, it produces +5V to one side of the motor and 0V to the other, turning the motor clockwise. As the other side of the H-Bridge is triggered, it produces +5V to that side, and 0V to the original side of the motor, turning the motor counter-clockwise.

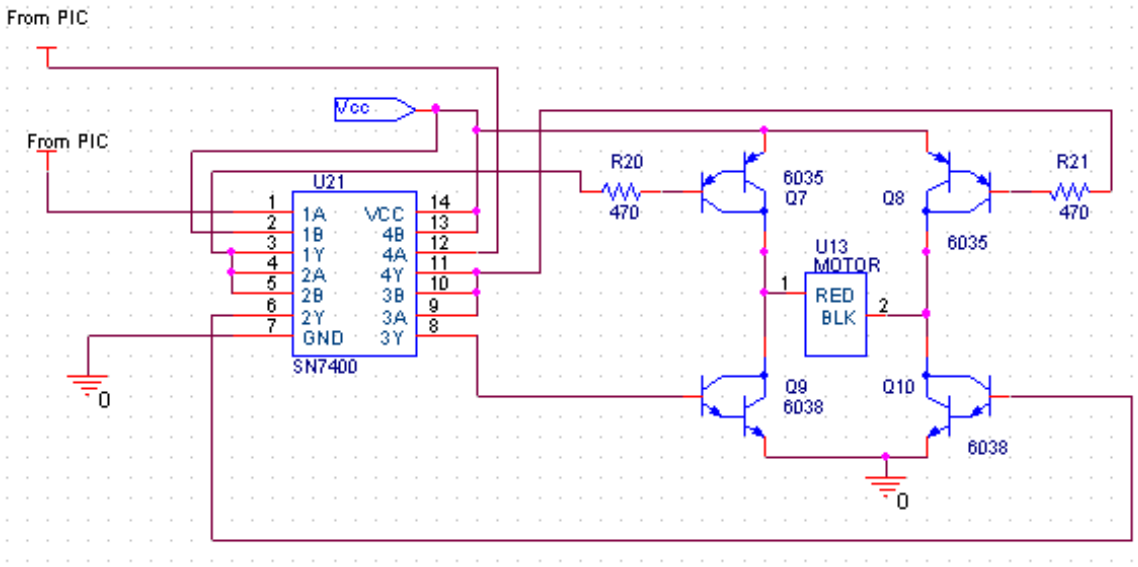

Figure R-2 - H-Bridge Schematic for Motor

Battery Backup

The electromagnetic deadbolts for our door lock are unable to be opened during a power outage since they run off of line voltage. If there was a mechanical systems in place to allow the user to physically push the deadbolt open from the outside, this could be a security risk as anyone could unlock the door.

Instead of an insecure physical movement solution, a battery backup system would be better. If there was a manual key lock to the deadbolt that triggered a battery backup to apply power to the deadbolt, it would allow the user to unlock their door during an outage. This is not currently implemented in our system's design.

Future Implementation/Changes

Surface Mount Technology (SMT)

SMT Antennas would provide an internal antenna, reducing the size of the remote, and creating no extra external components.

SMT Microcontrollers would create a smaller footprint, making the remote control smaller. These would require a SMT microcontroller programmer.

Pre-Made Electromagnetic Locks

Using electromagnetic locks for our system would make installation easier. They are stronger, smaller, and more efficient than the deadbolt we are currently using. They would have pre-configured specs readily available, so finding a lock to meet requirements would be easier.

Battery Backup

As mentioned previously, a battery backup circuit should be created to allow the user to have a key to trigger a battery to supply the electromagnetic deadbolt in case of a power outage.

Sleep Mode for Remote

This would allow the remote to have a longer battery life, making it cheaper, and easier to use for the user.

More Than 3 Devices, More Than One Remote

The RF600E can control up to four devices. Using multiple encoders in one remote could add multiple buttons to the remote, adding extra devices to the system.

The RF600D decoders can learn up to seven encoders, and with external EEPROM, they can learn up to 48 encoders. Therefore the RF600D decoder could respond to up to 48 remotes per decoder, enough for an extended family.

More Control over Command Signal

RF600D and RF600E only communicate button pressed and low battery messages between them. Using the HCS series of Keeloq ICs from Microchip.com, complete control over encrypted messages can be achieved.

Having complete control over messages would allow extra data to be transmitted, such as the last time the door was opened, the current state of devices, synchronizing the clock time between devices, or anything else required.

Conclusion

When you are coming home with a load of groceries, and do not have a third arm to open the door, wouldn't it be nice to have the ***DyckCo*** Wireless Remotely Controlled Home System? Pushing a button to unlock your front door, open the door, and turn the lights on for you sound appealing? The ***DyckCo*** Wireless Remotely Controlled Home System is a complete bi-directional, encrypted communication solution to combat the slow march of evolution giving you the third arm required to carry whatever your current two arms can handle. This system of convenience is built for people, who are elderly, have disabilities, muscle or back problems, or who are just tired of fighting with their front door, and searching around in the dark.

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Glossary

EEPROM	Electrically Erasable Programmable Read-Only Memory is a non-volatile storage chip used in computers and other devices to store small amounts of configuration data.
Keeloq	R.F. Solutions trademarked encryption technique.
RF	Radio Frequency. The portion of the frequency spectrum in which electromagnetic waves can be generated by alternating current which is than fed to an antenna.
Sleep Mode	The ability of the remote to reduce power consumption increasing battery life.
Wireless	The use of some form of radio wave technology to transmit signals.

Appendix A- Flowcharts

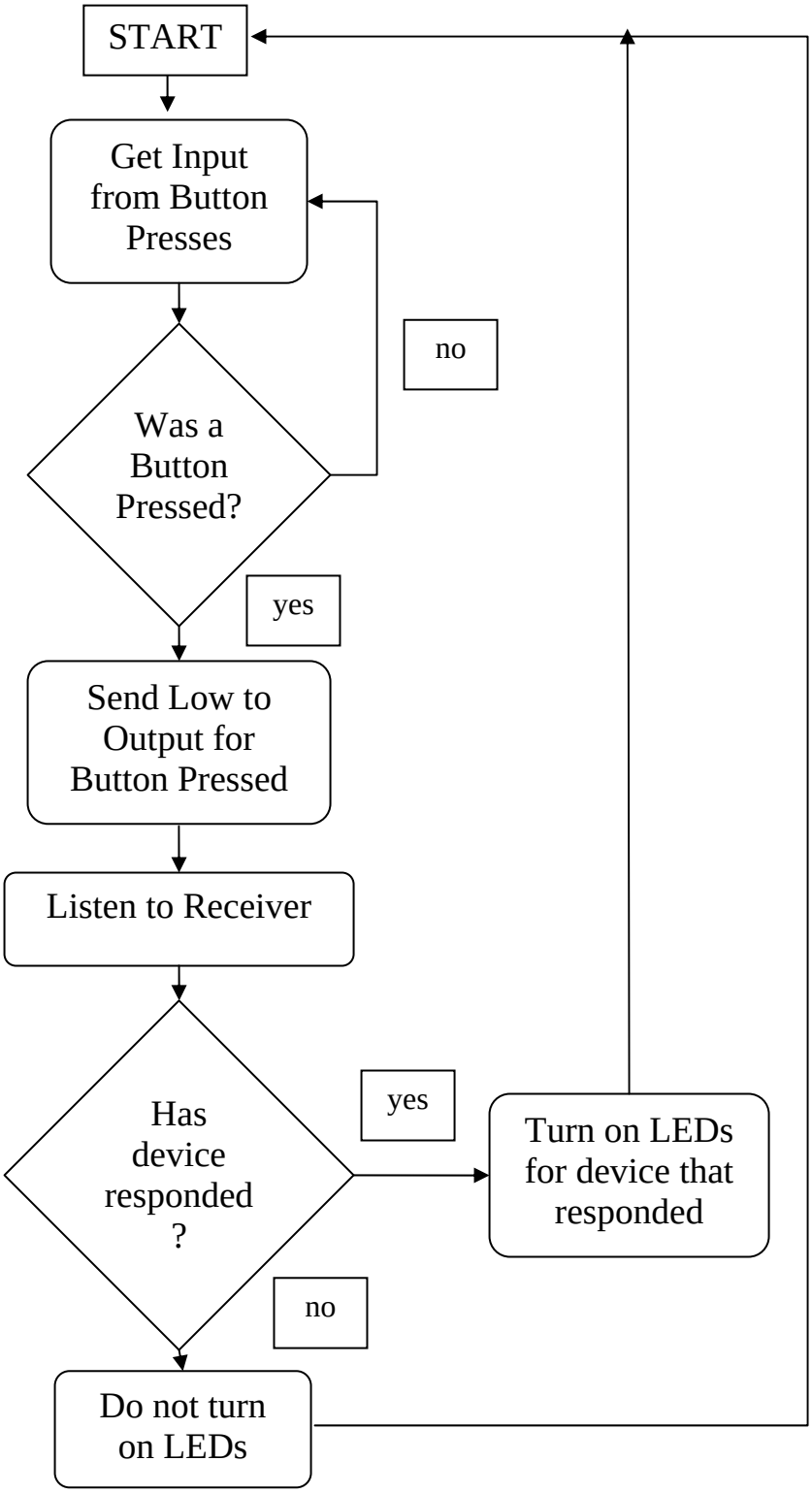

Figure A-1 – *Dyckco* Remote Control Flowchart

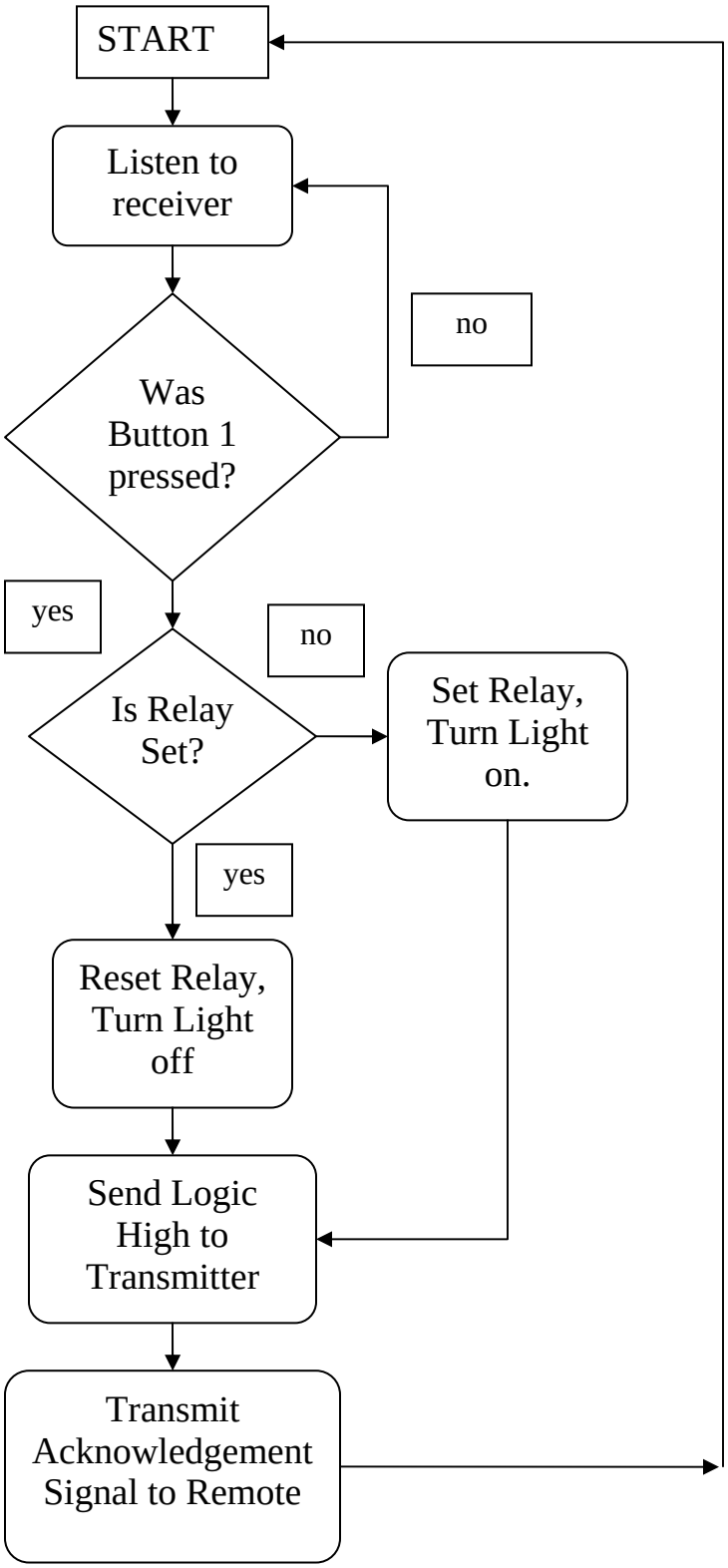

Figure A-2 – *DyckCo* Voltage Controller Flowchart

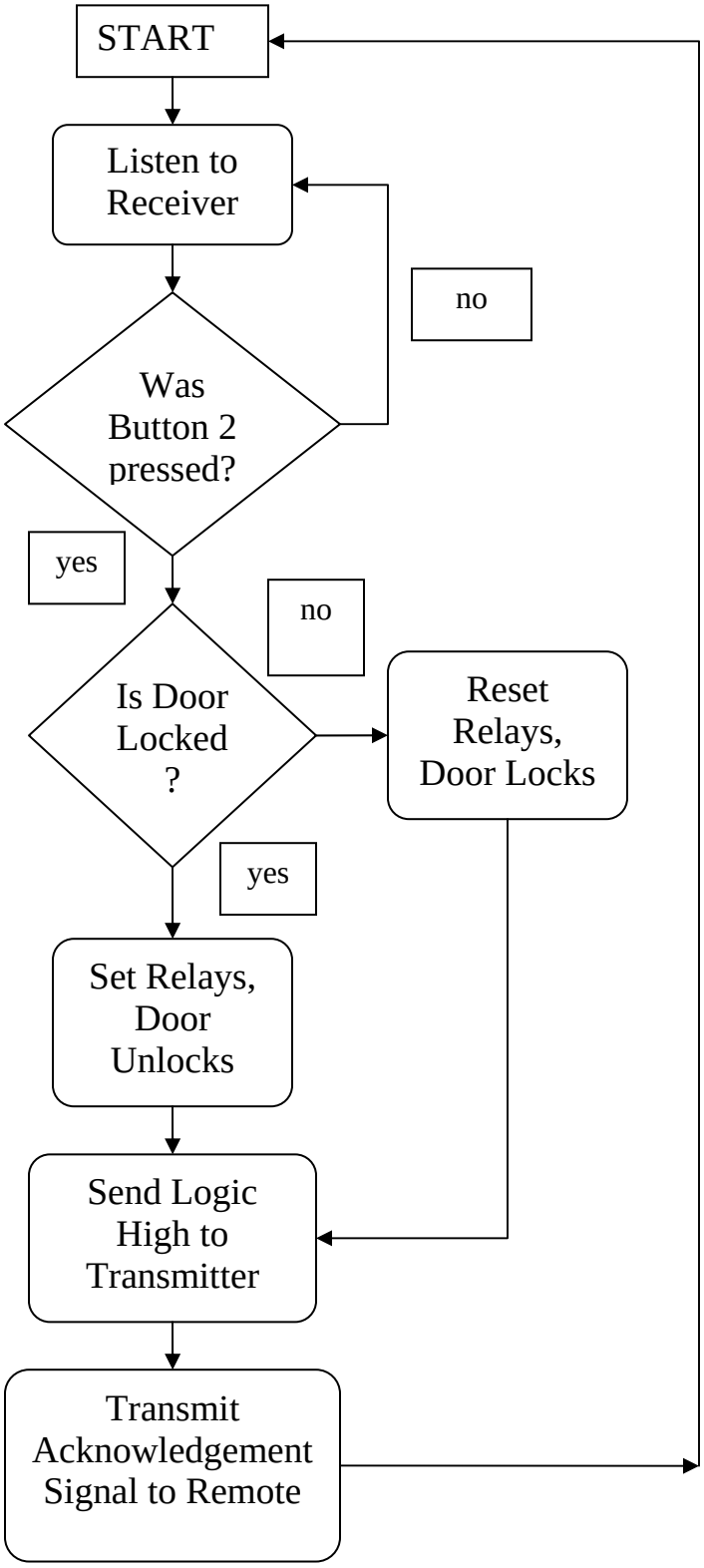

Figure A-3 – *DyckCo* Door Opener Flowchart

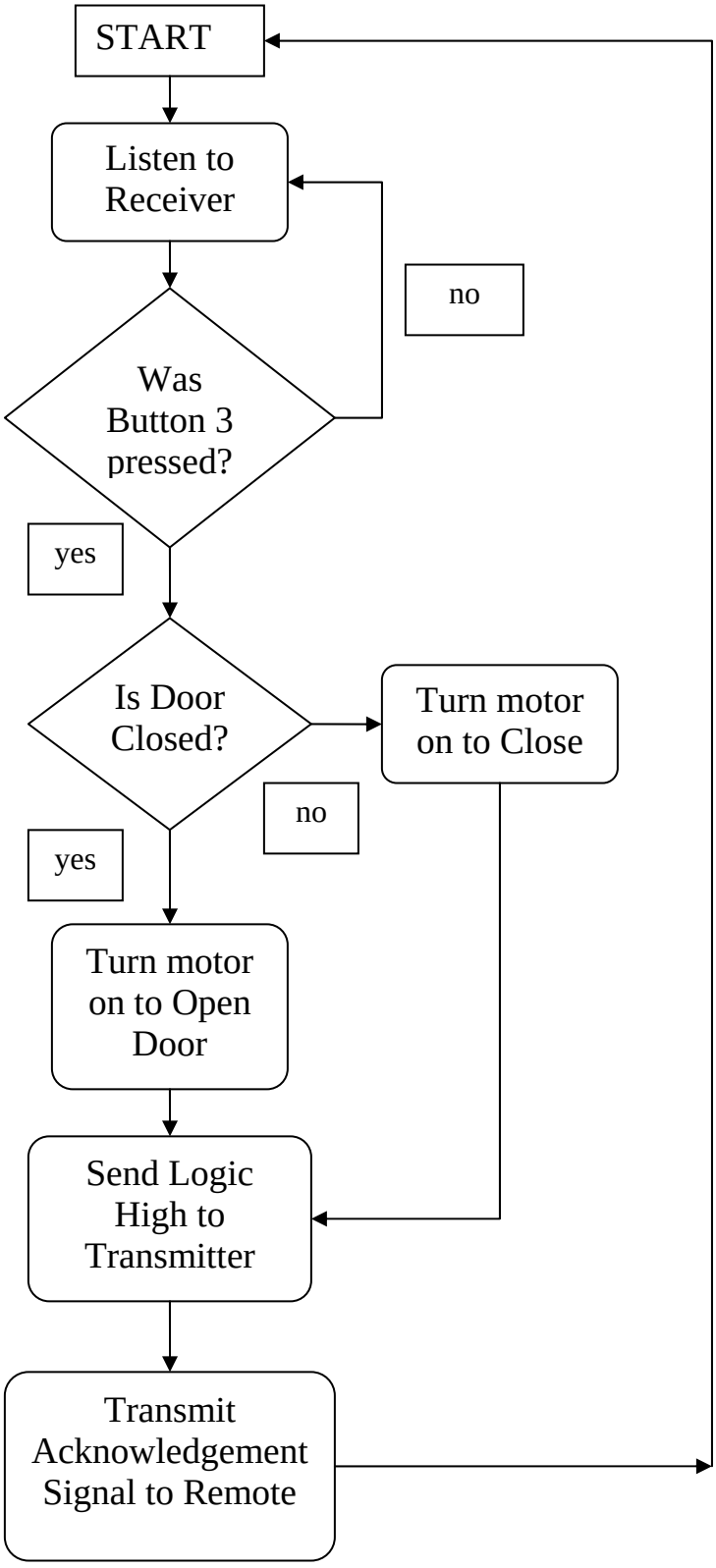

Figure A-4 – *DyckCo* Door Lock Flowchart

Appendix B – Schematics of Devices

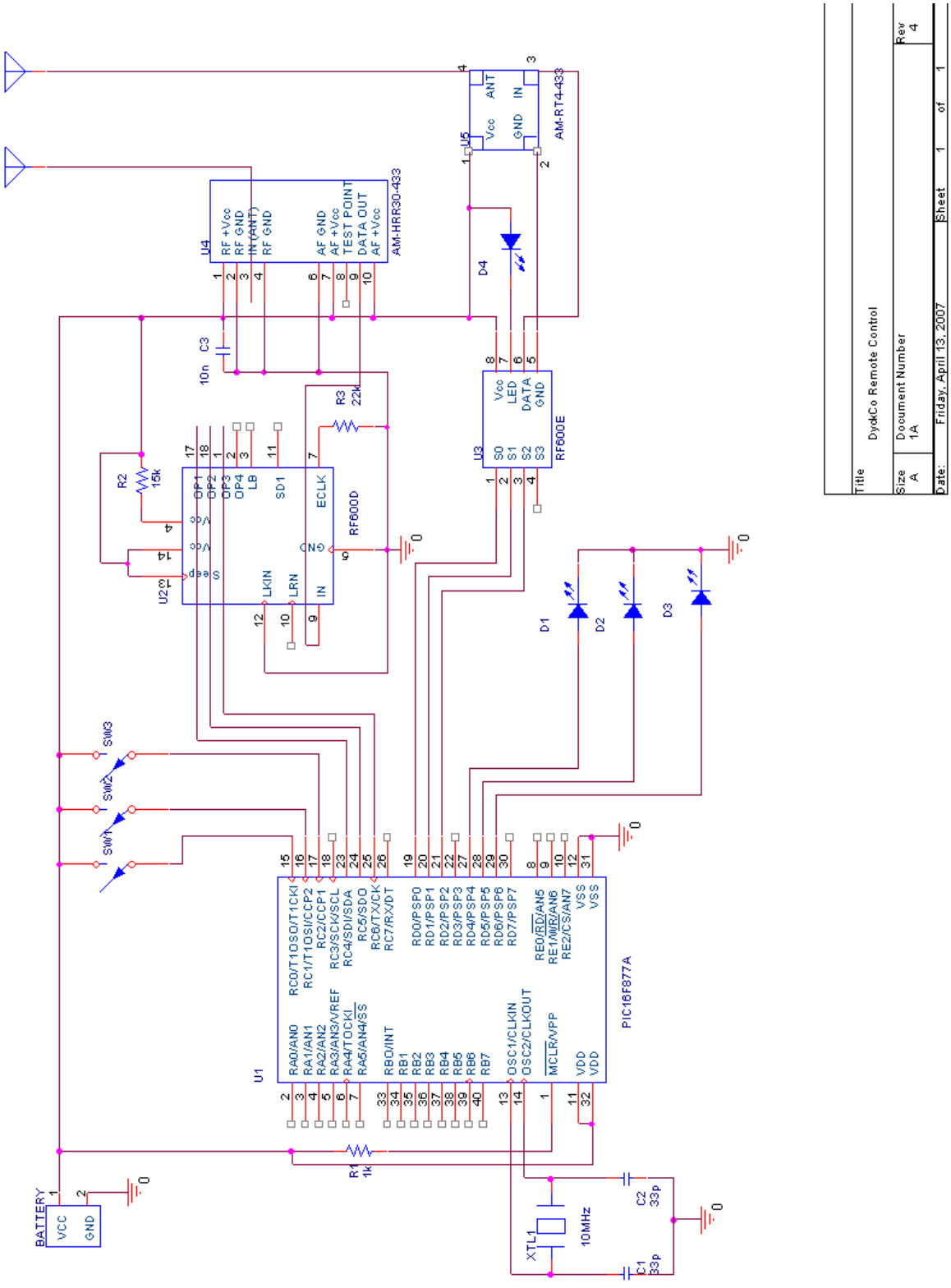

Figure B-1 – *DydkCo* Remote Control Schematic

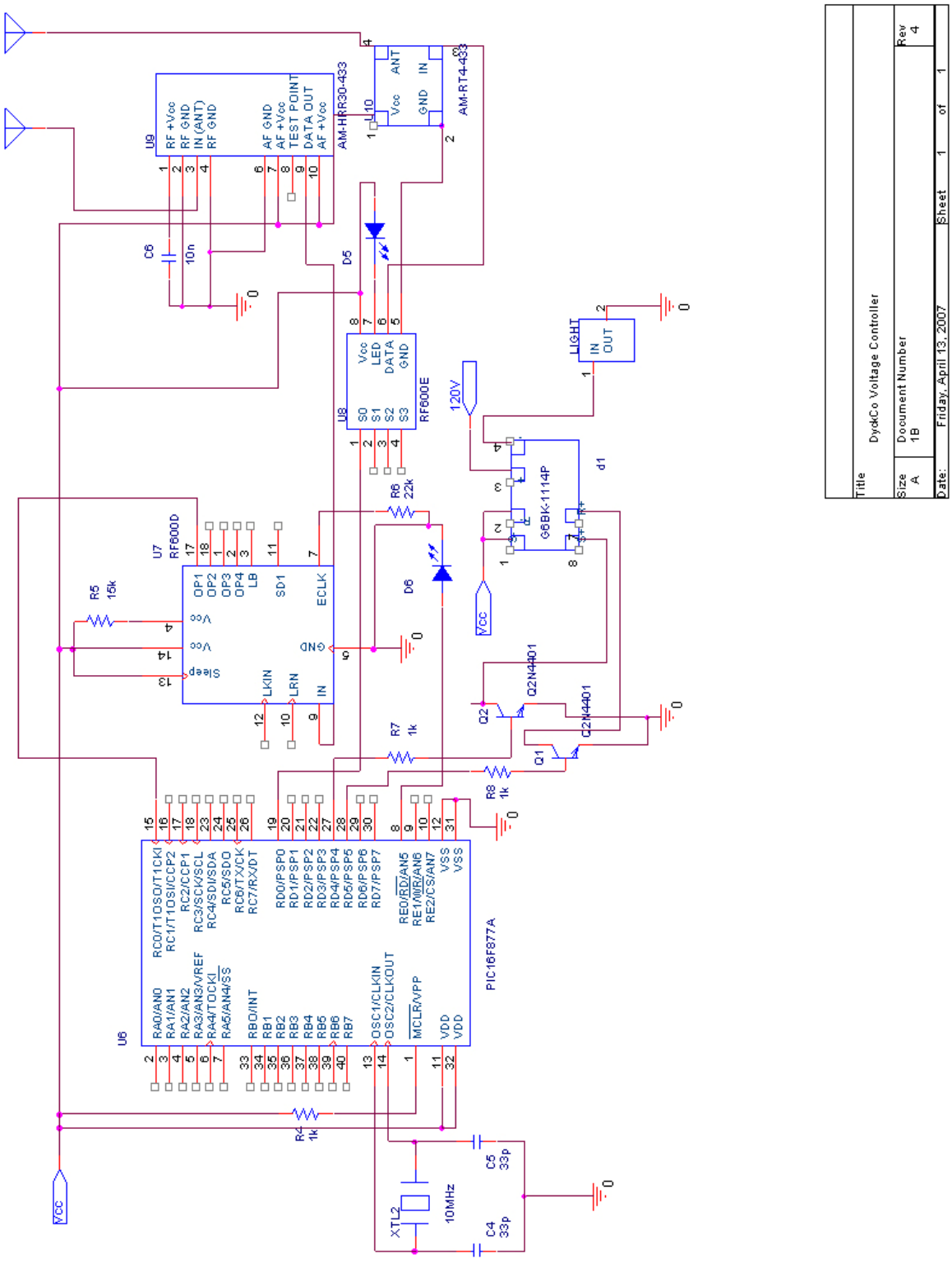

Figure B-2 – *DykCo* Voltage Controller Schematic

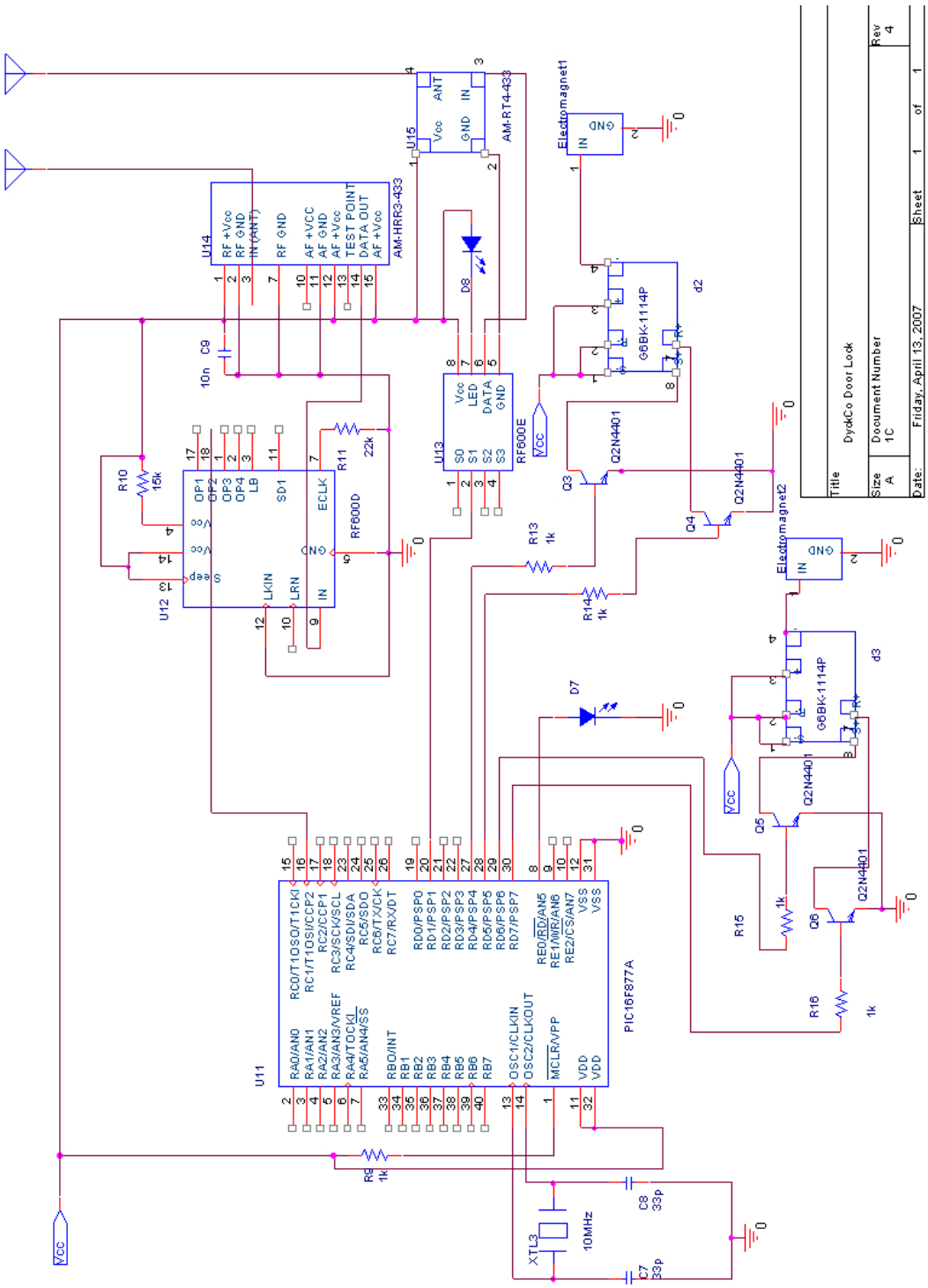

Figure B-3 – *DyckCo* Door Lock Controller Schematic

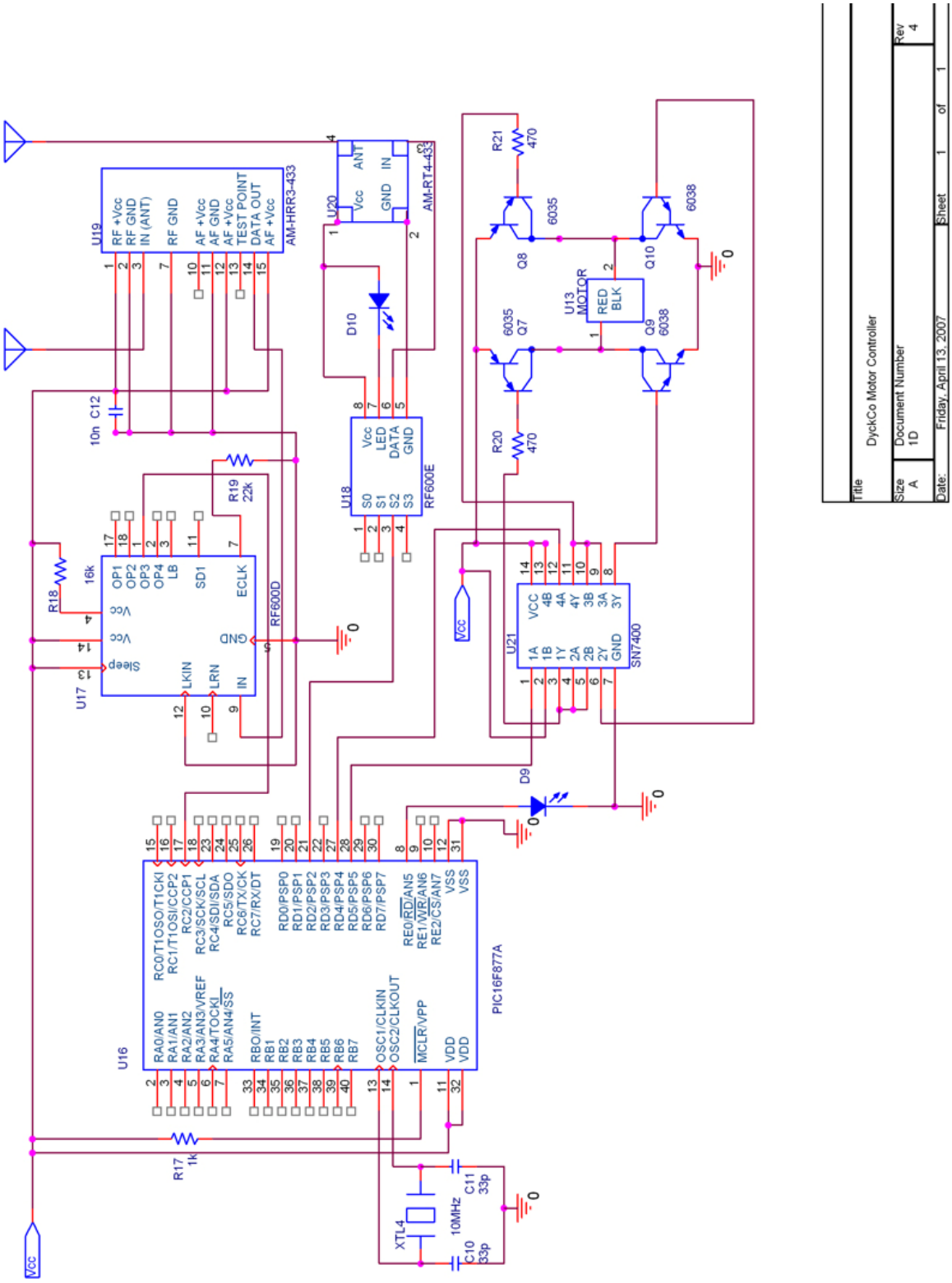

Figure B-4 – *DyckCo* Door Motor Controller Schematic

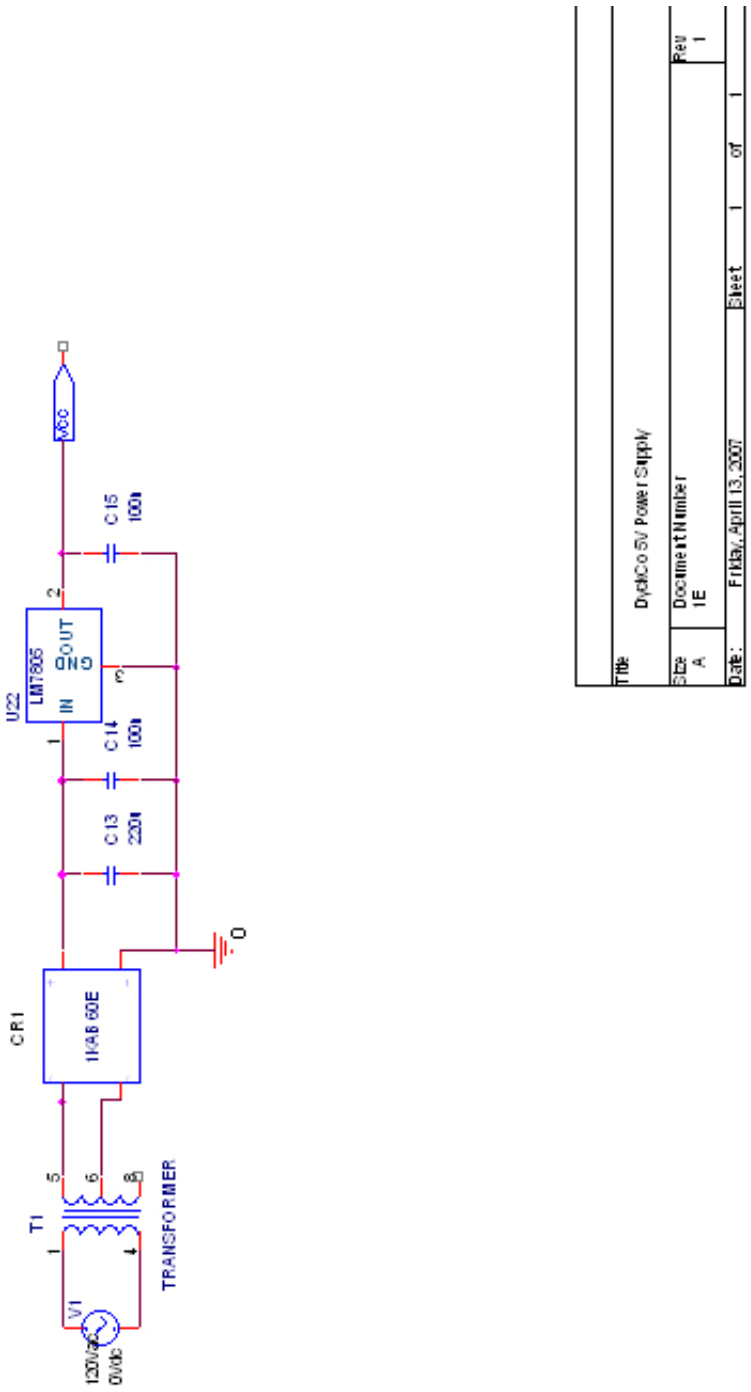

Figure B-5 – *DyckCo* 5V Power Supply Schematic