Microcontroller-based Bill-to-Coin Changer with UV Light-dependent Counterfeit Sensor

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APPROVAL SHEET

This is to certify that this design study entitled **"Microcontroller-based Bill-to-Coin Changer with UV Light-dependent Counterfeit Sensor"** prepared by **Jomer M. Bolo, Billie Nicolette B. Buenafe, Lyndon Jason M. Catalan, Jhune Bryan R. Reyes, and Caroline Jane P. Sambaoa** in partial fulfillment of the requirements for the degree **Bachelor of Science in Computer Engineering** have been supervised the preparation of and read the design documentation and hereby recommended for final examination by the Oral Examination Committee.

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Reader	Design Adviser

As members of the Oral Examination Committee, we hereby **APPROVED** this design study which was presented before a Panel of Examiners of the School of EE-ECE-CoE on **March 8, 2008.**

Engr. Isagani V. Villamor	**Engr. John Louie A. Ching**
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Engr. Gino Paolo Luis R. Villanueva
Panel Member 3

Accepted in partial fulfillment of the requirements for the degree **Bachelor of Science in Computer Engineering.**

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ABSTRACT

The bill-to-coin changer is a microcontroller-based design that changes peso bills inserted by the user to peso coins of choice. It is capable of changing 20-peso, 50-peso, and 100-peso bills only, with coin denominations of 25-cents, 1-peso, 5-peso, and 10-peso coins. The system consists of vital parts such as the counterfeit sensor device paired with an Ultraviolet light to detect the authenticity of bill, bill detector to identify the amount of money inserted, coin sensor as dispensing counter, relay driver circuit as switching device for gear motors and lamp, and the microcontroller circuit paired with a keypad and LCD for control and I/O processes. The research instrument used is descriptive for information gathering and experimental research for design implementation and testing. Schematic capture and testing is used to ensure that actual design is feasible. The software used to program PIC16F877 is Proton IDE which uses PICBASIC programming for flexibility and easy error-debugging capability.

Keywords: counterfeit sensor, ultraviolet light, bill detector, coin sensor, relay driver, microcontroller

Chapter 1

INTRODUCTION AND REVIEW OF RELATED LITERATURE AND STUDIES

Research Setting

Technological evolution is evidently visible nowadays. It can be seen through the different machines and devices that are used from the past to the present. Manual operations are gradually omitted by technological means. Bill to coin changer is a device innovated from the idea used on vending machines and change machines. But neither of the existing devices and/or machines provides the means to which people could exchange their bill/s to coins without having to pay for something first.

Most people take public transportation to reach their destination. Coins are essential in this scenario. Because it is inconvenient to pay a hundred peso bill for the seven peso and 25 cents minimum fare, especially in the morning trips, most people are forced to buy something just to have their money changed into smaller bills. Convenient stores and retail stores are likewise known to be in need of coins especially in the morning for their customer's change.

With this, the proponents came up with an innovation which is derived from the concept used on existing slot machines. The proposed machine would be capable of identifying and changing 100, 50 and 20 peso bill to 25 cents, 1, 5, and/or 10 peso coin. The inserted bill will first be tested using UV light technology to check if it is authentic or counterfeit. The UV light technology was chosen over other technologies because it is the most commonly used bill authenticity detector. Also, studies show that the ultraviolet light can scan fluorescent fibers of the bill, enabling the user to verify the authenticity of the bill accurately. After which, the user will be able to choose the combination of coin denomination he wants the machine to dispense.

Review of Related Literature and Studies

Bill Money Changer for Slot Machines

One of the studies done by Bruce Edward C. Kelly (Blue Bell, PA) in October 30, 1990 entitled Bill Money Changer for Slot Machines is very related to the system the proponents are trying to create. The author stated that "the present invention broadly relates to dispensing devices and, more particularly, to a coin dispenser for use with gaming devices, such as slot machines." He also added that "the dispenser changes paper bills into coinage" which is what the design is all about. Moreover, his studies contribute much of the information and data on how to create the design. One of this information includes the main parts of his design such as the bill-activated coin dispenser, cabinet enclosing the bill money changer, a plurality of separate coin storage cartridges, and shoe for receiving coins from each of said cartridges, which the proponents referenced and partially imitated.

Bill Acceptor

The study completed by Cheng-kang Yu (Taipei, TW) and Wen-yuan Tsai (Taipei, TW) in February 7, 2006 comprises the design the proponents are creating. One important quote the inventors said is that "the present invention relates to bill acceptors and, more particularly, to such a bill acceptor, which uses infrared light to fetch the image of inks of the bill to be examined and ultraviolet light to scan fluorescent fibers of the bill, enabling the user to verify the authenticity of the bill accurately." This line has given the proponents the idea to implement a UV light lamp to check whether the bill inserted is counterfeit or not.

Coin Dispensing Apparatus

Another study entitled Coin Dispensing Apparatus patented by Abe, Hiroshi (Tokyo, JP) last March 03, 1992 is related to the design. According to him, his design is "a coin dispensing apparatus for use in coin exchangers, coin operated gaming machines or the like and more particularly to such a coin dispensing apparatus comprising a hopper for holding a supply of coins or tokens in bulk and a rotary disc which is rotated in the hopper to dispense coins one at a time and in predetermined quantities." He continued that "when the rotary disc is rotated, a coin is transported from the bottom portion of the hopper to the outlet chute at the upper delivery portion by each of the transporting pins which project from the surface of the rotary disc and pass through the tunnel passage in the delivery guide." The proponents used this idea to create a coin dispenser using PVC tubes for coin container and a rotating metal shaft coupled in a motor gear for kicking the coins to be dispensed.

Microcontroller Unit

A microcontroller unit or an MCU is a computer-on-a-chip. It is a type of microprocessor emphasizing self-sufficiency and cost-effectiveness, in contrast to a general-purpose microprocessor (used in a PC). A typical microcontroller contains all the memory and interfaces needed for a simple application, whereas a general purpose microprocessor requires additional chips to provide these functions. A microcontroller is a single integrated circuit, commonly with the following features:

1. Central processing unit - ranging from small and simple 4-bit processors to sophisticated 32- or 64-bit processors.
2. Input/output interfaces such as serial ports.
3. Peripherals such as timers and watchdog circuits and signal conversion circuits.
4. RAM for data storage.
5. ROM, EPROM, EEPROM or Flash memory for program storage.
6. Clock generator - often an oscillator for a quartz timing crystal, resonator or RC circuit.

Light Dependent Resistor (LDR)

A photoresistor or LDR is an electronic component whose resistance decreases with increasing incident light intensity. It can also be referred to as a light-dependent resistor (LDR), photoconductor, or photocell.

A photoresistor is made of a high-resistance semiconductor. If light falling on the device is of high enough frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump into the conduction band. The resulting free electron (and its hole partner) conduct electricity, thereby lowering resistance.

There are just two ways of constructing the voltage divider with the LDR. It is located either at the top (figure at the left), or at the bottom (figure at the right), shown in Figure 1 below.

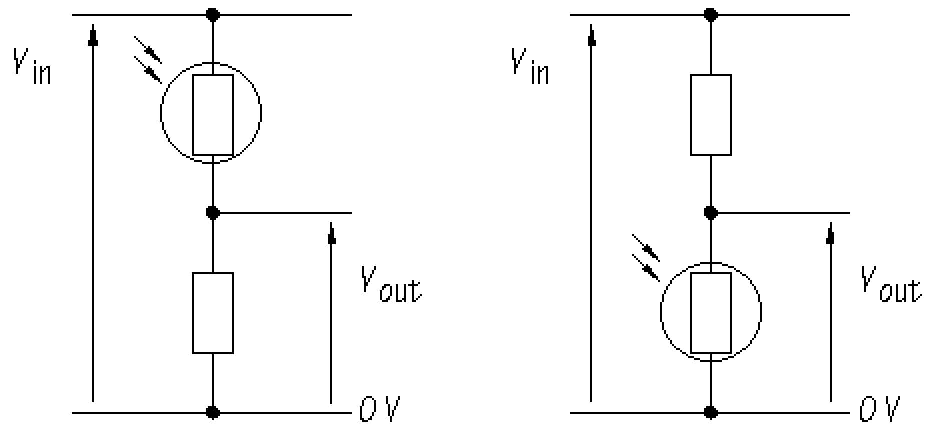


Figure 1: Constructing Voltage Divider Circuit using LDR

You are going to investigate the behavior of these two circuits. You will also find out how to choose a sensible value for the fixed resistor in a voltage divider circuit.

Remember the formula for calculating V_{OUT}:

$$V_{OUT} = \frac{R_{BOTTOM}}{R_{BOTTOM} + R_{TOP}} x V_{IN}$$

With the setting shown in Figure 2, the FSD, or full scale deflection of the ohmmeter is 200. This means that the meter will measure resistances from zero up to a maximum of 200. With this setting, you will be able to see how the resistance of an LDR changes with illumination.

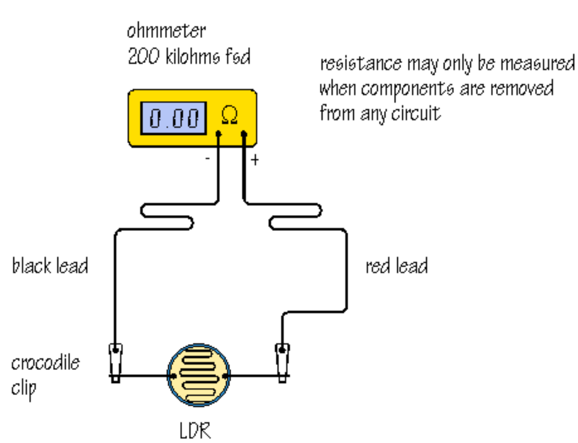


Figure 2: Measuring LDR Resistance using an Ohmmeter

Relay Interface

A relay is an electrical switch that opens and closes under the control of another electrical circuit. In the original form, the switch is operated by an electromagnet to open or close one or many sets of contacts. Because a relay is able to control an output circuit of higher power than the input circuit, it can be considered to be, in a broad sense, a form of an electrical amplifier.

When a current flows through the coil, the resulting magnetic field attracts an armature that is mechanically linked to a moving contact. The movement either makes or breaks a connection with a fixed contact. When the current to the coil is switched off, the armature is returned by a force approximately half as strong as the magnetic force to its relaxed position. Usually this is a spring, but gravity is also used commonly in industrial motor starters. Most relays are manufactured to operate quickly. In a low voltage application, this is to reduce noise. In a high voltage or high current application, this is to reduce arcing.

If the coil is energized with DC, a diode is frequently installed across the coil, to dissipate the energy from the collapsing magnetic field at deactivation, which would otherwise generate a spike of voltage and might cause damage to circuit components. Some automotive relays already include that diode inside the relay case. Alternatively a contact protection network, consisting of a capacitor and resistor in series, may absorb the surge. If the coil is designed to be energized with AC, a small copper ring can be crimped to the end of the solenoid. This "shading ring" creates a small out-of-phase current, which increases the minimum pull on the armature during the AC cycle.

By analogy with the functions of the original electromagnetic device, a solid-state relay is made with a thyristor or other solid-state switching device. To achieve electrical isolation an optocoupler can be used which is a light-emitting diode (LED) coupled with a photo transistor.

When we want to switch inductive loads such as relays we have to use a diode in the circuit to prevent the transistor from being damaged (see Figure 4). An inductive load can generate a back EMF which could easily damage a transistor. By connecting a diode in reverse bias mode this back EMF is dissipated without damaging the transistor.

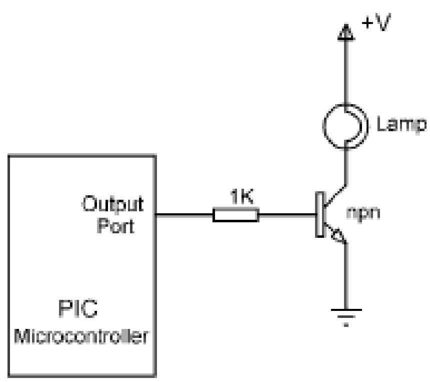


Figure 3: Driving a Lamp using Transistor

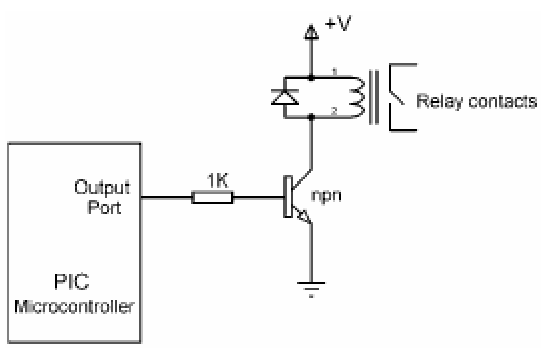


Figure 4: Driving an Inductive Load such as Relay

Since we can drive a relay, we can connect any load to the relay outputs as long as we do not exceed the contact ratings of the relay. Figure 5 shows how a mains lamp can be operated from the microcontroller output port using a relay. The relay could also be operated using a MOSFET power transistor. In this circuit the main lamp will turn ON when the output port of the microcontroller is logic 1.

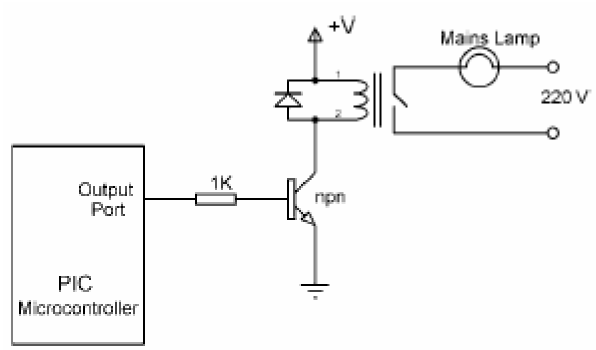


Figure 5: Driving a Lamp using Relay

Analog-to-Digital Converters

Analog devices usually consist of a sensor that will output a voltage that has a linear relationship with the unit that it is measuring. For instance an analog type temperature probe will output a voltage that will correlate to temperature. As the temperature increases so will its output voltage. The "measurable" range of this temperature will be such that it has a "linear" relationship with this voltage output.

A linear relationship means that a given change in the quantity being measured (such as a number of degrees of temperature) will produce a given corresponding quantity of change in its output (such as a voltage), over the device's entire measuring range. When a sensor has a linear output such as this, it can have a function or equation which represents a way to convert this voltage to temperature units.

An analog to digital converter will convert an input voltage to a reading that a computer can understand. This converted reading is based on a binary counting system. We all know a computer system understands bits, which are a value of zero or one. The binary counting system consists of a number of these bits, whose various values represent a number. The greater number of bits, the higher the possible maximum number which can be counted.

For instance say we have a simple two bit system. The maximum count will be two to the second power or four (ranging from zero to three). The first bit will represent a two to the zero power or one; the second bit will represent a two to the first power or two.

PIC Microcontrollers and Minimum Support Components

A PIC microcontroller, even though it may have been programmed, is not of much use unless it is supported by a number of components, such as the timing components and the reset circuitry. PIC microcontroller requires an external clock circuit (some PIC microcontrollers have built-in clock circuits) to function accurately.

Resonators are more often used in microcontroller clock circuits because of their low cost, simplicity, and low component count. The connection of a resonator to a PIC microcontroller is shown in Figure 6. The centre pin is connected to ground, and the two pins at either sides of the resonator are connected to the OSC1 and OSC2 oscillator inputs of the PIC microcontroller.

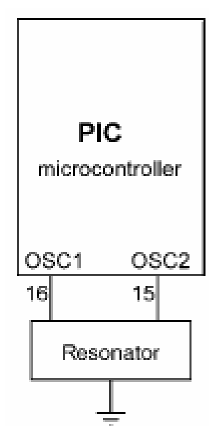


Figure 6: Using a Resonator in PIC Microcontroller

A PIC microcontroller starts executing the user program from address 0 of the program memory when power is applied to the chip. As shown in Figure 7, the reset input (MCLR) of the microcontroller is usually connected to the supply voltage through a 4.7K resistor.

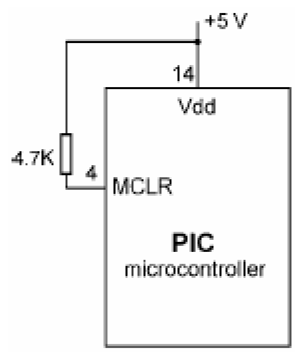


Figure 7: Connecting the Reset (MCLR) Input

Liquid Crystal Display (LCD)

In many microcontroller-based applications, it is required to display a message or the value of a variable. For example, in a temperature-control application, it may be required to display the value of the temperature dynamically. Basically, three types of displays can be used in practice. These are video displays, 7-segment LED displays, and LCD displays. Standard video displays require complex interfaces and their cost is relatively high. 7-segment LED displays are made up of LEDs. Although the 7-segment LEDs are bright, their disadvantage is the high power consumption which makes them unsuitable in many battery-operated portable applications.

LCDs are alphanumeric displays which are frequently used in microcontroller-based applications. Some of the advantages of LCDs are their low cost and low power consumption. LCDs are ideal in low-power, battery-operated portable applications. These displays come in different shapes and sizes. Some LCDs have 40 or more characters with several rows. Some more advanced LCDs can be programmed to display graphics images. Some modules, such as the ones used in games, offer color displays while some others may incorporate back lighting so that they can be viewed in dimly lit conditions.

Color, Light, and Sensor

Color is a visual perception property which is derived from the spectrum of light interacting in the eye. Color groups and physical specifications are often associated with objects, materials and light sources based on their physical properties such as light absorption, reflection, or emission spectra.

HSV are representations of points in an RGB color space. “H” represents hue which is the aspect of a color described with names such as “red”, “yellow”, etc. On the other hand, “S” represents saturation which is determined by combination of light intensity and how much it is distributed across the spectrum of different wavelengths. The most important is “V” or value because it is used in determination of the value of the bill in the design. Value is the lightness or darkness of a color; it is found useful in determining the kind of bill when using an LDR as a sensor.

For the particular design, the system is limited only to detect P20.00, P50.00, and P100.00. Each of the bills has corresponding color *value*, such as light for P20.00 (orange), medium for P50.00 (red), and dark for P100.00 (violet). Note that the strongest hue is located in the collar of the person imprinted in the bill, so it is advisable to focus in this area. Since LDR is sensitive to light, different voltage values are measured when each of these bills is placed in between the light source and the LDR (focused in the strongest hue). Thus, the different output voltage can be used to identify the kind of bill (i.e. the measured voltage across LDR: 1V = P20.00, 1.5V = P50.00, 2.25V = P 100.00).

Conceptual Framework

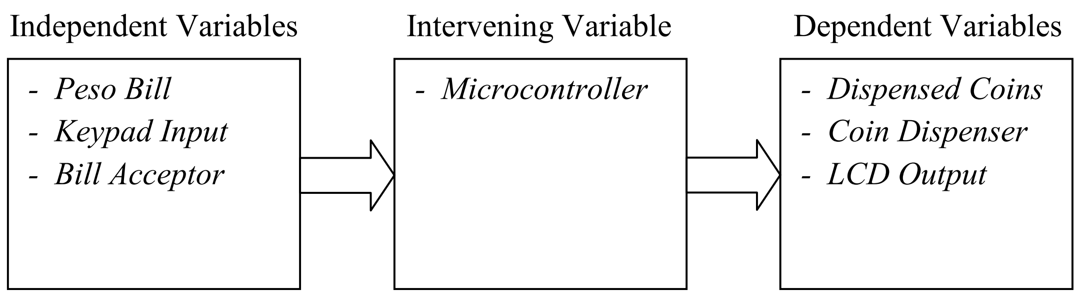


Figure 8: Conceptual Framework Diagram

In order for the system to do its purpose, fundamental variables are necessary. Figure 8 shows the conceptual framework diagram of the system. The input comes from the user; this includes the peso bill which could be 20, 50, or 100, the keypad input, and bill acceptor. The number of dispensed coins, coin dispenser, and LCD output are highly dependent to it. Without the user input, the system will not be functional. The principal part of the system is the microcontroller. The microcontroller controls the operation of the whole system and is the one that processes the independent variables to drive the dependent variables.

Statement of the Problem

The main problem of the design is the development of a device that could accept and identify bills to be changed into exactly similar amount in coins. Specific hindrances include the process of detecting fake money and identifying the amount of bill inserted. Moreover, the determination of the minimum and maximum amount of money to be accepted and dispensed, as well as the measure of accuracy and reliability of the study, are also particular problems.

Objective of the Study

This design aims to develop a user-friendly system capable of accepting authentic bills from the user and allowing the user to choose the coin denominations he wants his bills to be changed into. In addition to this, the system must not dispense insufficient coins; this means that the amount of coins to be dispensed must be of same amount as the inserted bill. The design also intends to know if an Ultraviolet light can really help determine fake bills when paired with a counterfeit sensor system. Moreover, the design also aims to know if light intensity from colored bills can be distinguished and used as a variable to know the value of the bill using a Light-Dependent Resistor and an A/D converter. Furthermore, the objective of the design is to see if an optical sensor can be used to count coins going out of the dispenser.

Significance of the Study

The use of a bill-to-coin-changer device is a more innovative and convenient way of having bills changed to coins. The trouble of providing coins for early morning transportation is a common problem to most Filipino commuters. With this device, the hassle brought by paying in bills to the commuters as well as public-utility vehicle drivers will be lesser.

As for students, this design has initiated the group members to apply their technical competence and creativity in creating an actual design that is relevant to the modernization and advancement of the lifestyles of citizens. This study also allows future researchers to come up with other methods on how to improve such device.

Scope and Delimitation

The system design has a narrow range of functionalities because of limited resources and time. The following are the capabilities covered by the design:

1. The device changes inserted bills to coin denomination of choice.
2. The device detects if the inserted bill is a fake money.
3. The device identifies 20, 50, and 100 Philippine peso bills.
4. The device dispenses coins with denominations of 25-cents, 10, 5 and 1 Philippine peso coins.
5. The device has an error detection functionality wherein an error message is displayed if a certain expression is false (e.g. the total value of selected denomination is not equal to the value of the inserted bill).
6. Inquired total number of remaining coins in the dispenser will reset to 300 if the system is restarted.
7. The device has a calibration test functionality which ensures that the color of the inserted bill is synchronized with the color detected by the system.
8. The device has backup battery in case of power failure.

In contrary to the functionalities of the design, the device has also a range of restrictions. The following are the limitations which the design cannot accomplish:

1. The device cannot correctly identify bills other than 20, 50 and 100 peso bills.
2. The device cannot dispense coin denominations other than the scope (e.g. 5-cents and 10-cents).
3. The device can only change one bill per transaction.
4. The bill is not retrievable once inserted in the system.
5. The device cannot differentiate a non-Philippine peso authentic bill with the same color as the scope (e.g. 20KD is also color red like P50.00 thus when it is inserted, the system will identify it as P50.00).
6. Very old or faded peso bills may not be recognized as to their respective values.
7. The coin dispenser of the device can only hold a maximum of 300 coins container.
8. The device cannot identify if there was a pending transaction prior to power interruption.
9. The backup battery of the device will last for approximately 4 hours during power failure.

Definition of Terms

Analog-to-Digital Converter (A/D) is an electronic integrated circuit, which converts continuous signals to discrete digital numbers. (Wikipedia, the Free Encyclopedia)

Buzzer is a signaling device, usually electronic, which most commonly consists a number of switches or sensors connected to a control unit that determines if and which button was pushed or a preset time has lapsed, and usually illuminates a light on the appropriate button or control panel, and sounds a warning in the form of a continuous or intermittent buzzing or beeping sound. (Wikipedia, the Free Encyclopedia)

Complementary metal–oxide–semiconductor (CMOS) is a major class of integrated circuits that is used in microprocessors, microcontrollers, static RAM, and other digital logic circuits; it uses complementary and symmetrical pairs of p-type and n-type metal oxide semiconductor field effect transistors (MOSFETs) for logic functions. (Webopedia Computer Dictionary)

Direct Current (DC) is the unidirectional flow of electric charge which is produced by such sources as batteries, thermocouples, solar cells, and commutator-type electric machines of the dynamo type; it may be obtained from an alternating current supply. (Wikipedia, the Free Encyclopedia)

Electrically Erasable Programmable Read-Only Memory (EEPROM) is user-modifiable read-only memory that can be erased and reprogrammed repeatedly through the application of higher than normal electrical voltage; it does not need to be removed from the computer to be modified but it has to be erased and reprogrammed in its entirety, not selectively. (WhatIs, the Leading IT Encyclopedia)

Electromotive force (EMF) is the energy per unit electric charge that is imparted by an energy source, such as an electric generator or a battery wherein energy is converted from one form to another. (Britannica Online Encyclopedia)

Flash memory is a non-volatile computer memory that can be electrically erased and reprogrammed. (Wikipedia, the Free Encyclopedia)

Human-Machine Interface (HMI or user interface) is the aggregate of means by which people – the users – interact with a particular machine, device, computer program or other complex tool – the system. (Wikipedia, the Free Encyclopedia)

Integrated Circuit (IC) is a device made of interconnected electronic components, such as transistors and resistors that are etched or imprinted onto a tiny slice of a semiconducting material, such as silicon or germanium. (The American Heritage Science Dictionary)

Keypad is an input device, sometimes part of a standard computer keyboard, consisting of a separate grid of numerical and function keys arranged for efficient data entry. (The American Heritage Dictionary of English Language)

Light Dependent Resistor (LDR) or photoresistor is an electronic component whose resistance decreases with increasing incident light intensity. (Wikipedia, the Free Encyclopedia)

Light-Emitting Diode (LED) is a semiconductor diode that emits incoherent narrow-spectrum light when electrically biased in the forward direction of the p-n junction, as in the common LED circuit. (Wikipedia, the Free Encyclopedia)

Liquid Crystal Display (LCD) is a thin, flat display device made up of any number of color or monochrome pixels arrayed in front of a light source or reflector. (WhatIs, the Leading IT Encyclopedia)

Microcontroller (MCU or µC) is a computer-on-a-chip, a type of microprocessor emphasizing high integration, low power consumption, self-sufficiency and cost-effectiveness, in contrast to a general-purpose microprocessor. (Wikipedia, the Free Encyclopedia)

Motor (electrical) uses electrical energy to produce mechanical energy which is found in household appliances such as fans, refrigerators, washing machines, pool pumps, floor vacuums, and fan-forced ovens. (Answers, Online Dictionary and Encyclopedia)

Phototransistor is a bipolar transistor that is encased in a transparent case so that light can reach the base-collector junction; it works like a photodiode, but with a much higher responsivity to light, because the electrons that are generated by photons in the base-collector junction are injected into the base, and this current is then amplified by the transistor operation. (Wikipedia, the Free Encyclopedia)

Potentiometer is a variable tapped resistor that can be used as a voltage divider; it is commonly used as controls for electrical devices such as volume control of a radio. (Wikipedia, the Free Encyclopedia)

Random access memory (RAM) is a type of computer data storage that allows the stored data to be accessed in any order, i.e. at random. (Britannica Online Encyclopedia)

Relay is an electrical switch that opens and closes under the control of another electrical circuit; the switch is operated by an electromagnet to open or close one or many sets of contacts. (Britannica Online Encyclopedia)

Transistor is a semiconductor device, commonly used as an amplifier or an electrically controlled switch. (Answers, Online Dictionary and Encyclopedia)

Ultraviolet Light (UV) is an electromagnetic radiation with a wavelength shorter than that of visible light, but longer than soft X-rays; the spectrum consists of electromagnetic waves with frequencies higher than those that humans identify as the color violet or purple. (The American Heritage Dictionary of English Language)

Chapter 2

METHODOLOGY

Research Design

The proponents used both descriptive research and experimental research to give solution to the main problem. Descriptive approach was used during the information gathering. The information gathered has led them to the solution on some of the specific problems stated in Chapter 1. Experimental research, on the other hand, was done in this design in order to implement what was researched for and to be able to do some testing. This has to be done in order to conclude whether or not the design was able to meet the objectives, and if it is efficient enough for the application that it is intended for.

To begin solving the problem, the proponents started with the data needed. The challenge was how to come up with a device that would satisfy the above listed objectives. The proponents started gathering data by researching on technologies and studies that are in some way parallel to the requirements of the system. Major components of the design, through a block diagram, were determined so as to know which of the available materials and technology in the market could be used in the design. Materials are then selected based on the criteria and requirements of the problem.

Since this design made use of microcontroller to coordinate and manipulate the functions of different circuits, a good programming language and skill is also necessary to complete the design. Again, consulting related books and knowledgeable persons are of help in designing and debugging the program. To visualize the summary of the steps above, Figure 9 shows the flowchart for the data gathering procedure.

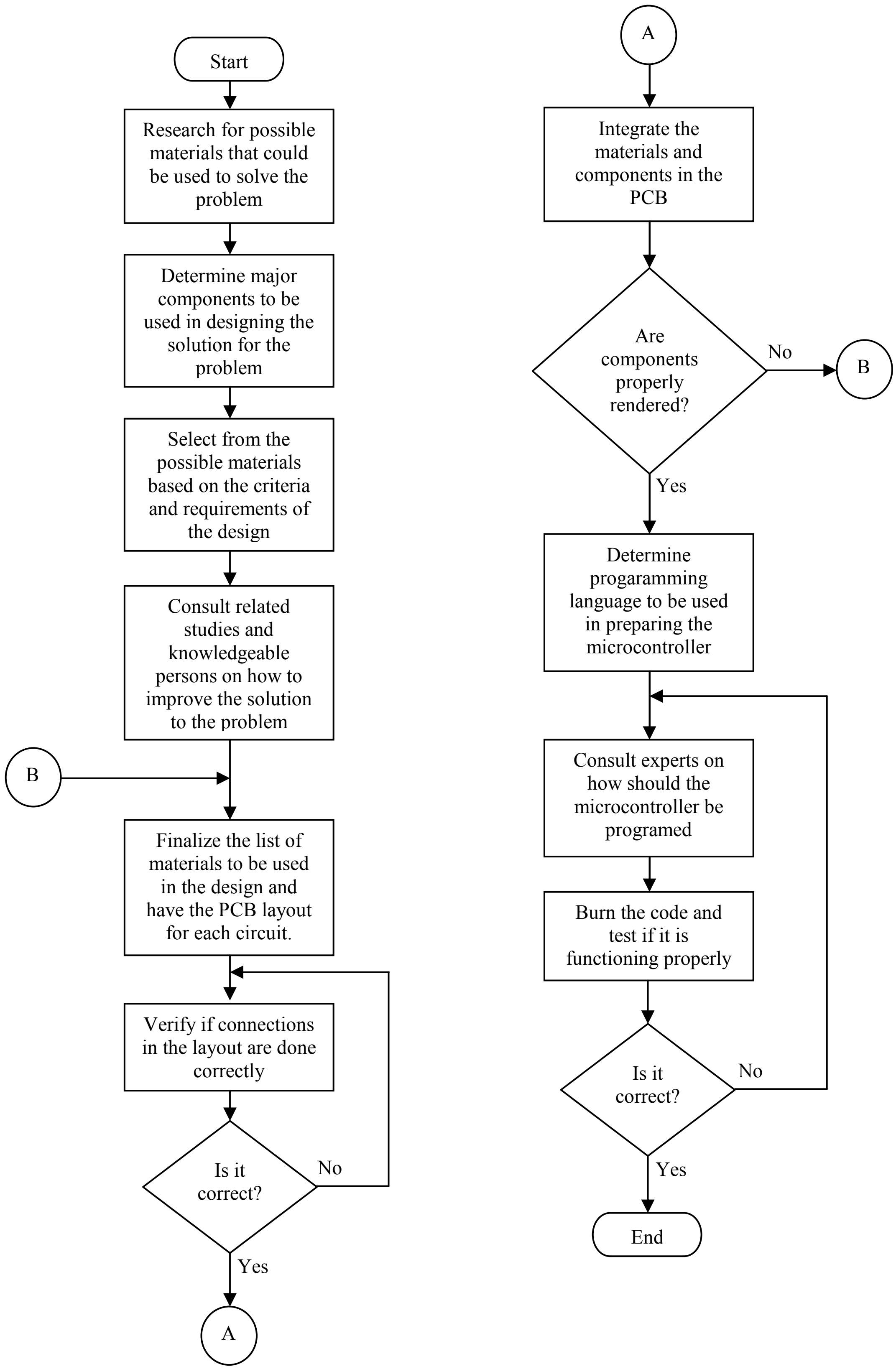


Figure 9: Data Gathering Procedure

Design Procedure for Actual Design

Based on the data gathered, the system must have 3 major parts (see Figure 10). These include the Bill Acceptor, Control System, and Coin Dispenser. The bill acceptor is the one responsible for detecting whether the inserted bill is authentic or not, for accepting the bill, and for identifying the value of the bill. The control system is the central brain of the system which typically is the microcontroller. It controls all the input and output devices and directs the system what operations to be done. On the other hand, the coin dispenser is the one responsible for dispensing coins as the name implied.

For the actual design, each of the major parts is divided into circuits. The bill acceptor is divided to counterfeit sensor, bill detector, buzzer, UV lamp and feeder-motor circuits. The control system is just the microcontroller circuit where the keypad and LCD are integrated. The coin dispenser consists of coin sensor and coin-motor circuits. Since the feeder motor, UV lamp, and coin motor are driven by a relay, these are grouped under relay driver circuit. All in all, there are five circuit-divisions such as the microcontroller, counterfeit sensor, bill detector, coin sensor, and relay driver circuits.

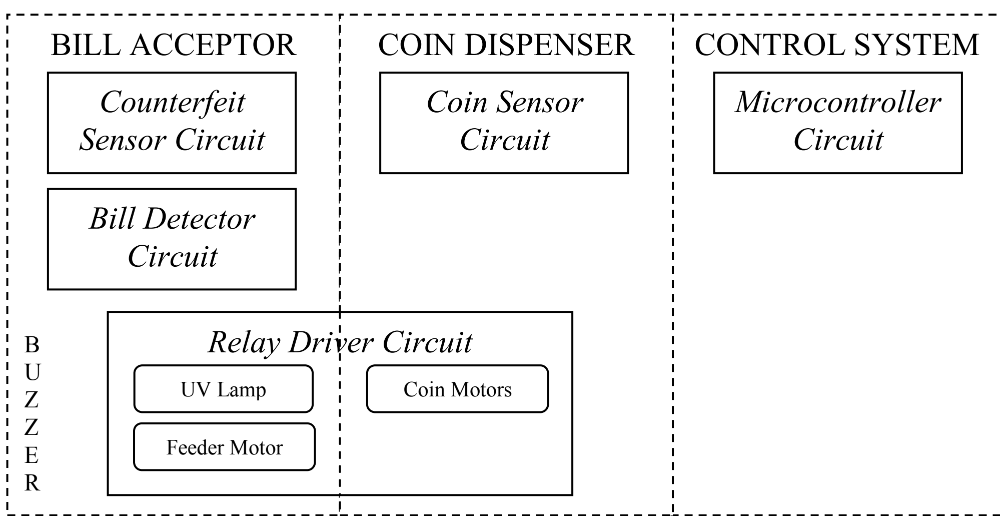


Figure 10: System Divisions

Hardware Design

List of Materials

Electronic List of Materials

QTY	UNIT	ITEM / PART NAME
4	Pc	Optocoupler
4	Pc	10k ¼w Resistor
5	Pc	1k ¼w Resistor
4	Pc	220k ¼w Resistor
1	Pc	10k Trimmer Resistor
15	Pc	4.7k ¼w Resistor
5	Pc	LED Red
4	Pc	PN100 Transistor
1	Pc	4 MHZ Resonator
1	Pc	Tack Switch
2	Pc	7805 IC Regulator
2	Pc	1N4001 Rectifier Diode
5	Pc	0.01μF Capacitor
2	Pc	8-Pin M/F Connector
2	Pc	6-Pin M/F Connector
2	Pc	3-Pin M/F Connector
2	Pc	2-Pin M/F Connector
1	Pc	PIC16F877 IC Microcontroller
1	Pc	ADC0804 IC A/D Converter
1	Set	UV Light
1	Pc	Power Supply
1	Pc	4x20 LCD w/ Backlight
2	Pc	LDR
2	Pc	Super Brite LED
1	Pc	Pre-sensitized PCB 12x18
1	Pc	Transformer 12 0 12 @ 1A
2	Pc	1N5404 Rectifier Diode
1	Pc	2200μF/50V Capacitor
6	Pc	Single Pole Double Throw Relay
1	Pc	Piezo Buzzer
1	Pc	Numeric Keypad

Table 1: Electronic List of Materials

Mechanical List of Materials

QTY	UNIT	ITEM / PART NAME
5	Pc	DC Gear Motor
2	Pc	Rubber Roller
1	Pc	Threaded Rod
2	Pc	Plastic Gear

Table 2: Mechanical List of Materials

Miscellaneous List of Materials

QTY	UNIT	ITEM / PART NAME
1	Bag	Ferric Chloride
2	Pack	DP-20 Developer
2	Sheet	Inkjet Acetate Foil
1	Bottle	Acetone
1	Pack	Masking Tape
2	L	Lacquer Paint
1	G	Lacquer Paint
2	Pc	Brush
2	Pc	Paint Roller
1	Sheet	½" x 4' x 8' Plywood
1	Sheet	¼" x 4' x 8' Plywood
½	K	1" Nail
1	Pc	1/8 x ¾ x ¾ Angular Aluminum
1	Pc	1/8 x ¼ x 1 Angular Aluminum
1	Pc	1/8 x 1½ x 1½ Angular Aluminum
1	Pc	1" PVC
1	Pc	¾" PVC
1	Pc	½" PVC
1	Sheet	Polyglass
100	Pc	3/16 x ½ Screw
100	Pc	3/16 x ¼ Screw
100	Pc	3/16 x 1 Screw
1	Pack	Cable Tie
1	Set	Drawer Lock
2	Set	Hinges

Table 3: Miscellaneous List of Materials

Hardware Component

Microcontroller – PIC16F877

The microcontroller is the brain of the system. It is a 40-pin 8-bit CMOS FLASH microcontroller that functions as the main control unit by driving all input and output devices interfaced in the system. It is used to control the output levels of the DC motors, the UV lamp, the buzzer, and the LCD. Moreover, it is also used to read the inputs from the keypad, coin sensor, counterfeit and bill detector circuits and directs what each circuit component should do.

Specifications:

- 2-5.5V DC operating voltage
- 8-bit CMOS FLASH program memory
- 368 bytes of data memory (RAM)
- 256 bytes of EEPROM data memory
- Low power consumption < 0.6mA typical at 3V, 4MHz

A/D Converter – ADC0804

ADC0804 is an 8-bit A/D converter used to translate analog signals into digital signals. It is easy to interface with all microprocessors and it operates as stand-alone. This IC is used to convert analog signals from the light radiated by the color of the bill through the LDR to a digital 8-bit binary code.

Specifications:

- 8 bits resolution
- 4.5-6.3VDC supply voltage

- 100µS conversion time
- -65°C to +150°C temperature range

SPDT Relay – SRUDH series

SRUDH SPDT Relay is a 12 Amp Miniature Power PC Board Relay that is used as a switch that opens and closes under the control of another electrical circuit. It is used to control the motors and UV light which are separated from the main circuit (the said components require higher voltage than the normal 5VDC supply that is why these are separated).

Specifications:

- 12 Amp switching capacity
- 6-48VDC
- 360mW except 48 VDC (510mW)
- 35°C Max

Geared Motor – RB-35

The motor is used in the coin dispenser which limits the number of coins going out. The number of turns is dependent on the inputted number of coin denomination.

Specifications:

- 12V 6000RPM
- Output-120RPM/≤80mA w/ no load
- 100RPM/250mA w/ 1.2kgf.cm

4x20-line Dot-Matrix Liquid Crystal Display – HD4478OU

The LCD is primarily used as the output HMI of the system that displays the output such as instructions and messages to the user.

Specifications:

- 5 x 10 or 5 x 8 dot matrix
- 2.7-5.5V low power operation support
- 80 x 8-bit display RAM
- Low power consumption

Numeric Keypad

The keypad basically serves as an input HMI device that allows the user to interact with the system.

UV Lamp

The UV lamp is used to help the counterfeit sensor circuit detect the fake bill. When the bill is illuminated, the light will reflect from it if it is fake money; on the other hand, real money will absorb the light illuminated by the UV lamp.

Buzzer

The buzzer operates as a sound device that functions as a warning mechanism. It is mounted to the counterfeit sensor and is activated when the microcontroller sends a high signal during counterfeit detection.

Circuit Design

In order to create the system, hardware components and circuit connections must be visualized; fundamental components include the microcontroller, bill detector, counterfeit sensor, keypad, LCD, buzzer, UV lamp, coin sensors, and motors for coin and feeder. Figure 11 shows the hardware block diagram to illustrate the circuit modules and their I/O connection.

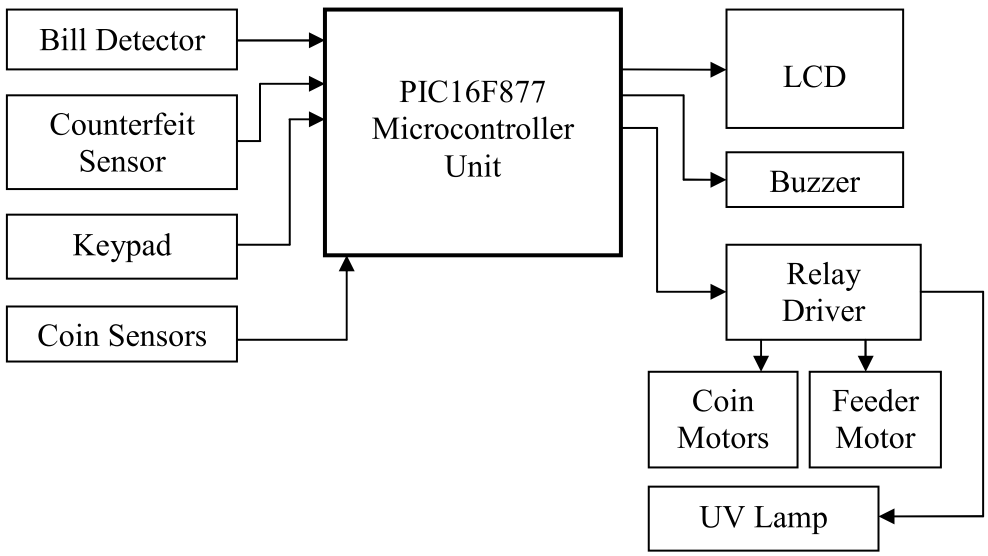


Figure 11: Hardware Block Diagram

PIC16F877 MCU is the primary point of reference because it is the main control unit of the system. The blocks with arrows pointing to the MCU represents the input devices and blocks with arrows pointing away from the MCU stands for output devices. Input devices include the bill detector, counterfeit sensor, keypad, and coin sensors; output devices include the LCD, buzzer, and relay driver. Coin motors, the feeder motor, and the UV lamp are also output devices but in order for them to trigger, the MCU must first send a signal to the relay driver. With the given block diagram, connecting I/O devices to the MCU is made simple and easy.

The proponents subdivided the system into five circuits. These are the microcontroller, the counterfeit detector, the bill detector, the relay driver, and the coin sensor. Each of these parts' schematic diagram are created using Proteus 7, a software tool that is used for schematic capture, simulation, and PCB layout. This is to ensure that the system is feasible and operational through testing and simulation.

The counterfeit sensor is one of the inputs based on the block diagram (Figure 11), thus the circuit's output is very important to the microcontroller. This circuit detects whether the bill inserted is authentic or not. Since UV light is used to check on the bill's validity, LDR plays a major role in this process.

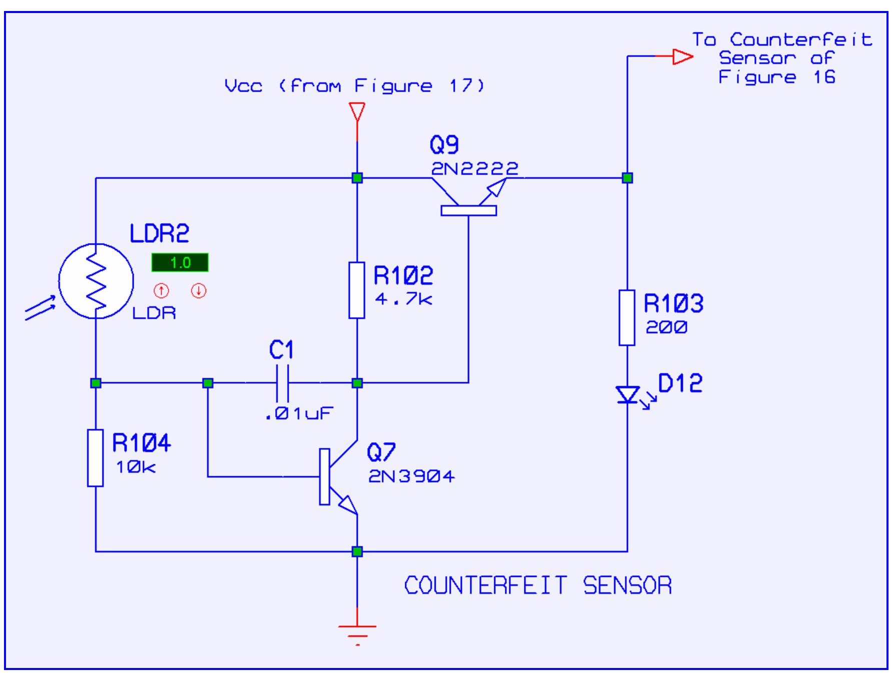


Figure 12: Counterfeit Sensor Circuit

Consider the circuit in Figure 12. When the light level is low (authentic bill or nothing), the resistance of the LDR is high. This prevents the current to flow in the base of Q7 transistor, thus allowing the current to flow in the base of Q9. Because of this, the collector-emitter of Q9 is shorted which allows the current to flow. Consequently, the D12 LED is lighted and the output is high. However, when light shines into the LDR (fake bill), its resistance falls, thus allowing the current to flow in the base of Q7 which shorts the base of Q9 to the ground. Because of this, the collector-emitter of Q9 is open, preventing the current to flow. This does not light up D12 and the output is low.

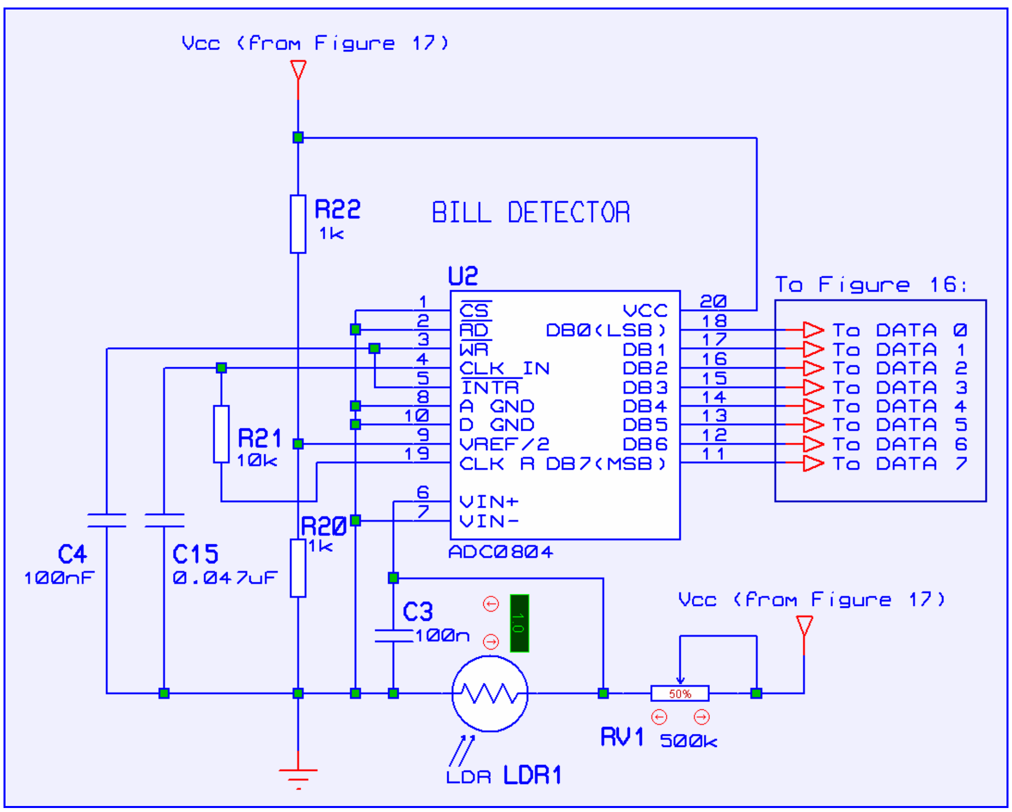


Figure 13: Bill Detector Circuit

The bill detector identifies the value of the bill inserted to the feeder. To make this possible, the circuit requires an A/D converter and LDR. LDR is used as the transducer where the A/D converter receives analog input voltage range; A/D converter translates the measured analog voltage along the LDR to digital signal in 8-bit binary form. In Figure 13, the converted 8-bit signal which is an input to the microcontroller can be obtained in the DB0-DB7 data output of the A/D converter. Moreover, the potentiometer RV1 is used to vary the analog voltage measure in LDR1 for calibration.

The process on how the counterfeit sensor and bill detector works is described in the following. When a bill is inserted in the system and the '#' sign is pressed, the microcontroller will turn on the UV lamp as well as it will wait for the counterfeit sensor to send a low signal at a certain duration (by default, the counterfeit sensor sends a high signal to the microcontroller). When an authentic bill is inserted, the bill will just absorb the light making the resistance of LDR at the counterfeit sensor high. The counterfeit sensor will still send a high signal to the microcontroller. As the time expires and there is still no change of signal (high to low) sent by the counterfeit sensor to the MCU, the microcontroller will identify the bill as authentic and it will detect the value of the bill by comparing the data obtained from the bill detector to the reference values of P20.00 as 2, P50.00 as 4, and P100.00 as 5 (00000010, 00000011, 00000100 in binary form, respectively). By default, the bill detector reads a converted value of 00001111 and 00010000 (15 and 16 in decimal form, respectively) when there is no bill inserted. If any bill is inserted whether fake or not, the bill detector will produce a digital converted value. For instance, if the color *value* (lightness or darkness of color) of the inserted bill is light, such as 20 pesos, the bill detector will obtain a binary value of 00000010 (2 in decimal form). Subsequently, the microcontroller will compare this data to the reference values. Since the reference value of P20.00 as 2 matches the data obtained, the microcontroller will identify the bill as 20 pesos. The bill will be fed to the system and the transaction will begin. In contrary to this, if the bill detector has obtained a value less than 2 or greater than 5, the system will not accept the bill; the system will return to the main menu and wait for another input from the user.

The coin sensor circuit is another fundamental part of the system. It is used to detect if a coin is dispensed properly. The detection depends on the signal that is sent by the circuit to the microcontroller. The circuit is partnered to a motor with a metal shaft or kicker that is placed between the gap of an optical sensor. During the rotation of the metal shaft, there is an instance where the metal shaft blocks the gap of the optical sensor. At this moment, the optical sensor's phototransistor is not activated because the light coming from the optical sensor's LED is blocked.

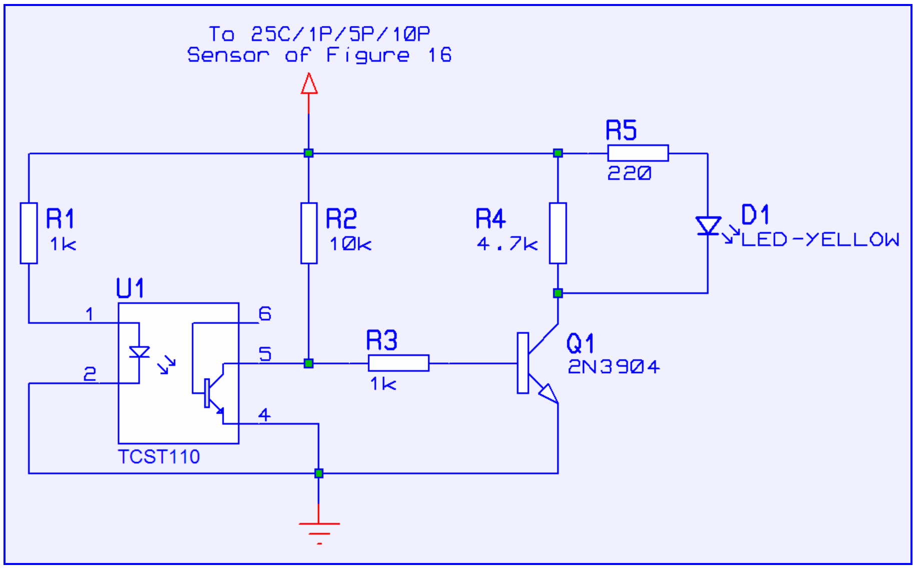


Figure 14: Coin Sensor Circuit

Consider the coin sensor circuit in Figure 14. When the light from the optical sensor U1's LED is not blocked, the U1's phototransistor allows current to flow in its base, making its collector-emitter shorted. Because of this, the current will flow to the base of Q1 as well as in its collector-emitter; this connects D1 LED to the ground lighting it up and producing a high signal output. On the other hand, the current is not allowed to flow in the base of phototransistor if the light is blocked. The collector-emitter of Q1 is open when this happens, so D1 is dimmed and the output is low.

The relay driver circuit is composed of motors and UV lamp; each of these components is controlled by a relay. The relay switches these hardware components with the microcontroller control. In Figure 15, coin and feeder motor circuit (left) is identical with the UV lamp circuit (right). Take note that the relay driver circuit is an output based on the block diagram in Figure 11.

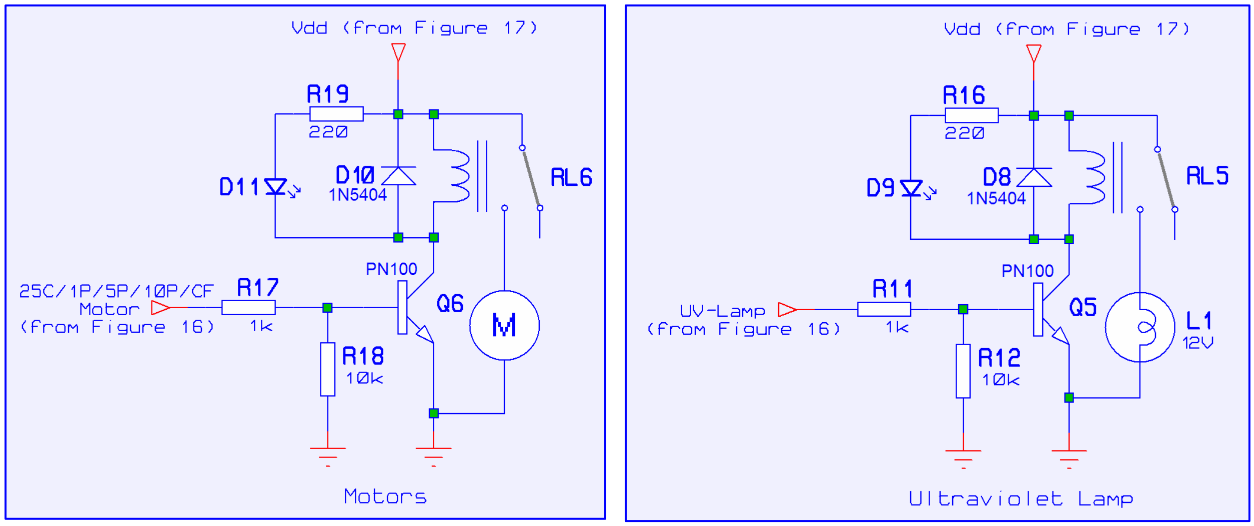


Figure 15: Relay Driver Circuit

Considering the figure in the left, without the microcontroller's high signal output to the circuit, no current will flow in the base of transistor Q6. Because of this, the collector to emitter is open thus making the relay switch open, allowing the motor off and D11 LED dim. If the microcontroller sends a high signal to the circuit, the current will flow in the base of Q6. This will allow the current to flow in the collector-emitter triggering an induction which creates a back EMF in the relay. Simultaneously, the switch becomes close which allows the motor to run and D11 to light up. This is the same with the UV lamp circuit since it is identical to the feeder and coin circuit. Furthermore, notice that there is a diode connected to the relay in reverse-biased mode. This is necessary because a relay (inductive load) which creates a back EMF can damage the transistor.

The main part for the system is the microcontroller circuit where the control processing takes place. The microcontroller circuit shown in Figure 16 illustrates all I/O pin connections as depicted by the hardware block diagram in

Figure 11. Since the system dispenses four different kinds of coins, requires one bill acceptor, and uses a UV lamp for counterfeit detection, six relay drivers are allocated to ports A0-A3, A5, and B7. Other connections comprise the following: LCD to ports C0-C5, keypad to ports B0-B6, coin sensor to ports A4 and E0-E2, counterfeit sensor to C6, buzzer to C7, and bill detector to all D ports.

During power failure, the system must integrate a backup-battery circuit to prevent data loss and to continue current transaction. In order to do this, four rechargeable 2V-1A Lead Acid batteries (8V total) are OR-wired with the AC-to-DC power supply using rectifier diodes to power the whole system.

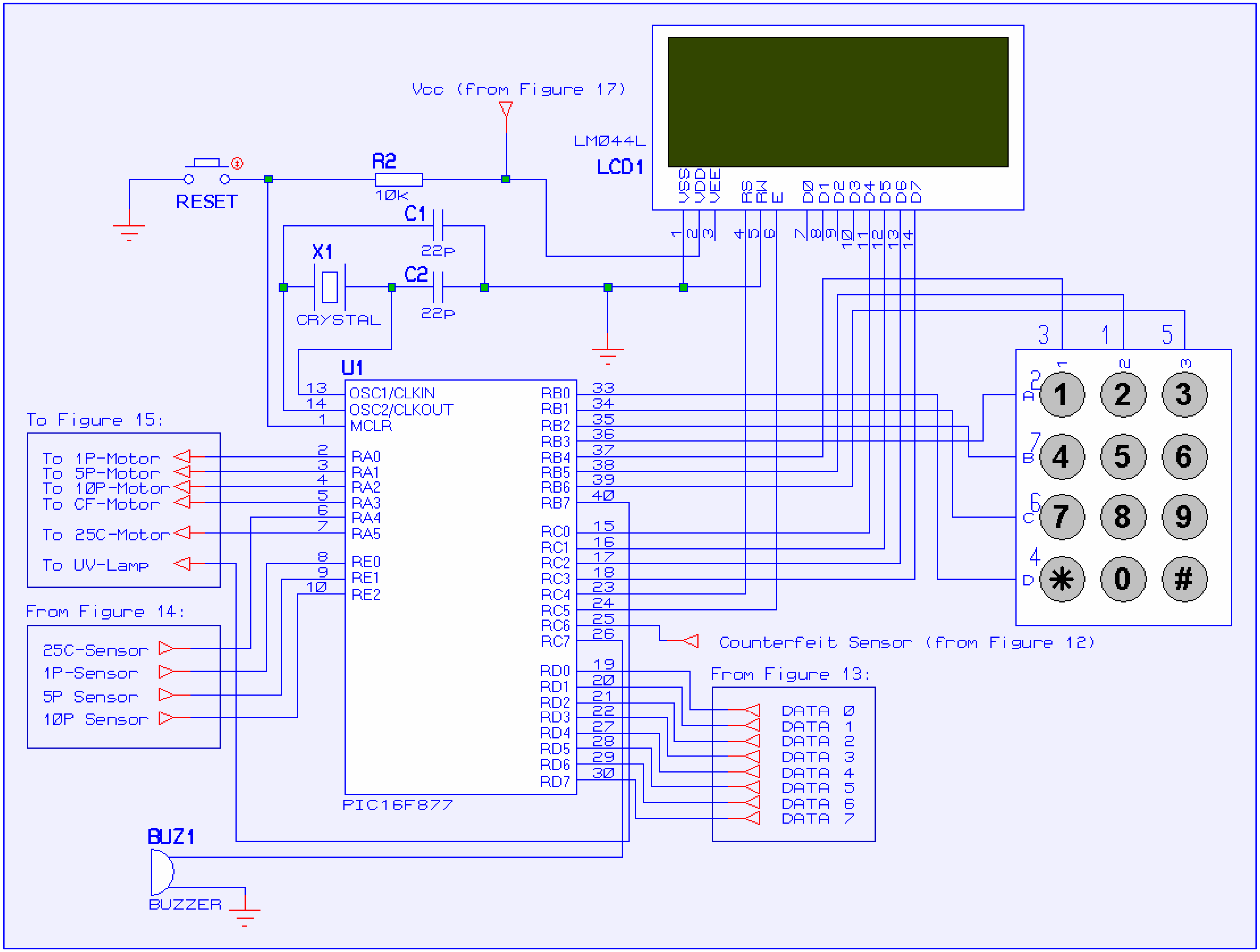


Figure 16: Microcontroller Circuit

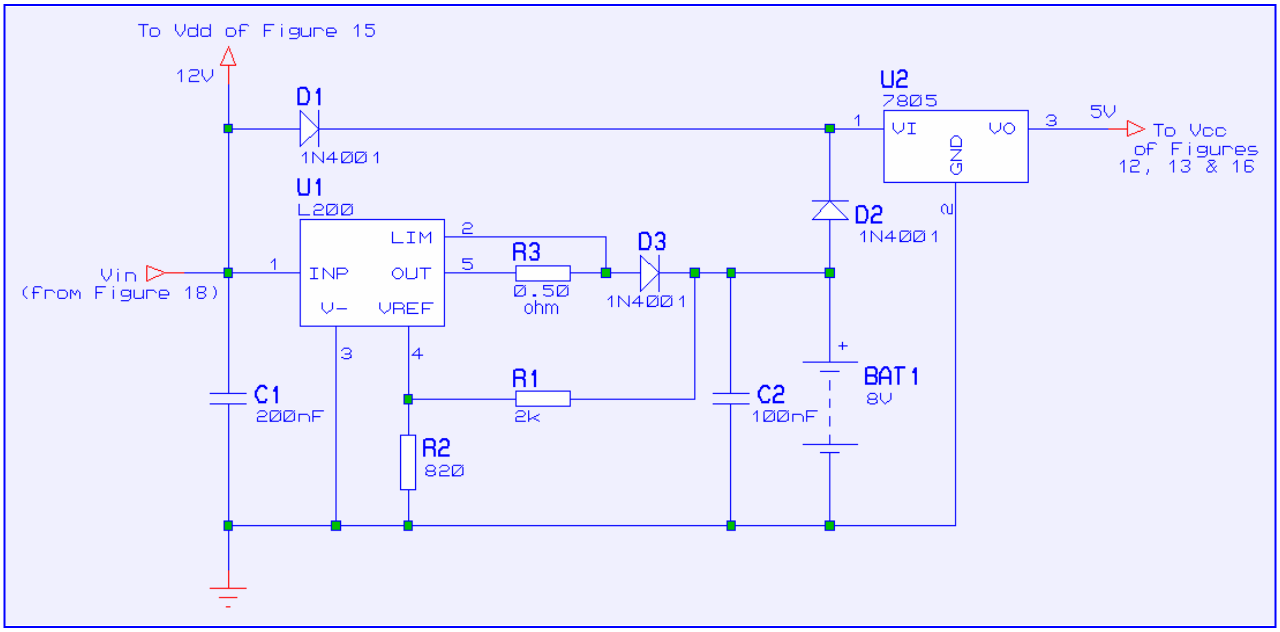


Figure 17: Backup-Battery Circuit

In Figure 17, D1 and D2 are the diodes that connect the power supply (V_{IN}) and the batteries (BAT1) in an OR-wire connection. When power line is available, V_{IN} has $12V_{DC}$. D1 is closed which allows the current to pass since its cathode has 0V. Simultaneously, D2 is open because its cathode measures 12V from V_{IN}. In the event of power failure, D2 is closed; this allows the batteries to supply power to the system. At the same time, D1 is open since its anode has 0V from V_{IN} and its cathode has 8V from the batteries. Voltage Regulator 7805 is connected in the cathodes of D1 and D2 to maintain a constant voltage of $5V_{DC}$ in the output.

The backup batteries are charged using Variable Voltage and Current Regulator (L200 Chip). The circuit in Figure 17 is the typical connection of L200 to form a battery charger. C1 and C2 are used to smooth the voltage input and output. Pin 2 (LIM) and Pin 4 (VREF) are responsible for current and voltage regulation, respectively. Both pins have internal voltmeters that measure corresponding voltages in the output. R3 is used to maintain 1A of current from Pin 5 (OUT) regulated by L200 through Pin 2 (1A is the rated charging current for Lead Acid batteries). R1 and R2 form a voltage divider where the input is the voltage coming from the batteries and the output is the one going to Pin 4. The fraction of voltage that goes to Pin 4 sets the float voltage going out of Pin 5. This float voltage is a constant voltage applied continuously to the lead acid batteries; it maintains the cells in a fully-charge condition when power-line is available. So overcharging is not a problem since float voltage is only applied to the batteries. The only disadvantage is that the batteries will charge slowly compared to smart chargers.

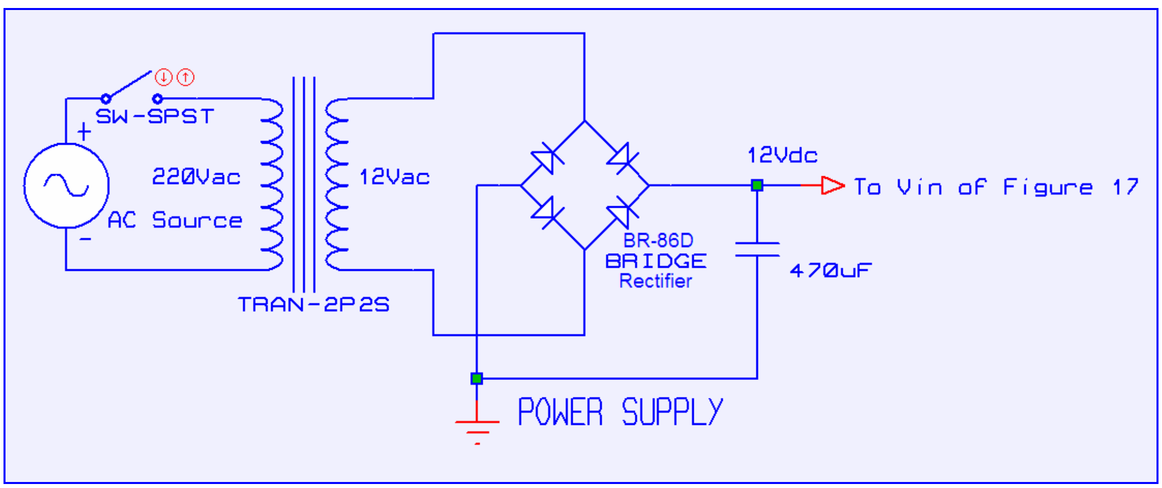


Figure 18: Power Supply Circuit

Figure 18 shows the circuit of the AC to DC Power Supply with model WY-03C. It is plugged into 220V_{AC} socket which is reduced to 12V_{AC} and rectified to 12V_{DC}. 12V_{DC} is connected to the V_{IN} of the backup-battery circuit in Figure 17.

Each of the circuits are created using Proteus 7 software (see Appendix A for the complete circuit diagrams); each are tested, simulated, and properly considered. Since all simulations are successful and the desired data are generated by the simulation output, hardware can now be implemented.

Software Design

Software Component

The software used in programming the code to integrate with PIC16F877 microcontroller is Proton IDE. Proton IDE is a professional and powerful visual Integrated Development Environment (IDE) which has been designed specifically for the Proton Plus compiler. Proton IDE accelerates product development in a comfortable user environment without compromising performance, flexibility or control. It has the following features: Code Explorer, Compiler Results, Programmer Integration, Integrated Boot-loader, Real Time Simulation Support, Serial Communicator, Online Updating, and Plug-in Architecture.

The PROTON compiler takes full advantage of each type of PIC microcontroller available, and offers a friendly and intuitive language that allows very complex operations to be carried out with a minimum of fuss, and provides a flexibility and functionality that is unparalleled in the world of PIC programming. It is functionally compatible with the language of PICBASIC Pro Compiler which offers the beginner a comfortable and familiar environment.

System Flowchart

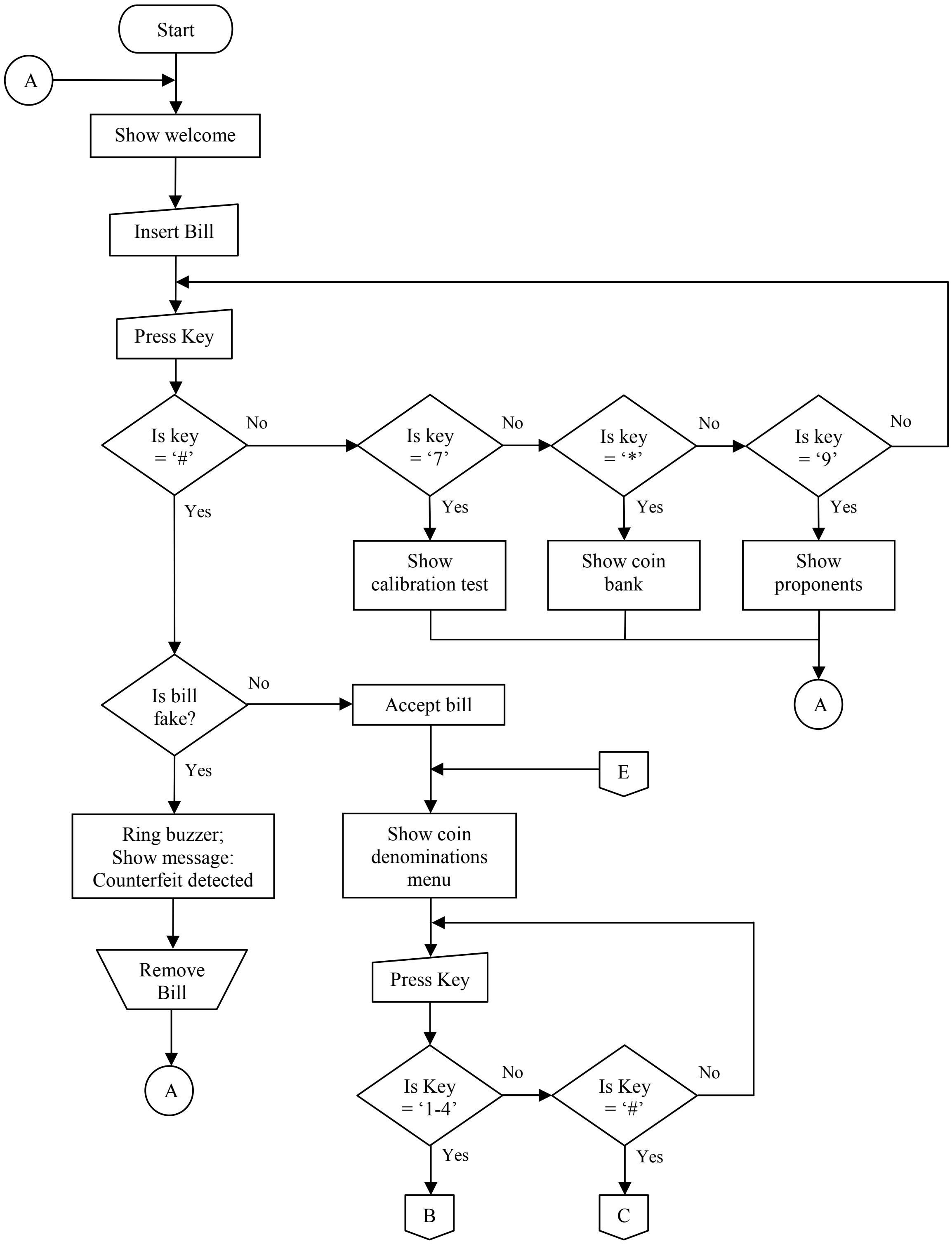


Figure 19: System Flowchart (Part 1)

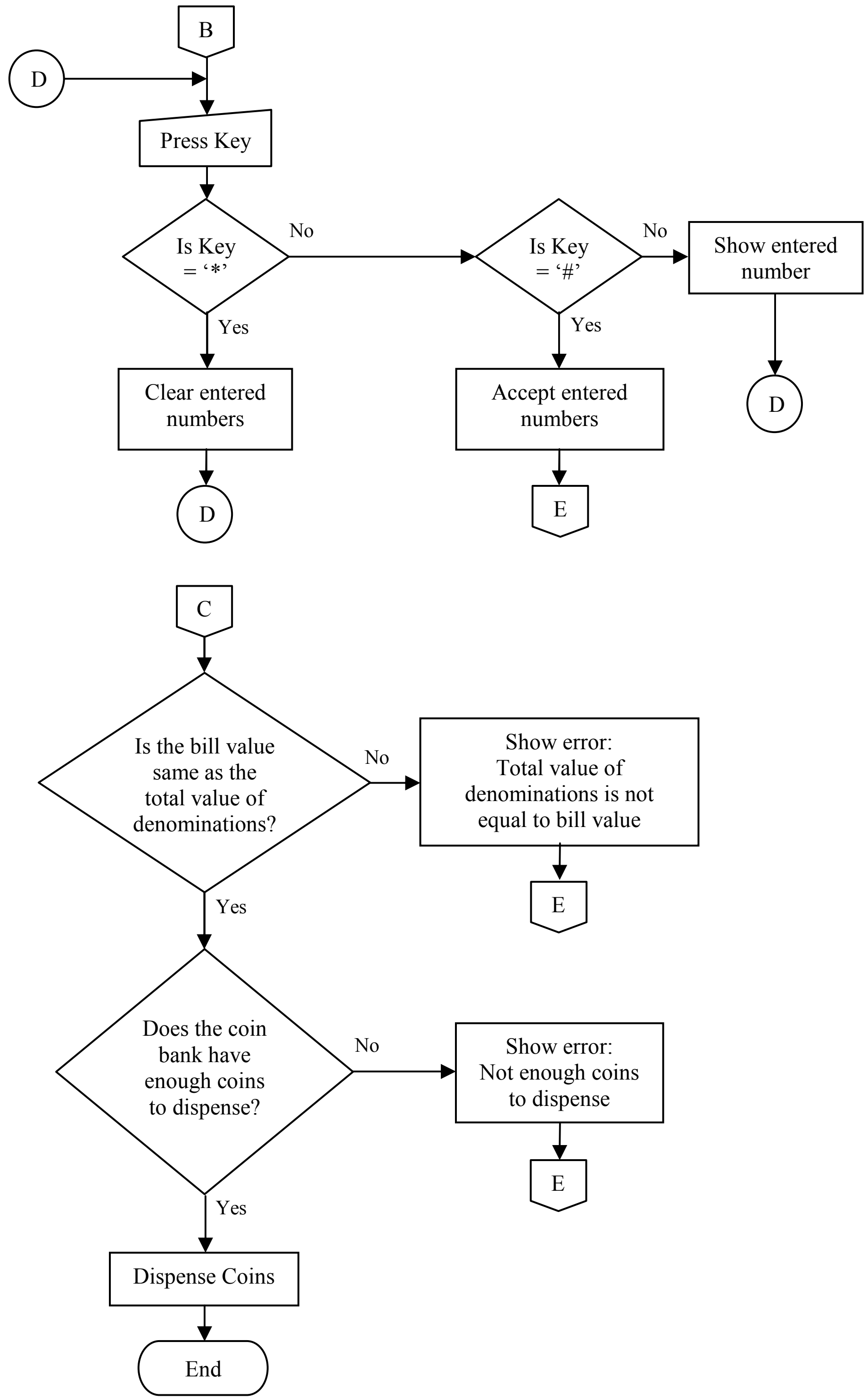


Figure 20: System Flowchart (Part 2)

Figure 17-18 show the design's system flowchart. The main process of the system starts when the user enters a bill. This will serve as input to the counterfeit sensor. For the counterfeit sensor to be activated it will have to wait for another input from the keypad (which is "#"). It will then return a value of either 1 or 0 to the microcontroller depending if it is fake or not. An input of 0 (meaning the money is fake) to the microcontroller from the counterfeit sensor would make the microcontroller send a signal to the buzzer for it to be activated and the whole process will be terminated. Otherwise, the microcontroller will send a high signal to the relay (for the feeder to work) and to the bill detector.

The bill detector will send the binary value of the inserted bill, as read by the LDR, to the microcontroller for it to determine how much coin the system should dispense. The system will then provide the user with a menu in which he could choose the number of coins (per denomination) he wants his bill to be changed into. Number '1' in the keypad would be for the centavo, '2' for one-peso coins, and so on. The system shall ensure that the total amount of coins to be dispensed will be the same as the amount of bill inserted. The user will be asked to reenter the quantity of coins (per denomination) if in case the desired amount of coins is not equal to the inserted bill.

The whole process is started if the user entered a bill and then pressed the "#" sign in the keypad. The user could also view the content of the coin bank by pressing "*". Proponents' names are also available upon pressing "9".

Chapter 3

PRESENTATION AND INTERPRETATION OF DATA

Accuracy and Reliability of Design

After implementing the hardware, various tests are made in order to evaluate the system. Initially, the bill acceptor's accuracy is tested. It is very important that the system's bill acceptor should detect the value of the bill accurately. Table 4 and 5 shows the result of the test which are done twice to ensure consistency.

Bill Inserted	Detected Value	Result
P20.00	P20.00	Successful
P50.00	P50.00	Successful
P100.00	P100.00	Successful
P200.00	P50.00	Failed
P500.00	P50.00	Failed
P1000.00	P50.00	Failed

Table 4: Bill Value Detection Test (preliminary testing)

Bill Inserted	Detected Value	Result
P20.00	P20.00	Successful
P50.00	P50.00	Successful
P100.00	P100.00	Successful
P200.00	P20.00	Failed
P500.00	P50.00	Failed
P1000.00	P50.00	Failed

Table 5: Bill Value Detection Test (final testing)

Note: *Failed – incorrect value of the inserted bill is detected.*
Successful – correct value for the inserted bill is detected.

Tables 4 and 5 show the results of the tests done to see if the system could detect bills other than 20, 50, and 100 peso bill. Notice that tests for the P200.00, P500.00, and P1000.00 peso bills failed. This is because the bill acceptor is designed only to detect bill values of P20.00, P50.00, and P 100.00. Other bills inserted may result to erroneous and unexpected values.

After the test, the proponents decided to test old and faded bills to check whether the system still detects the value of the bill accurately. Table 6 shows the results of inserting old and faded bills.

Bill Inserted	Detected Value	Result
P20.00	P50.00	Failed
P50.00	P50.00	Successful
P100.00	P100.00	Successful

Table 6: Bill Value Detection of Old Bills Test

Notice that the P20.00 bill failed. One primary cause of this is that the true color of it is somewhat darkened due to the fact that it is worn-out and faded. Thus, the system erroneously distinguished the value of the bill as P50.00.

After testing the accuracy of the system with regards to the bill value, the proponents tested the precision of the counterfeit sensor. Printed bills on a bond paper are used to test it. Table 7 shows the results of inserting the fake bills.

Bill Inserted (Fake)	Message Output	Result
P20.00	Counterfeit Detected	Successful
P50.00	Counterfeit Detected	Successful
P100.00	Counterfeit Detected	Successful

Table 7: Counterfeit Sensor Precision Test

No errors are found during the testing of the counterfeit sensor. The next tests involve the accuracy of the coin dispenser with respect to the inputted number of denomination. Each kind of bill (P20.00, P50.00, and P100.00) is tested with 10 sets of denomination. The *denomination(s)* row represents the type of coin tested; the *input* row represents the number of pieces of each denomination; and the *output* row represents the number of coins dispensed by the system. In this, the accuracy of the coin dispenser is tested by ensuring that the output is equal to the input.

<u>*Inserted Bill: P20.00*</u>

Set #	Denomination(s)	Input	Output	Result
1	25c	80 pcs.	78 pcs.	Failed
2	P1.00	20 pcs.	19 pcs.	Failed
3	P5.00	4 pcs.	4 pcs.	Successful
4	P10.00	2 pcs.	2 pcs.	Successful
5	P1.00	10 pcs.	10 pcs.	Successful
	P5.00	2 pcs.	2 pcs.	
6	P1.00	10 pcs.	10 pcs.	Successful
	P10.00	1 pc.	1 pc.	
7	P5.00	2 pcs.	2 pcs.	Successful
	P10.00	1 pc.	1 pc.	
8	25c	20 pcs.	20 pcs.	Successful
	P1.00	5 pcs.	5 pcs.	
	P5.00	2 pcs.	2 pcs.	
9	P1.00	5 pcs.	5 pcs.	Successful
	P5.00	1 pc.	1 pc.	
	P10.00	1 pc.	1 pc.	
10	25c	4 pcs.	4 pcs.	Successful
	P1.00	4 pcs.	4 pcs.	
	P5.00	1 pc.	1 pc.	
	P10.00	1 pc.	1 pc.	

Table 8: 20-peso Bill Output Test

Note: *Failed – incorrect number of coins was dispensed.*
Successful – correct number of coins is dispensed.

In the 20-peso bill output result (Table 8), sets 1 and 2 have failed the tests. Set 1 failed because the input of the user of 80 pieces 25-cents is not equal to the dispensed coins (output) which are only 78 pieces. For Set 2, it has failed because the output is only 19 pieces 1-peso coins instead of the input of 20 pieces. The errors are caused by unguided flow of centavo coins from the coin dispenser to the coin cargo and the narrow gap between the 1-peso coin holder (PVC tube) and the platform where the metal shaft kicks the coins. The errors are tolerable with just 1-2 input/output difference and 2 out of 10 failed sets.

Inserted Bill: P50.00

Set #	Denomination(s)	Input	Output	Result
1	25c	200 pcs.	200 pcs.	Successful
2	P1.00	50 pcs.	50 pcs.	Successful
3	P5.00	10 pcs.	10 pcs.	Successful
4	P10.00	5 pcs.	5 pcs.	Successful
5	P1.00	30 pcs.	30 pcs.	Successful
	P5.00	4 pcs.	4 pcs.	
6	P1.00	40 pcs.	40 pcs.	Successful
	P10.00	1 pc.	1 pc.	
7	P5.00	6 pcs.	6 pcs.	Successful
	P10.00	2 pcs.	2 pcs.	
8	25c	80 pcs.	79 pcs.	Failed
	P1.00	5 pcs.	5 pcs.	
	P5.00	5 pcs.	5 pcs.	
9	P1.00	30 pcs.	30 pcs.	Successful
	P5.00	2 pcs.	2 pcs.	
	P10.00	1 pc.	1 pc.	
10	25c	40 pcs.	40 pcs.	Successful
	P1.00	10 pcs.	10 pcs.	
	P5.00	2 pcs.	2 pcs.	
	P10.00	2 pcs.	2 pcs.	

Table 9: 50-peso Bill Output Test

Note: *Failed – incorrect number of coins was dispensed.*
Successful – correct number of coins is dispensed.

For the 50-peso bill output test in Table 9, only set 8 failed the test because the output is only 79 pieces 25-cents, which is contrary to the 80 pieces input of the user. It has 1 input/output difference which is still tolerable because the error is minimal. The cause of error is the absence of guide from the dispenser to the cargo of 25-cents.

<u>*Inserted Bill: P100.00*</u>

Set #	Denomination(s)	Input	Output	Result
1	25c	400 pcs.	None	Not Possible
2	P1.00	100 pcs.	100 pcs.	Successful
3	P5.00	20 pcs.	20 pcs.	Successful
4	P10.00	10 pcs.	10 pcs.	Successful
5	P1.00	50 pcs.	50 pcs.	Successful
	P5.00	10 pcs.	10 pcs.	
6	P1.00	40 pcs.	40 pcs.	Successful
	P10.00	6 pc.	6 pc.	
7	P5.00	6 pcs.	6 pcs.	Successful
	P10.00	7 pcs.	7 pcs.	
8	25c	300 pcs.	300 pcs.	Successful
	P1.00	5 pcs.	5 pcs.	
	P5.00	4 pcs.	4 pcs.	
9	P1.00	10 pcs.	10 pcs.	Successful
	P5.00	8 pcs.	8 pcs.	
	P10.00	5 pc.	5 pc.	
10	25c	300 pcs.	298 pcs.	Failed
	P1.00	5 pcs.	5 pcs.	
	P5.00	2 pcs.	2 pcs.	
	P10.00	1 pcs.	1 pcs.	

Table 10: 100-peso Bill Output Test

Note: *Failed – incorrect number of coins was dispensed.*
Successful – correct number of coins is dispensed.
Not Possible – the operation is not viable.

In the 100-peso bill output test (Table 10), only set 10 has a failing result with 2 input/output differences. Set 10 failed because only 298 pieces of coins are dispensed (output) by the system instead of 300 pieces, which is the input of the user. The error is caused by the same reason as before, thus the proponents placed a guide on each of the coin path from the coin platform to the coin cargo. On the other hand, notice that set 1 has a *Not Possible* result. The reason for this is that the system is programmed to hold a maximum of 300 pieces per coin type. Since the input is 400 pieces, the system will change the input to 300 pieces by default. Pressing the enter key will not dispense the coin since the input denomination value is less than the bill value. With this kind of instance another kind of test must be done regarding the inequality of the input denomination value and the bill value.

The following tests check the system if it displays an error whenever the input denominations' total value is not equal to the value of the bill. The results are shown in Tables 11-13, where the *denomination(s)* row represents the coin type; the *input count* row stands for the number of pieces per denomination; the *total value* row represents the total value of the input count; and *shows error* row corresponds to whether the system displays an error message if the total value of the input count is not equal to the inserted bill value.

<u>*Inserted Bill: P20.00*</u>

Set #	Denomination(s)	Input Count	Total Value	Shows Error	Result
1	25c	300 pcs.	P75.00	Yes	Successful
2	P1.00	21 pcs.	P21.00	Yes	Successful
3	P5.00	3 pcs.	P15.00	Yes	Successful
4	P10.00	100 pcs.	P1000.00	Yes	Successful
5	P1.00	5 pcs.	P45.00	Yes	Successful
	P10.00	4 pcs.		Yes	

Table 11: 20-peso/Denomination Value Error Test

<u>*Inserted Bill: P50.00*</u>

Set #	Denomination(s)	Input Count	Total Value	Shows Error	Result
1	25c	250 pcs.	P62.50	Yes	Successful
2	P1.00	30 pcs.	P30.00	Yes	Successful
3	P5.00	95 pcs.	P475.00	Yes	Successful
4	P10.00	6 pcs.	P60.00	Yes	Successful
5	P5.00	10 pcs.	P80.00	Yes	Successful
	P10.00	3 pcs.		Yes	

Table 12: 50-peso/Denomination Value Error Test

<u>*Inserted Bill: P100.00*</u>

Set #	Denomination(s)	Input Count	Total Value	Shows Error	Result
1	25c	100 pcs.	P25.00	Yes	Successful
2	P1.00	101 pcs.	P101.00	Yes	Successful
3	P5.00	25 pcs.	P125.00	Yes	Successful
4	P10.00	8 pcs.	P80.00	Yes	Successful
5	25c	20 pcs.	P25.00	Yes	Successful
	P10.00	2 pcs.		Yes	

Table 13: 100-peso/Denomination Value Error Test

Note: *Failed – the system shows no error message*
Successful – the systems shows an error message

All tests are successful in different kinds of denomination since all sets show an error saying that the denominations' total value is not equal to the bill value. Another test must be executed which checks the coin bank remaining coins. The results are shown in Table14.

Bill	Denomination(s)	Count	Coin Bank	Shows Error	Result
P20.00	P1.00	20 pcs.	15 pcs.	Yes	Successful
P50.00	P5.00	10 pcs.	5 pcs.	Yes	Successful
P100.00	P10.00	10 pcs.	9 pcs.	Yes	Successful
P20.00	25c	80 pcs.	4 pcs.	Yes	Successful
P100.00	P1.00	20 pcs.	0	Yes	Successful
	P5.00	6 pcs.	2 pcs.		
	P10.00	5 pcs.	0		

Table 14: Coin Bank Error Test

Note: *Failed – the system shows no error message*
Successful – the systems shows an error message

The test checks the system if it shows an error whenever the coin bank's remaining coins is less than the desired number of denominations. Since all sets show an error, the results are successful. After this the proponents tried to empty all the remaining coins of the coin bank to 0. When the last transaction ended, an error message is displayed saying that the coin bank is depleted and can no longer dispense any coins. This particular test means that system is operational and functioning well.

In summary, the design is accurate and reliable in terms of program-related factors such as the displaying of error during wrong inputs or certain cases. The only problem is in the mechanical part where there is a 1-2 input/output difference in dispensing coins. The reason for this minimal error is maybe caused by the small tube containers of coins or the flow of coins during the kicking of the rotating metal shaft.

Chapter 4

CONCLUSION AND RECOMMENDATION

CONCLUSION

After the proponents developed and tested the system entitled Bill-to-Coin Changer, they have found out that the usage of UV light could detect fake money. The value of money was identified using its binary value as converted by the A/D converter from the analog signal read through the Light Dependent Resistor or LDR. Moreover, blocking and unblocking the optical sensor could be used as counter as to how many coin/s was/were already dispensed. The only observed disadvantage in using such materials (A/D converter and LDR) is that it is not capable of differentiating bills of the same color intensity. All in all, the group was able to construct a circuit design that enables users to change twenty, fifty and one-hundred peso bills to their exact equivalent amount in twenty-five cents, one, five, and ten peso coins.

RECOMMENDATION

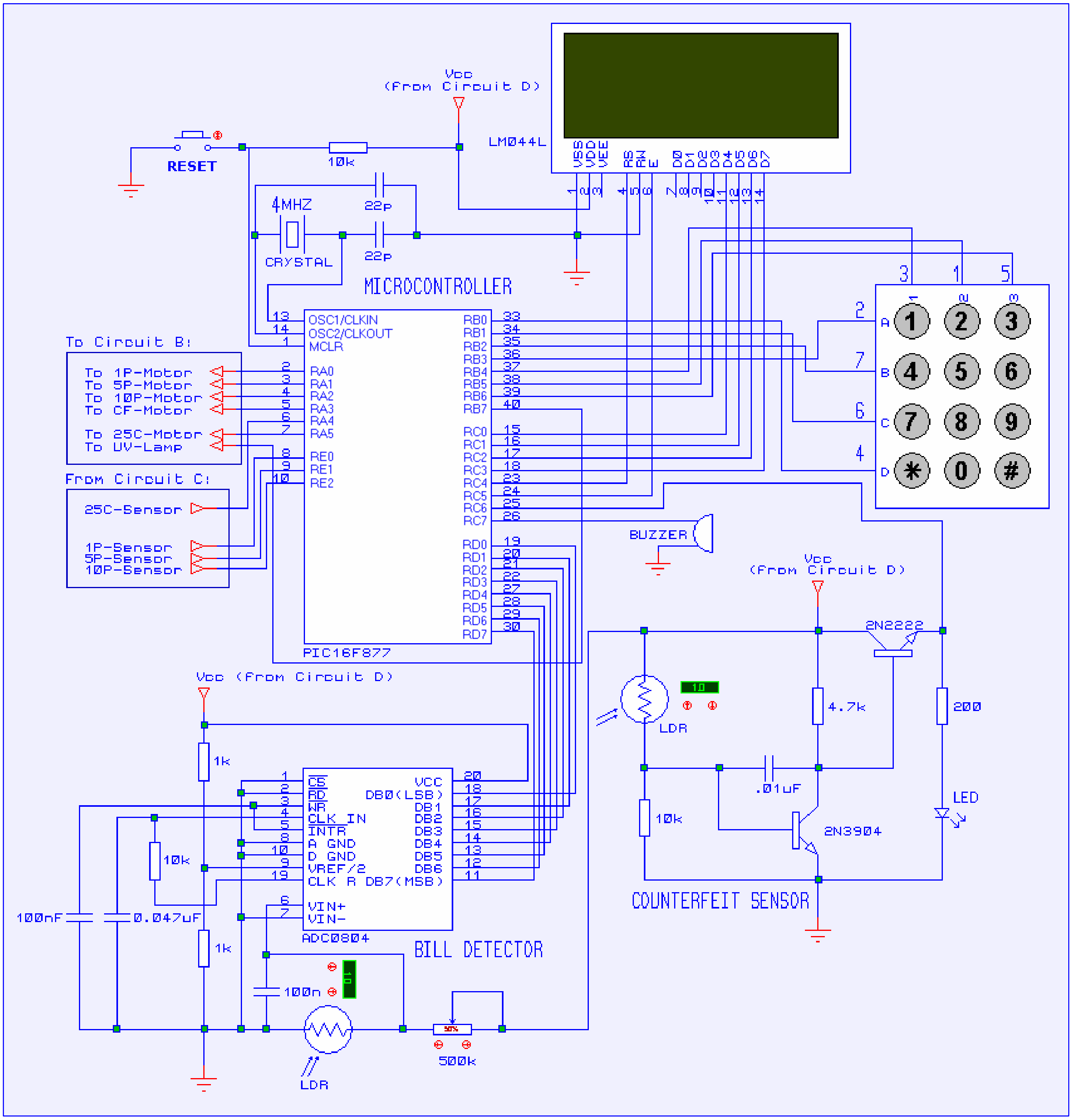
For further improvement on the development of a bill-to-coin changer device, the proponents recommend that the future researchers and designers should look for another alternative device or component other than A/D converter and LDR, since it is not capable of differentiating bills of same color intensity. Another suggestion is to enable alternative device to support the acceptance of higher amounts or wider range of bills. It is also advisable for the design not just to dispense coins but also bills. This design could further be improved to support foreign currencies wherein one could change one form of money to their preferred currency using this device.

BIBLIOGRAPHY

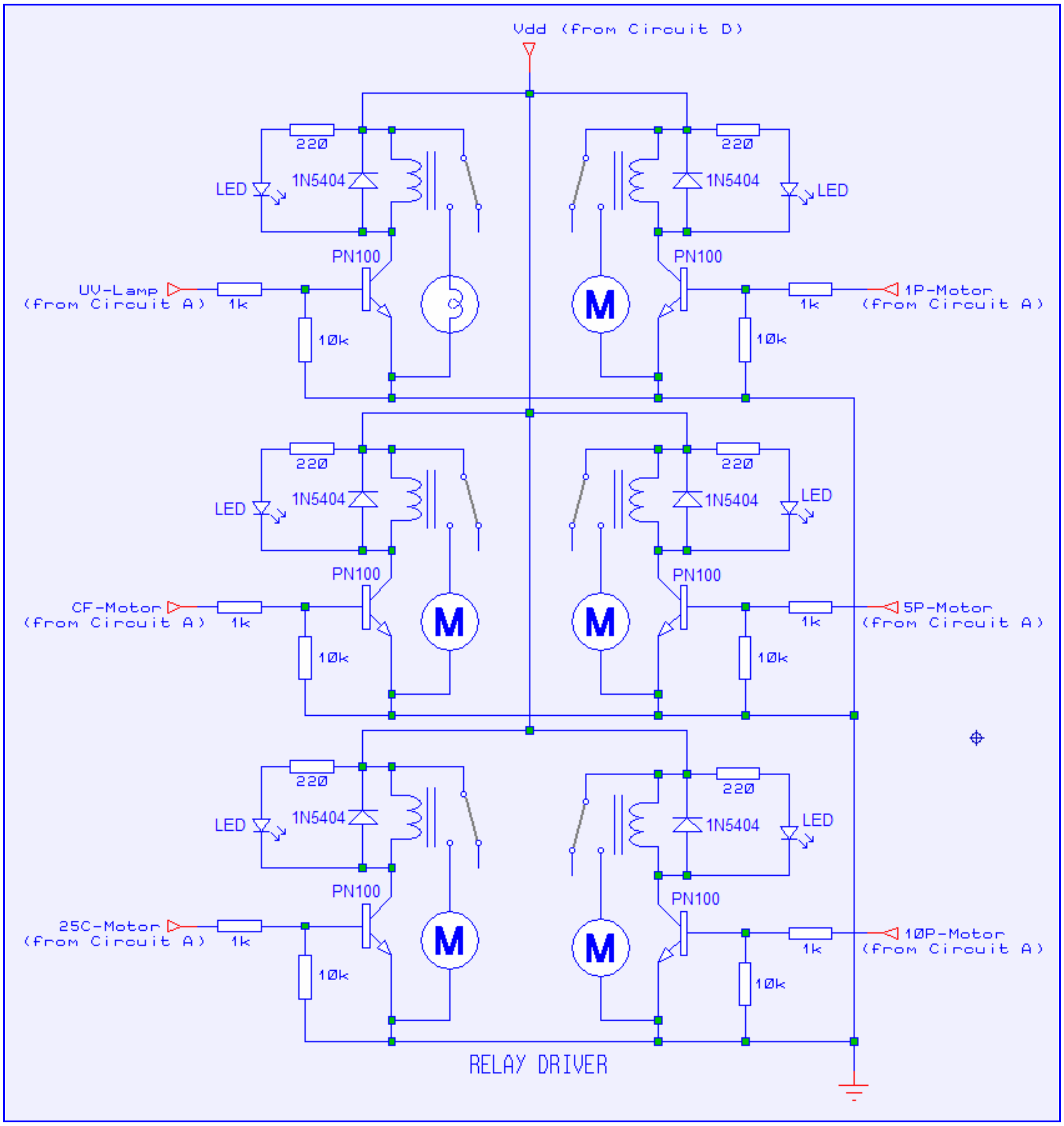
1. Abe, H. (1992). Coin dispensing apparatus, United States ASAHI SEIKO CO LTD (JP), Patent US5092817, 1-6.
2. Cayne, B.S. (1993). The New Lexicon Webster's Dictionary of the English Language, Volume 1-2, Lexicon Publications, Inc., Danbury CT.
3. Kelly, E. C. (1990). Bill money changer for slot machines, United States LAMBA BETA EPSILON GROUP (US), Patent US4966304, 1-11.
4. Burkett, R. D. (2007). Vending Machine. The Columbia Encyclopedia, Sixth edition, Columbia University Press, New York.
5. Yu, C.K. and W.Y. Tsai (2006). Bill acceptor, United States INTERNAT CURRENCY TECHNOLOGIES (TW), Patent US6994201, 1-10.

APPENDIX A

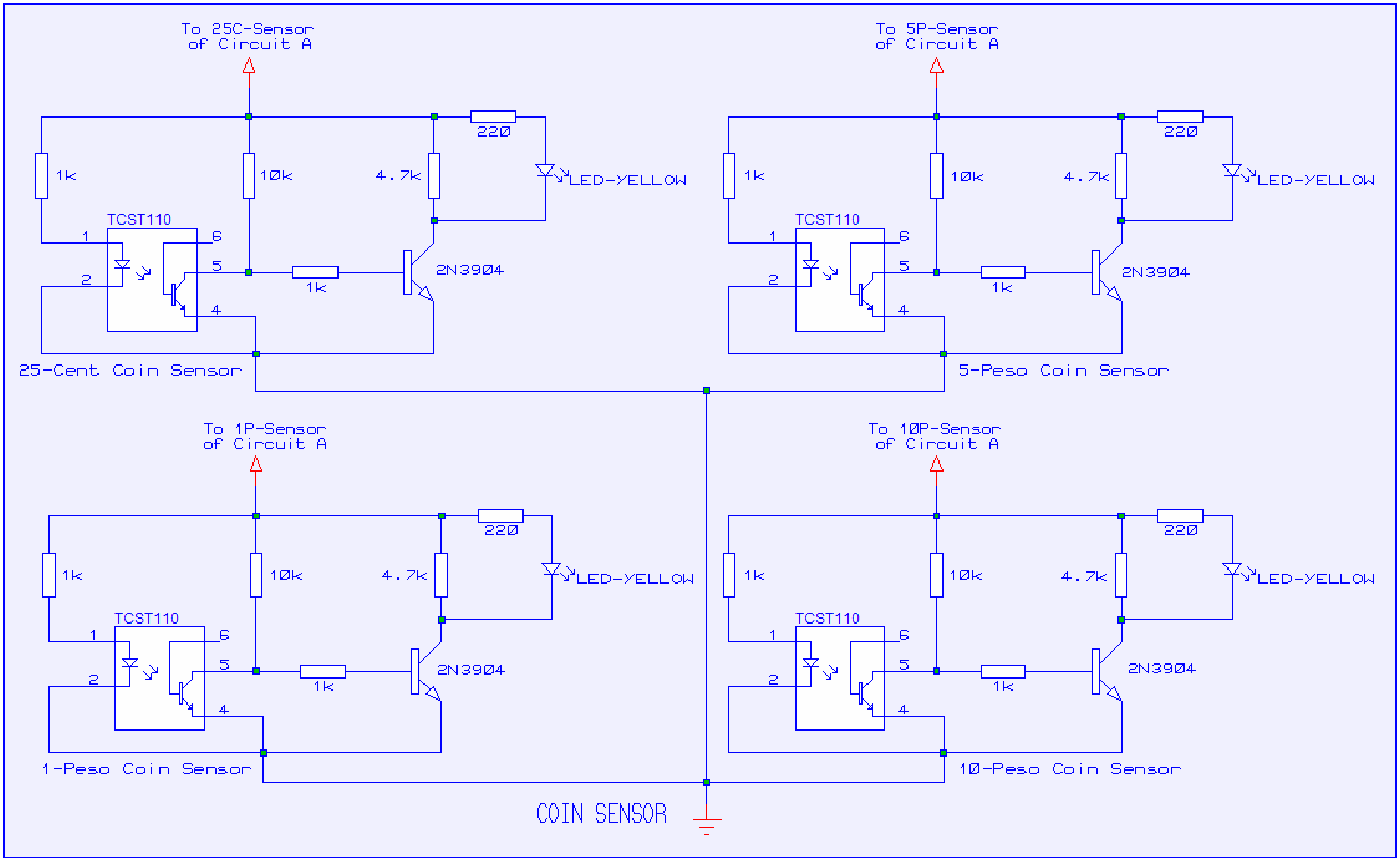
Circuit Diagrams



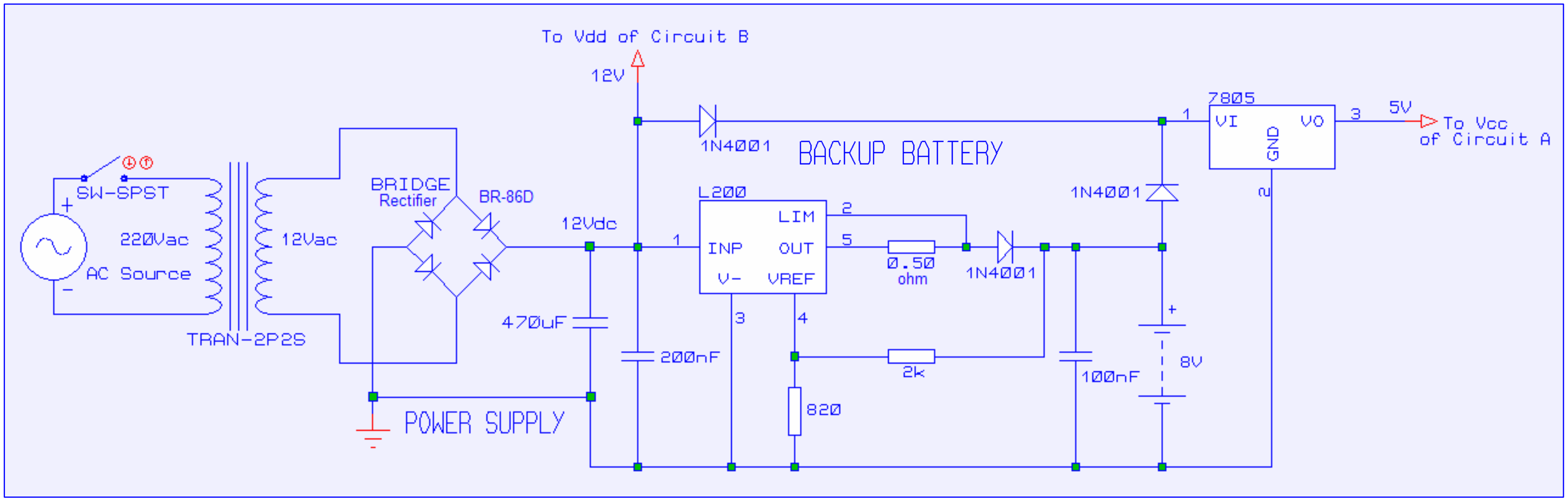
Bill-to-Coin Changer – Circuit A



Bill-to-Coin Changer – Circuit B



Bill-to-Coin Changer – Circuit C



Bill-to-Coin Changer – Circuit D

APPENDIX B

Source Code

```
Device = 16F877

XTAL = 4

ADCON1 = 7
LCD_DTPIN = PORTC.0
LCD_RSPIN = PORTC.4
LCD_ENPIN = PORTC.5
LCD_INTERFACE = 4
LCD_LINES = 4
LCD_TYPE = 0
DelayMS 500

ALL_DIGITAL = True
PORTB_PULLUPS = On

Dim key As Byte
Dim cb_25c As Word
Dim cb_1p As Word
Dim cb_5p As Word
Dim cb_10p As Word

Dim coin_totval As Word
Dim bill_val As Word
Dim ctr As Byte

Dim centavo As Word
Dim onepeso As Word
Dim fivepeso As Word
Dim tenpeso As Word

Dim Num As Byte
Dim Number As Word
Dim flag_25c As Bit
Dim flag_1p As Bit
Dim flag_5p As Bit
Dim flag_10p As Bit
Dim chk As Byte
Dim portd_cmp As Byte
```

```
flag_1p = 0
flag_5p = 0
flag_10p = 0
flag_25c = 0
coin_totval = 0
ctr = 0

onepeso = 0
fivepeso = 0
tenpeso = 0
centavo = 0
bill_val = 0

cb_25c = 300
cb_1p = 300
cb_5p = 300
cb_10p = 300

TRISA = %010000
TRISB = %01110000
TRISC = %01000000
TRISE = %111
TRISD = %11111111

PORTA = 0
PORTB = 0
PORTC = 0

DelayMS 100

menu_main:
   PORTC = 0

   portd_cmp = 0
   chk = 0

   If cb_25c < 80 Then
            chk = chk + 1
   EndIf
   If cb_1p < 20 Then
            chk = chk + 1
   EndIf
   If cb_5p < 4 Then
            chk = chk + 1
   EndIf
```

```
   If cb_10p < 2 Then
              chk = chk + 1
   EndIf
   If chk = 4 Then msg_errorcb

   Cls
   Print At 1, 1,  "     M A P U A      "
   Print At 2, 1,  "School of EE-ECE-CoE"
   Print At 3, 1,  "    Bill-to-Coin    "
   Print At 4, 1,  "      Changer       "
   DelayMS 2000

   Cls
   Print At 1, 1,  "  [ INSERT  BILL ]  "
   Print At 3, 1,  " (7)Test   (9)Prop. "
   Print At 4, 1,  " (*)Bank   (#)Enter "
   DelayMS 250

menu_mainloop:
   GoSub getkeys

   If key = 6 Then show_prop
   If key = 4 Then show_test
   If key = 3 Then test_fake
   If key = 1 Then show_cb

   GoTo menu_mainloop

test_fake:
   portd_cmp = PORTD
   High PORTB.7
   ctr = 0

test_fakeloop:
   If PORTC.6=0 Then
      High PORTC.7
      Cls
      Print At 1, 1,  "       WARNING      "
      Print At 2, 1,  "     COUNTERFEIT    "
      Print At 3, 1,  "      DETECTED!     "
      DelayMS 3000
      Low PORTC.7
           GoTo menu_main
   EndIf
```

```
   If PORTD < 3 Then menu_main
   If PORTD > 5 Then menu_main

   ctr = ctr + 1
   DelayMS 1000
   GoSub msg_billdetect

   If ctr = 3 Then detect_valloop

   GoTo test_fakeloop

detect_valloop:
   If PORTD <> portd_cmp Then menu_main

   If PORTD=%00000011 Then
      bill_val = 20
      GoTo show_amt
   EndIf

   If PORTD=%00000100 Then
      bill_val = 50
      GoTo show_amt
   EndIf

   If PORTD=%00000101 Then
      bill_val = 100
      GoTo show_amt
   EndIf

   GoTo detect_valloop

show_amt:
   High PORTA.3
   Cls
   Print At 2, 1,  "  [ PLEASE  WAIT ]  "
   Print At 3, 1,  "  [ FEEDING BILL ]  "
   DelayMS 5000
   Low PORTA.3

   Cls
   Print At 1, 1,  "  Amount to Change  "
   Print At 2, 1,  "     - P",Dec bill_val,".00 -"
   Print At 3, 1,  "                    "
   Print At 4, 1,  "     [ Press # ]    "
```

```
show_amtloop:
   GoSub getkeys
   If key = 3 Then menu_denom

   GoTo show_amtloop

menu_denom:
   Cls
   Print At 1, 1,  " (1) 25-Cents = ",@centavo
   Print At 2, 1,  " (2) 1-Peso   = ",@onepeso
   Print At 3, 1,  " (3) 5-Peso   = ",@fivepeso
   Print At 4, 1,  " (4) 10-Peso  = ",@tenpeso
   DelayMS 500

menu_denomloop:
   GoSub getkeys

   If key = 10 Then
      DelayMS 150
      GoTo enter_25c
   EndIf

   If key = 11 Then
      DelayMS 150
      GoTo enter_1p
   EndIf

   If key = 12 Then
      DelayMS 150
      GoTo enter_5p
   EndIf

   If key = 7 Then
      DelayMS 150
      GoTo enter_10p
   EndIf

   If key = 3 Then dispense_coins
   If key = 1 Then
           centavo=0
      onepeso=0
      fivepeso=0
      tenpeso=0
      coin_totval=0
           GoTo menu_denom
   EndIf
```

```
   GoTo menu_denomloop

enter_25c:
   Cls
   Print At 1, 1, "  [ ENTER PIECES ]  "
   Print At 4, 1, " (*)Clear  (#)Enter "
   DelayMS 250

   flag_25c = 1
   GoSub Loop
   GoTo menu_denom

enter_1p:
   Cls
   Print At 1, 1, "  [ ENTER PIECES ]  "
   Print At 4, 1, " (*)Clear  (#)Enter "
   DelayMS 250

   flag_1p = 1
   GoSub Loop
   GoTo menu_denom

enter_5p:
   Cls
   Print At 1, 1, "  [ ENTER PIECES ]  "
   Print At 4, 1, " (*)Clear  (#)Enter "
   DelayMS 500

   flag_5p = 1
   GoSub Loop
   GoTo menu_denom

enter_10p:
   Cls
   Print At 1, 1, "  [ ENTER PIECES ]  "
   Print At 4, 1, " (*)Clear  (#)Enter "
   DelayMS 500

   flag_10p = 1
   GoSub Loop
   GoTo menu_denom
```

```
dispense_coins:
   If centavo > 0 Then
      If centavo // 4 = 0 Then dispense_here
      GoTo msg_error
   EndIf

dispense_here:
   coin_totval = centavo / 4 + onepeso * 1 + fivepeso * 5 + tenpeso * 10

   If coin_totval > bill_val Then msg_error
   If coin_totval < bill_val Then msg_error
   If cb_25c < centavo Then msg_error25c
   If cb_1p < onepeso Then msg_error1p
   If cb_5p < fivepeso Then msg_error5p
   If cb_10p < tenpeso Then msg_error10p

   Cls
   Print At 1, 1, "25Cent:",#centavo," 1Peso:",#onepeso
   Print At 2, 1, " 5Peso:",#fivepeso," 10Peso:",#tenpeso
   Print At 3, 1, "--------------------"
   Print At 4, 1, "Bill Value: P",#bill_val,".00 "
   DelayMS 750

   Cls
   Print At 2, 1, "[   PLEASE  WAIT   ]"
   Print At 3, 1, "[ DISPENSING COINS ]"
   DelayMS 500

dispense_25cloop:

   If centavo = 0 Then
      Low PORTA.5
      GoSub show_dispctr
      GoTo dispense_1ploop
   EndIf

   High PORTA.5

   If PORTA.4=0 Then
      DelayMS 350
      centavo = centavo - 1
      cb_25c = cb_25c - 1
      GoSub show_dispctr
   EndIf

   GoTo dispense_25cloop
```

```
dispense_1ploop:
   If onepeso = 0 Then
      Low PORTA.0
      GoSub show_dispctr
      GoTo dispense_5ploop
   EndIf

   High PORTA.0

   If PORTE.0=0 Then
      DelayMS 350
      onepeso = onepeso - 1
      cb_1p = cb_1p - 1
      GoSub show_dispctr
   EndIf

   GoTo dispense_1ploop

dispense_5ploop:
   If fivepeso = 0 Then
      Low PORTA.1
      GoSub show_dispctr
      GoTo dispense_10ploop
   EndIf

   High PORTA.1

   If PORTE.1=0 Then
      DelayMS 350
      fivepeso = fivepeso - 1
      cb_5p = cb_5p - 1
      GoSub show_dispctr
   EndIf

   GoTo dispense_5ploop

dispense_10ploop:
   If tenpeso = 0 Then
      GoSub show_dispctr
      Low PORTA.2
      bill_val=0
      centavo=0
      onepeso=0
      fivepeso=0
      tenpeso=0
```

```
    coin_totval=0
        GoTo msg_success
  EndIf

  High PORTA.2

  If PORTE.2=0 Then
    DelayMS 350
    tenpeso = tenpeso - 1
    cb_10p = cb_10p - 1
    GoSub show_dispctr
  EndIf

  GoTo dispense_10ploop

msg_billdetect:
  Cls
  Print At 1, 1,  " [  PLEASE WAIT   ] "
  Print At 2, 1,  " [ BILL DETECTION ] "
  Print At 3, 1,  " [   IN PROGRESS  ] "
  Return

msg_error:
  Cls
  Print At 1, 1, " SORRY! The Desired "
  Print At 2, 1, "Denominations' Total"
  Print At 3, 1, " Value is NOT EQUAL "
  Print At 4, 1, " to the Bill Value! "
  DelayMS 2000
  coin_totval=0
  GoTo menu_denom

msg_error25c:
  Cls
  Print At 1, 1, "      SORRY!      "
  Print At 2, 1, "    Not Enough     "
  Print At 3, 1, "  25-CENTAVO COINS  "
  Print At 4, 1, "    to dispense    "
  DelayMS 2000
  GoTo menu_denom

msg_error1p:
  Cls
  Print At 1, 1, "      SORRY!      "
  Print At 2, 1, "    Not Enough     "
  Print At 3, 1, "   ONE-PESO COINS   "
```

```
   Print At 4, 1, "     to dispense    "
   DelayMS 2000
   GoTo menu_denom

msg_error5p:
   Cls
   Print At 1, 1, "       SORRY!       "
   Print At 2, 1, "     Not Enough     "
   Print At 3, 1, "   FIVE-PESO COINS  "
   Print At 4, 1, "     to dispense    "
   DelayMS 2000
   GoTo menu_denom

msg_error10p:
   Cls
   Print At 1, 1, "       SORRY!       "
   Print At 2, 1, "     Not Enough     "
   Print At 3, 1, "   TEN-PESO COINS   "
   Print At 4, 1, "     to dispense    "
   DelayMS 2000
   GoTo menu_denom

msg_errorcb:
   Cls
   High PORTB.7
   Print At 1, 1, "                    "
   Print At 2, 1, " SORRY! Not Enough  "
   Print At 3, 1, "  COINS to dispense "
   Print At 4, 1, "                    "
   DelayMS 2000
   Low PORTB.7

   Cls
   Print At 1, 1, "  [ Out of Order ]  "
   Print At 2, 1, "       SORRY!       "
   Print At 3, 1, "     Coin  Bank     "
   Print At 4, 1, "      Is Empty      "
   DelayMS 5000
   GoTo Exit2

msg_success:
   Cls
   Print At 1, 1, "[===============]   "
   Print At 2, 1, " [ Transaction   ]  "
   Print At 3, 1, "  [   Successful! ] "
   Print At 4, 1, "   [===============]"
```

```
   DelayMS 2000
   GoTo menu_main

show_dispctr:
   Cls
   Print At 1, 1,  " 25-Cents : ", #centavo
   Print At 2, 1,  "  1-Peso  : ", #onepeso
   Print At 3, 1,  "  5-Peso  : ", #fivepeso
   Print At 4, 1,  " 10-Peso  : ", #tenpeso
   Return

show_cb:
   DelayMS 500
   Cls
   Print At 1, 1, " 25-Cents : ", #cb_25c," Pcs"
   Print At 2, 1, "  1-Peso  : ", #cb_1p," Pcs"
   Print At 3, 1, "  5-Peso  : ", #cb_5p," Pcs"
   Print At 4, 1, " 10-Peso  : ", #cb_10p," Pcs"
   DelayMS 2000
   GoTo menu_main

show_test:
   Cls
   Print At 1, 1, "                    "
   Print At 2, 1, "    CALIBRATION     "
   Print At 3, 1, "    Value = ",Dec PORTD
   Print At 4, 1, "                    "
   DelayMS 1000
   GoTo menu_main

show_prop:
   Cls
   Print At 1, 1, "Proponents:         "
   Print At 2, 1, " - Caroline Sambaoa "
   Print At 3, 1, " - Jhune Bryan Reyes"
   Print At 4, 1, " - Jomer Bolo       "
   DelayMS 3000

   Cls
   Print At 1, 1, "Proponents:         "
   Print At 2, 1, " - Billie Buenafe   "
   Print At 3, 1, " - Lyndon Catalan   "
   Print At 4, 1, "[B.S. CoE Students] "
   DelayMS 3000
   GoTo menu_main
```

```
getkeys:
  key = 0

  PORTB = %00001110
  If PORTB.4 = 0 Then
    key = 1
    GoTo Exit
  EndIf

  If PORTB.5 = 0 Then
    key = 2
    GoTo Exit
  EndIf

  If PORTB.6 = 0 Then
    key = 3
    GoTo Exit
  EndIf

  PORTB = %00001101
  If PORTB.4 = 0 Then
        key = 4
        GoTo Exit
  EndIf

  If PORTB.5 = 0 Then
        key = 5
        GoTo Exit
  EndIf

  If PORTB.6 = 0 Then
        key = 6
        GoTo Exit
  EndIf

  PORTB = %00001011
  If PORTB.4 = 0 Then
    key = 7
        GoTo Exit
  EndIf

  If PORTB.5 = 0 Then
        key = 8
        GoTo Exit
  EndIf
```

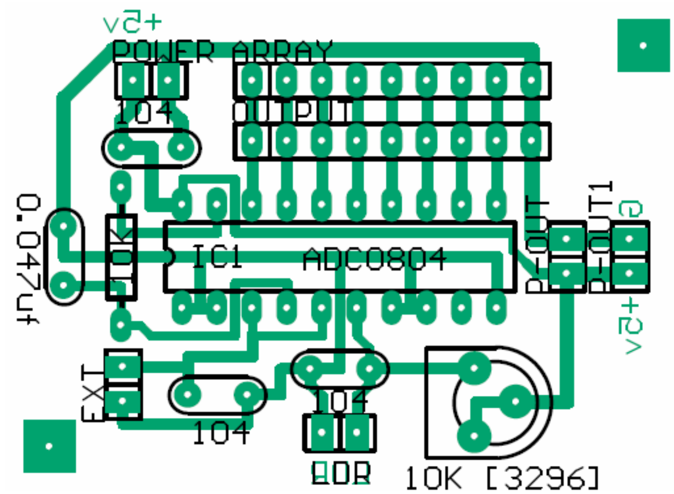
```
   If PORTB.6 = 0 Then
         key = 9
         GoTo Exit
   EndIf

   PORTB = %00000111
   If PORTB.4 = 0 Then
         key = 10
         GoTo Exit
   EndIf

   If PORTB.5 = 0 Then
         key = 11
         GoTo Exit
   EndIf

   If PORTB.6 = 0 Then
         key = 12
         GoTo Exit
   EndIf

Exit:
   Return

Loop:
   Number = 0
   key = 255

   While Num <> 16
      Num = InKey
   Wend

   While key <> "#"
      Num=InKey
      DelayMS 50
      key = LookUpL Num,["*",0,"#",0,7,8,9,0,4,5,6,0,1,2,3,0,255]
      If key = "*" Then
         Cls
         Print At 1, 1, "  [ ENTER PIECES ]  "
               Print At 4, 1, " (*)Clear  (#)Enter "
         Number = 0
      EndIf

      If key < 10 Then
         Number = Number * 10 + key
```

```
   If flag_25c = 1 Then
            If Number < 301 Then
         centavo = Number
      EndIf

                  If Number > 300 Then
                     centavo = 300
      EndIf
   EndIf

   If flag_1p = 1 Then
                  If Number < 101 Then
         onepeso = Number
                  EndIf

                  If Number > 100 Then
                     onepeso = 100
                  EndIf
   EndIf

   If flag_5p = 1 Then
      If Number < 21 Then
         fivepeso = Number
                  EndIf

                  If Number > 20 Then
                     fivepeso = 20
            EndIf
   EndIf

   If flag_10p = 1 Then
      If Number < 11 Then
         tenpeso = Number
                  EndIf

                  If Number > 10 Then
                     tenpeso = 10
                  EndIf
   EndIf

   Print At 2,1,"     ",@Number," Piece(s)"
EndIf

While Num <> 16
   Num = InKey
   DelayMS 50
```

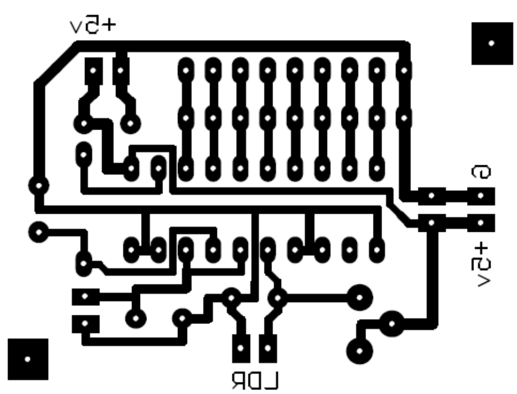
```
    Wend
  Wend

  Cls
  Clear Number
  flag_1p = 0
  flag_5p = 0
  flag_10p = 0
  flag_25c = 0
  Return

Exit2:
  End
```

APPENDIX C

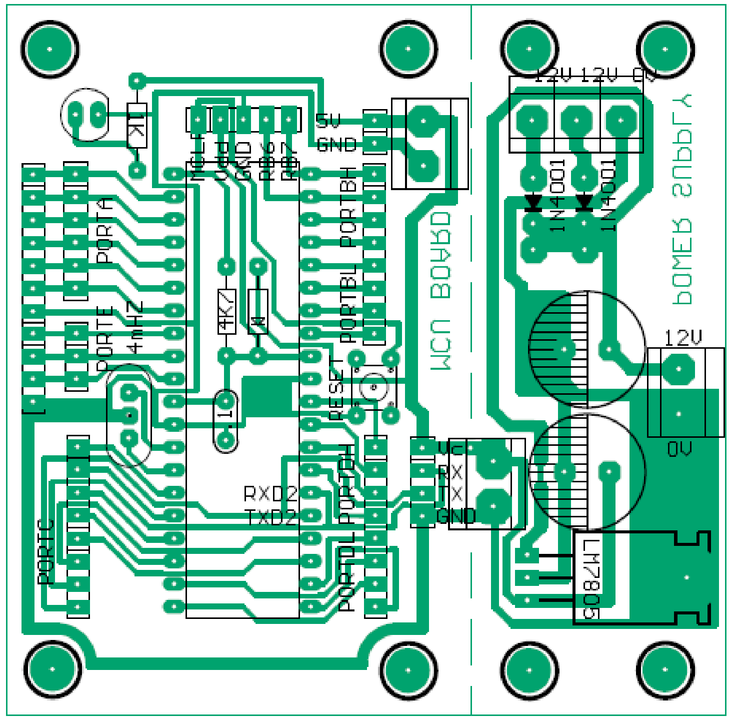
PCB Layouts



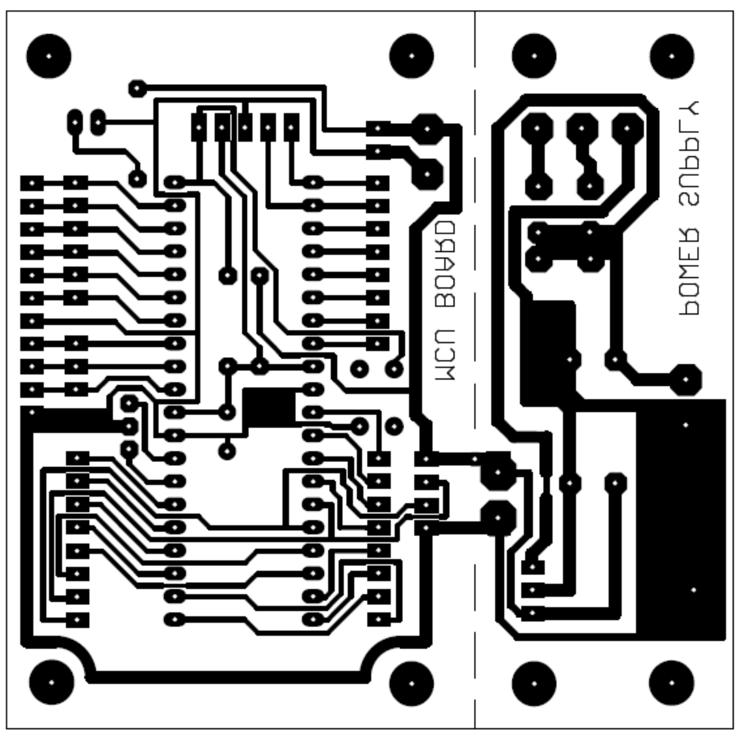
Bill Detector PCB Layout



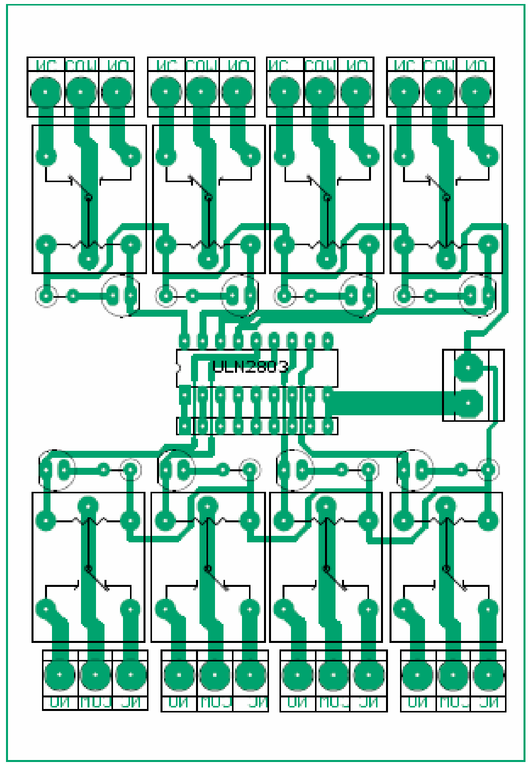
Bill Detector Foil Pattern Layout



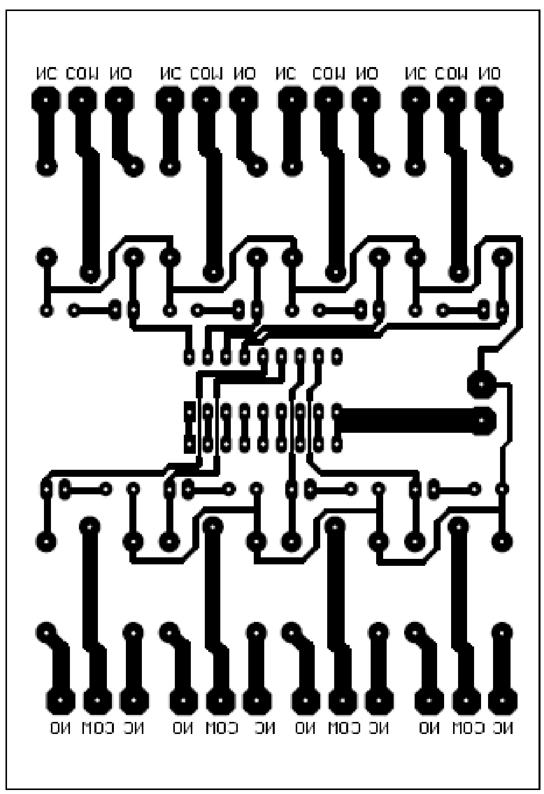
Microcontroller Board PCB Layout



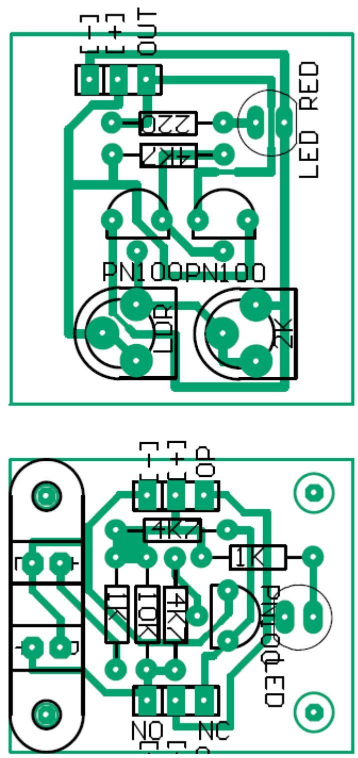
Microcontroller Board Foil Pattern Layout



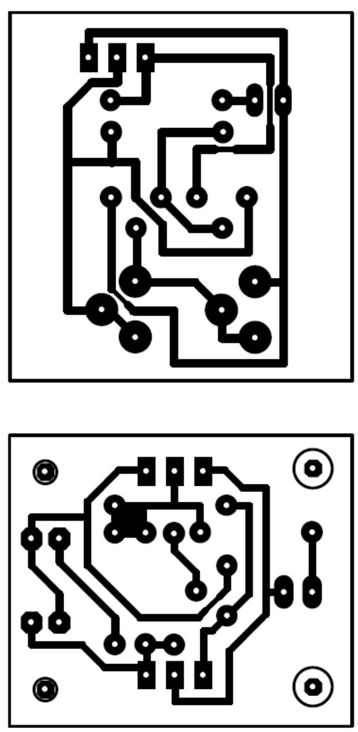
Relay Driver PCB Layout



Relay Driver Foil Pattern Layout



Counterfeit Sensor and Coin Sensor PCB Layout



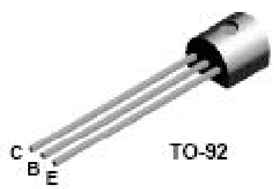
Counterfeit Sensor and Coin Sensor Foil Pattern Layout

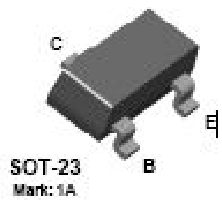
APPENDIX D

NPN General Purpose Amplifier Data Sheet

FAIRCHILD SEMICONDUCTOR™

2N3904 **MMBT3904** **PZT3904**





NPN General Purpose Amplifier

This device is designed as a general purpose amplifier and switch. The useful dynamic range extends to 100 mA as a switch and to 100 MHz as an amplifier.

Absolute Maximum Ratings* $T_A = 25°C$ unless otherwise noted

Symbol	Parameter	Value	Units
V_{CEO}	Collector-Emitter Voltage	40	V
V_{CBO}	Collector-Base Voltage	60	V
V_{EBO}	Emitter-Base Voltage	6.0	V
I_C	Collector Current - Continuous	200	mA
T_J, T_{stg}	Operating and Storage Junction Temperature Range	-55 to +150	°C

*These ratings are limiting values above which the serviceability of any semiconductor device may be impaired.

NOTES:
1) These ratings are based on a maximum junction temperature of 150 degrees C.
2) These are steady state limits. The factory should be consulted on applications involving pulsed or low duty cycle operations.

Thermal Characteristics $T_A = 25°C$ unless otherwise noted

Symbol	Characteristic	Max			Units
		2N3904	*MMBT3904	**PZT3904	
P_D	Total Device Dissipation Derate above 25°C	625 5.0	350 2.8	1,000 8.0	mW mW/°C
$R_{\theta JC}$	Thermal Resistance, Junction to Case	83.3			°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	200	357	125	°C/W

*Device mounted on FR-4 PCB 1.6" X 1.6" X 0.06."

**Device mounted on FR-4 PCB 38 mm X 18 mm X 1.5 mm; mounting pad for the collector lead min. 6 cm^2.

NPN General Purpose Amplifier
(continued)

Electrical Characteristics
T_A = 25°C unless otherwise noted

Symbol	Parameter	Test Conditions	Min	Max	Units
OFF CHARACTERISTICS					
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 1.0 mA, I_B = 0	40		V
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	I_C = 10 μA, I_E = 0	60		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	I_E = 10 μA, I_C = 0	6.0		V
I_{BL}	Base Cutoff Current	V_{CE} = 30 V, V_{EB} = 3V		50	nA
I_{CEX}	Collector Cutoff Current	V_{CE} = 30 V, V_{EB} = 3V		50	nA
ON CHARACTERISTICS*					
h_{FE}	DC Current Gain	I_C = 0.1 mA, V_{CE} = 1.0 V I_C = 1.0 mA, V_{CE} = 1.0 V I_C = 10 mA, V_{CE} = 1.0 V I_C = 50 mA, V_{CE} = 1.0 V I_C = 100 mA, V_{CE} = 1.0 V	40 70 100 60 30	 300	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_C = 10 mA, I_B = 1.0 mA I_C = 50 mA, I_B = 5.0 mA		0.2 0.3	V V
$V_{BE(sat)}$	Base-Emitter Saturation Voltage	I_C = 10 mA, I_B = 1.0 mA I_C = 50 mA, I_B = 5.0 mA	0.65	0.85 0.95	V V
SMALL SIGNAL CHARACTERISTICS					
f_T	Current Gain - Bandwidth Product	I_C = 10 mA, V_{CE} = 20 V, f = 100 MHz	300		MHz
C_{obo}	Output Capacitance	V_{CB} = 5.0 V, I_E = 0, f = 1.0 MHz		4.0	pF
C_{ibo}	Input Capacitance	V_{EB} = 0.5 V, I_C = 0, f = 1.0 MHz		8.0	pF
NF	Noise Figure	I_C = 100 μA, V_{CE} = 5.0 V, R_S =1.0kΩ,f=10 Hz to 15.7kHz		5.0	dB
SWITCHING CHARACTERISTICS					
t_d	Delay Time	V_{CC} = 3.0 V, V_{BE} = 0.5 V,		35	ns
t_r	Rise Time	I_C = 10 mA, I_{B1} = 1.0 mA		35	ns
t_s	Storage Time	V_{CC} = 3.0 V, I_C = 10mA		200	ns
t_f	Fall Time	I_{B1} = I_{B2} = 1.0 mA		50	ns

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%

Spice Model

NPN (Is=6.734f Xti=3 Eg=1.11 Vaf=74.03 Bf=416.4 Ne=1.259 Ise=6.734 Ikf=66.78m Xtb=1.5 Br=.7371 Nc=2 Isc=0 Ikr=0 Rc=1 Cjc=3.638p Mjc=.3085 Vjc=.75 Fc=.5 Cje=4.493p Mje=.2593 Vje=.75 Tr=239.5n Tf=301.2p Itf=.4 Vtf=4 Xtf=2 Rb=10)

Test Circuits

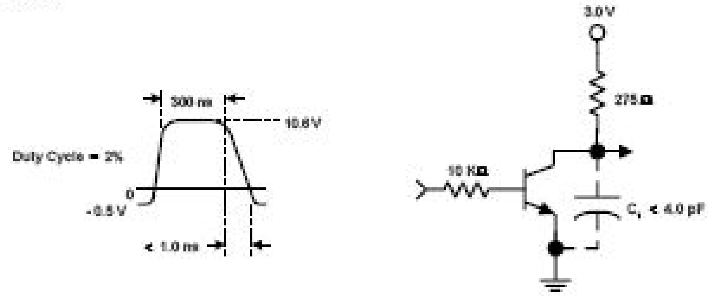


FIGURE 1: Delay and Rise Time Equivalent Test Circuit

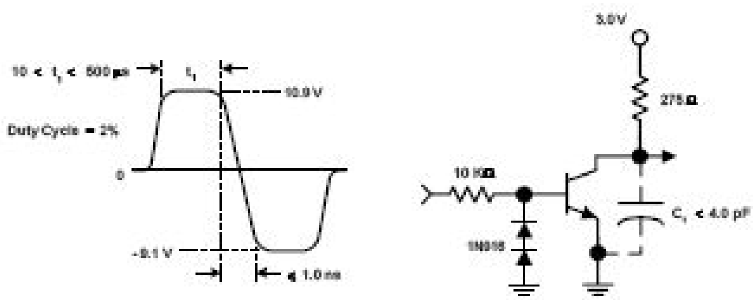


FIGURE 2: Storage and Fall Time Equivalent Test Circuit

APPENDIX E

ADC0804 A/D Converter Data Sheet

National Semiconductor

December 1994

ADC0801/ADC0802/ADC0803/ADC0804/ADC0805 8-Bit μP Compatible A/D Converters

General Description

The ADC0801, ADC0802, ADC0803, ADC0804 and ADC0805 are CMOS 8-bit successive approximation A/D converters that use a differential potentiometric ladder—similar to the 256R products. These converters are designed to allow operation with the NSC800 and INS8080A derivative control bus with TRI-STATE® output latches directly driving the data bus. These A/Ds appear like memory locations or I/O ports to the microprocessor and no interfacing logic is needed.

Differential analog voltage inputs allow increasing the common-mode rejection and offsetting the analog zero input voltage value. In addition, the voltage reference input can be adjusted to allow encoding any smaller analog voltage span to the full 8 bits of resolution.

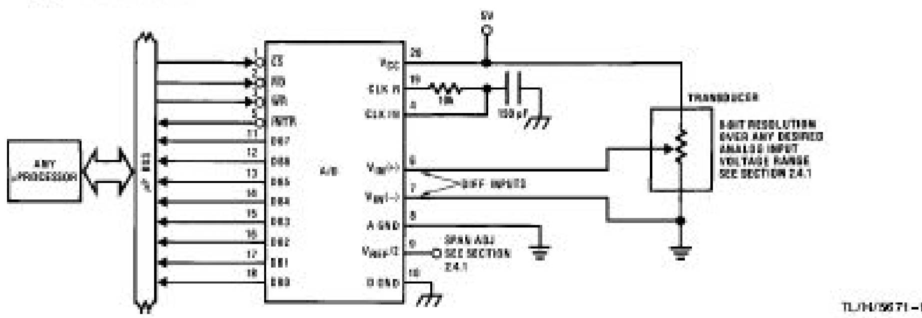
Features

- Compatible with 8080 μP derivatives—no interfacing logic needed - access time - 135 ns
- Easy interface to all microprocessors, or operates "stand alone"
- Differential analog voltage inputs
- Logic inputs and outputs meet both MOS and TTL voltage level specifications
- Works with 2.5V (LM336) voltage reference
- On-chip clock generator
- 0V to 5V analog input voltage range with single 5V supply
- No zero adjust required
- 0.3" standard width 20-pin DIP package
- 20-pin molded chip carrier or small outline package
- Operates ratiometrically or with 5 V_{DC}, 2.5 V_{DC}, or analog span adjusted voltage reference

Key Specifications

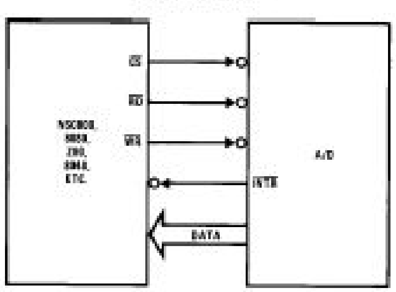
- Resolution 8 bits
- Total error ±¼ LSB, ±½ LSB and ±1 LSB
- Conversion time 100 μs

Typical Applications



TL/H/5671–1

8080 Interface



TL/H/5671–31

Error Specification (Includes Full-Scale, Zero Error, and Non-Linearity)			
Part Number	Full-Scale Adjusted	$V_{REF}/2 = 2.500\ V_{DC}$ (No Adjustments)	$V_{REF}/2$ = No Connection (No Adjustments)
ADC0801	±¼ LSB		
ADC0802		±½ LSB	
ADC0803	±½ LSB		
ADC0804		±1 LSB	
ADC0805			±1 LSB

TRI-STATE® is a registered trademark of National Semiconductor Corp.
Z-80® is a registered trademark of Zilog Corp.

ADC0801/ADC0802/ADC0803/ADC0804/ADC0805 8-Bit μP Compatible A/D Converters

Absolute Maximum Ratings (Notes 1 & 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Supply Voltage (V_{CC}) (Note 3)	6.5V
Voltage	
Logic Control Inputs	−0.3V to +18V
At Other Input and Outputs	−0.3V to (V_{CC}+0.3V)
Lead Temp. (Soldering, 10 seconds)	
Dual-In-Line Package (plastic)	260°C
Dual-In-Line Package (ceramic)	300°C
Surface Mount Package	
Vapor Phase (60 seconds)	215°C
Infrared (15 seconds)	220°C
Storage Temperature Range	−65°C to +150°C
Package Dissipation at T_A=25°C	875 mW
ESD Susceptibility (Note 10)	800V

Operating Ratings (Notes 1 & 2)

Temperature Range	$T_{MIN} \le T_A \le T_{MAX}$
ADC0801/02LJ, ADC0802LJ/883	$-55°C \le T_A \le +125°C$
ADC0801/02/03/04LCJ	$-40°C \le T_A \le +85°C$
ADC0801/02/03/05LCN	$-40°C \le T_A \le +85°C$
ADC0804LCN	$0°C \le T_A \le +70°C$
ADC0802/03/04LCV	$0°C \le T_A \le +70°C$
ADC0802/03/04LCWM	$0°C \le T_A \le +70°C$
Range of V_{CC}	4.5 V_{DC} to 6.3 V_{DC}

Electrical Characteristics

The following specifications apply for V_{CC}=5 V_{DC}, $T_{MIN} \le T_A \le T_{MAX}$ and f_{CLK}=640 kHz unless otherwise specified.

Parameter	Conditions	Min	Typ	Max	Units
ADC0801: Total Adjusted Error (Note 8)	With Full-Scale Adj. (See Section 2.5.2)			±1/4	LSB
ADC0802: Total Unadjusted Error (Note 8)	$V_{REF}/2$=2.500 V_{DC}			±1/2	LSB
ADC0803: Total Adjusted Error (Note 8)	With Full-Scale Adj. (See Section 2.5.2)			±1/2	LSB
ADC0804: Total Unadjusted Error (Note 8)	$V_{REF}/2$=2.500 V_{DC}			±1	LSB
ADC0805: Total Unadjusted Error (Note 8)	$V_{REF}/2$-No Connection			±1	LSB
$V_{REF}/2$ Input Resistance (Pin 9)	ADC0801/02/03/05 ADC0804 (Note 9)	2.5 0.75	8.0 1.1		kΩ kΩ
Analog Input Voltage Range	(Note 4) V(+) or V(−)	Gnd−0.05		V_{CC}+0.05	V_{DC}
DC Common-Mode Error	Over Analog Input Voltage Range		±1/16	±1/8	LSB
Power Supply Sensitivity	V_{CC}=5 V_{DC} ±10% Over Allowed $V_{IN}(+)$ and $V_{IN}(-)$ Voltage Range (Note 4)		±1/16	±1/8	LSB

AC Electrical Characteristics

The following specifications apply for V_{CC}=5 V_{DC} and T_A=25°C unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Units
T_C	Conversion Time	f_{CLK}=640 kHz (Note 6)	103		114	μs
T_C	Conversion Time	(Note 5, 6)	66		73	$1/f_{CLK}$
f_{CLK}	Clock Frequency Clock Duty Cycle	V_{CC}=5V, (Note 5) (Note 5)	100 40	640	1460 60	kHz %
CR	Conversion Rate in Free-Running Mode	$\overline{INTR}$ tied to $\overline{WR}$ with $\overline{CS}$=0 V_{DC}, f_{CLK}=640 kHz	8770		9708	conv/s
$t_{W(\overline{WR})L}$	Width of $\overline{WR}$ Input (Start Pulse Width)	$\overline{CS}$=0 V_{DC} (Note 7)	100			ns
t_{ACC}	Access Time (Delay from Falling Edge of $\overline{RD}$ to Output Data Valid)	C_L=100 pF		135	200	ns
t_{1H}, t_{0H}	TRI-STATE Control (Delay from Rising Edge of $\overline{RD}$ to Hi-Z State)	C_L=10 pF, R_L=10k (See TRI-STATE Test Circuits)		125	200	ns
t_{WI}, t_{RI}	Delay from Falling Edge of $\overline{WR}$ or $\overline{RD}$ to Reset of $\overline{INTR}$			300	450	ns
C_{IN}	Input Capacitance of Logic Control Inputs			5	7.5	pF
C_{OUT}	TRI-STATE Output Capacitance (Data Buffers)			5	7.5	pF
CONTROL INPUTS [Note: CLK IN (Pin 4) is the input of a Schmitt trigger circuit and is therefore specified separately]						
V_{IN} (1)	Logical "1" Input Voltage (Except Pin 4 CLK IN)	V_{CC}=5.25 V_{DC}	2.0		15	V_{DC}

AC Electrical Characteristics (Continued)

The following specifications apply for $V_{CC} = 5V_{DC}$ and $T_{MIN} \leq T_A \leq T_{MAX}$, unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Units
CONTROL INPUTS [Note: CLK IN (Pin 4) is the input of a Schmitt trigger circuit and is therefore specified separately]						
V_{IN} (0)	Logical "0" Input Voltage (Except Pin 4 CLK IN)	$V_{CC} = 4.75\ V_{DC}$			0.8	V_{DC}
I_{IN} (1)	Logical "1" Input Current (All Inputs)	$V_{IN} = 5\ V_{DC}$		0.005	1	μA_{DC}
I_{IN} (0)	Logical "0" Input Current (All Inputs)	$V_{IN} = 0\ V_{DC}$	−1	−0.005		μA_{DC}
CLOCK IN AND CLOCK R						
V_T+	CLK IN (Pin 4) Positive Going Threshold Voltage		2.7	3.1	3.5	V_{DC}
V_T-	CLK IN (Pin 4) Negative Going Threshold Voltage		1.5	1.8	2.1	V_{DC}
V_H	CLK IN (Pin 4) Hysteresis $(V_T+)-(V_T-)$		0.6	1.3	2.0	V_{DC}
V_{OUT} (0)	Logical "0" CLK R Output Voltage	$I_O = 360\ \mu A$ $V_{CC} = 4.75\ V_{DC}$			0.4	V_{DC}
V_{OUT} (1)	Logical "1" CLK R Output Voltage	$I_O = -360\ \mu A$ $V_{CC} = 4.75\ V_{DC}$	2.4			V_{DC}
DATA OUTPUTS AND $\overline{INTR}$						
V_{OUT} (0)	Logical "0" Output Voltage Data Outputs $\overline{INTR}$ Output	 $I_{OUT} = 1.6$ mA, $V_{CC} = 4.75\ V_{DC}$ $I_{OUT} = 1.0$ mA, $V_{CC} = 4.75\ V_{DC}$			 0.4 0.4	 V_{DC} V_{DC}
V_{OUT} (1)	Logical "1" Output Voltage	$I_O = -360\ \mu A$, $V_{CC} = 4.75\ V_{DC}$	2.4			V_{DC}
V_{OUT} (1)	Logical "1" Output Voltage	$I_O = -10\ \mu A$, $V_{CC} = 4.75\ V_{DC}$	4.5			V_{DC}
I_{OUT}	TRI-STATE Disabled Output Leakage (All Data Buffers)	$V_{OUT} = 0\ V_{DC}$ $V_{OUT} = 5\ V_{DC}$	−3		 3	μA_{DC} μA_{DC}
I_{SOURCE}		V_{OUT} Short to Gnd, $T_A = 25°C$	4.5	6		mA_{DC}
I_{SINK}		V_{OUT} Short to V_{CC}, $T_A = 25°C$	9.0	16		mA_{DC}
POWER SUPPLY						
I_{CC}	Supply Current (Includes Ladder Current) ADC0801/02/03/04LCJ/05 ADC0804LCN/LCV/LCWM	$f_{CLK} = 640$ kHz, $V_{REF}/2 = NC$, $T_A = 25°C$ and $\overline{CS} = 5V$		 1.1 1.9	 1.8 2.5	 mA mA

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its specified operating conditions.

Note 2: All voltages are measured with respect to Gnd, unless otherwise specified. The separate A Gnd point should always be wired to the D Gnd.

Note 3: A zener diode exists, internally, from V_{CC} to Gnd and has a typical breakdown voltage of 7 V_{DC}.

Note 4: For $V_{IN}(-) \geq V_{IN}(+)$ the digital output code will be 0000 0000. Two on-chip diodes are tied to each analog input (see block diagram) which will forward conduct for analog input voltages one diode drop below ground or one diode drop greater than the V_{CC} supply. Be careful, during testing at low V_{CC} levels (4.5V), as high level analog inputs (5V) can cause this input diode to conduct–especially at elevated temperatures, and cause errors for analog inputs near full-scale. The spec allows 50 mV forward bias of either diode. This means that as long as the analog V_{IN} does not exceed the supply voltage by more than 50 mV, the output code will be correct. To achieve an absolute 0 V_{DC} to 5 V_{DC} input voltage range will therefore require a minimum supply voltage of 4.950 V_{DC} over temperature variations, initial tolerance and loading.

Note 5: Accuracy is guaranteed at f_{CLK} = 640 kHz. At higher clock frequencies accuracy can degrade. For lower clock frequencies, the duty cycle limits can be extended so long as the minimum clock high time interval or minimum clock low time interval is no less than 275 ns.

Note 6: With an asynchronous start pulse, up to 8 clock periods may be required before the internal clock phases are proper to start the conversion process. The start request is internally latched, see *Figure 2* and section 2.0.

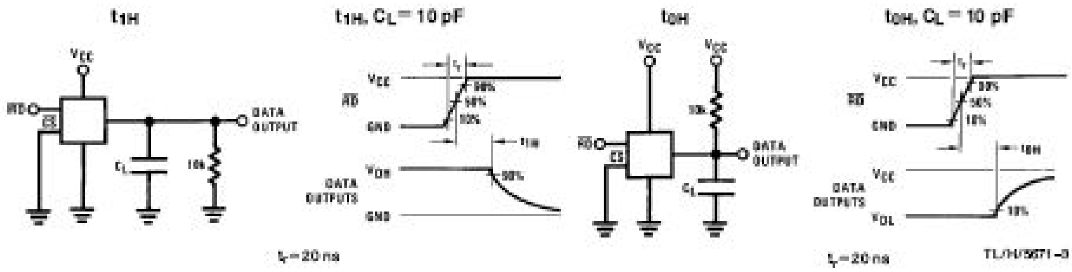
Note 7: The $\overline{CS}$ input is assumed to bracket the $\overline{WR}$ strobe input and therefore timing is dependent on the $\overline{WR}$ pulse width. An arbitrarily wide pulse width will hold the converter in a reset mode and the start of conversion is initiated by the low to high transition of the $\overline{WR}$ pulse (see timing diagrams).

Note 8: None of these A/Ds requires a zero adjust (see section 2.5.1). To obtain zero code at other analog input voltages see section 2.5 and *Figure 5*.

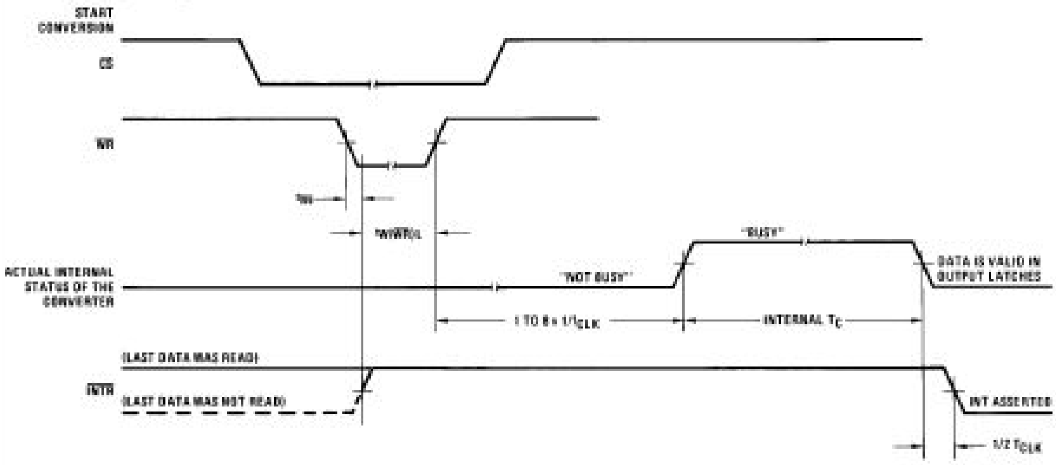
Note 9: The $V_{REF}/2$ pin is the center point of a two-resistor divider connected from V_{CC} to ground. In all versions of the ADC0801, ADC0802, ADC0803, and ADC0805, and in the ADC0804LCJ, each resistor is typically 16 kΩ. In all versions of the ADC0804 except the ADC0804LCJ, each resistor is typically 2.2 kΩ.

Note 10: Human body model, 100 pF discharged through a 1.5 kΩ resistor.

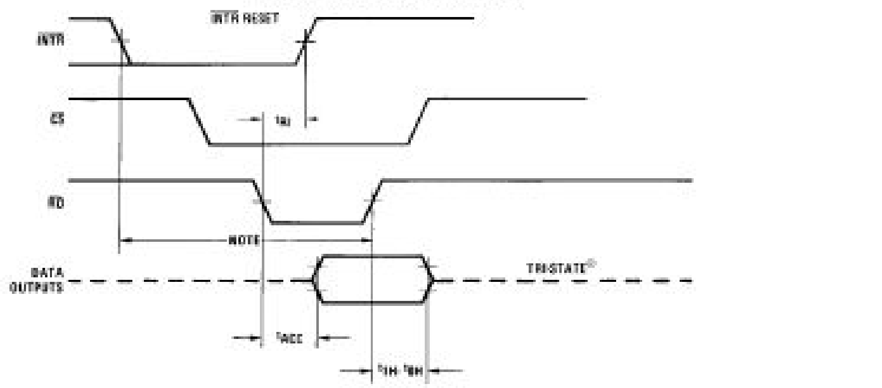
TRI-STATE Test Circuits and Waveforms



Timing Diagrams (All timing is measured from the 50% voltage points)



Output Enable and Reset $\overline{INTR}$



Note: Read strobe must occur 8 clock periods (8/f_{CLK}) after assertion of interrupt to guarantee reset of $\overline{INTR}$.

APPENDIX F

Liquid Crystal Display Data Sheet

HD44780U (LCD-II)

(Dot Matrix Liquid Crystal Display Controller/Driver)

HITACHI

ADE-207-272(Z)
'99.9
Rev. 0.0

Description

The HD44780U dot-matrix liquid crystal display controller and driver LSI displays alphanumerics, Japanese kana characters, and symbols. It can be configured to drive a dot-matrix liquid crystal display under the control of a 4- or 8-bit microprocessor. Since all the functions such as display RAM, character generator, and liquid crystal driver, required for driving a dot-matrix liquid crystal display are internally provided on one chip, a minimal system can be interfaced with this controller/driver.

A single HD44780U can display up to one 8-character line or two 8-character lines.

The HD44780U has pin function compatibility with the HD44780S which allows the user to easily replace an LCD-II with an HD44780U. The HD44780U character generator ROM is extended to generate 208 5 × 8 dot character fonts and 32 5 × 10 dot character fonts for a total of 240 different character fonts.

The low power supply (2.7V to 5.5V) of the HD44780U is suitable for any portable battery-driven product requiring low power dissipation.

Features

- 5 × 8 and 5 × 10 dot matrix possible
- Low power operation support:
  — 2.7 to 5.5V
- Wide range of liquid crystal display driver power
  — 3.0 to 11V
- Liquid crystal drive waveform
  — A (One line frequency AC waveform)
- Correspond to high speed MPU bus interface
  — 2 MHz (when V_{CC} = 5V)
- 4-bit or 8-bit MPU interface enabled
- 80 × 8-bit display RAM (80 characters max.)
- 9,920-bit character generator ROM for a total of 240 character fonts
  — 208 character fonts (5 × 8 dot)
  — 32 character fonts (5 × 10 dot)

HD44780U

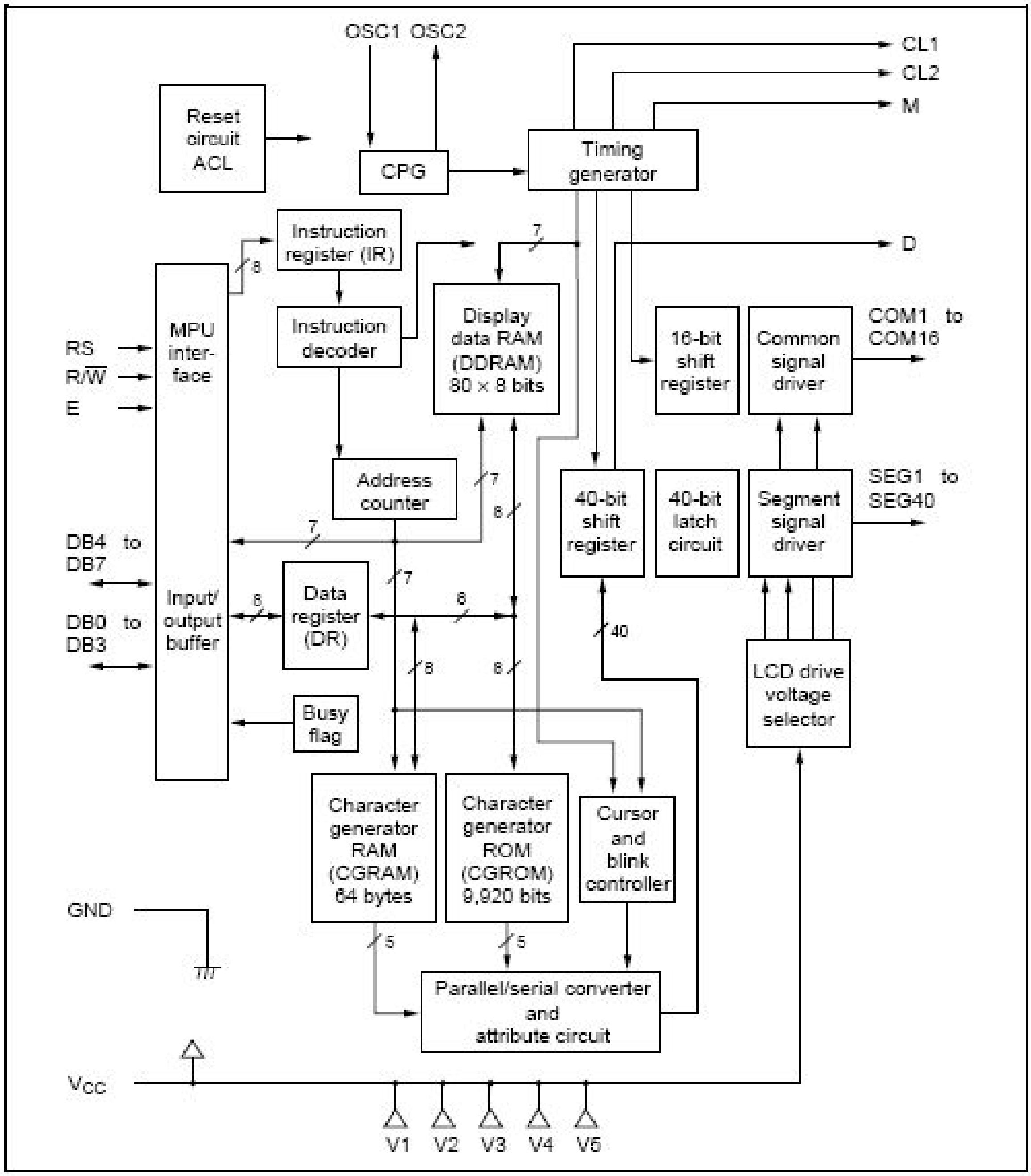
- 64 × 8-bit character generator RAM
  — 8 character fonts (5 × 8 dot)
  — 4 character fonts (5 × 10 dot)
- 16-common × 40-segment liquid crystal display driver
- Programmable duty cycles
  — 1/8 for one line of 5 × 8 dots with cursor
  — 1/11 for one line of 5 × 10 dots with cursor
  — 1/16 for two lines of 5 × 8 dots with cursor
- Wide range of instruction functions:
  — Display clear, cursor home, display on/off, cursor on/off, display character blink, cursor shift, display shift
- Pin function compatibility with HD44780S
- Automatic reset circuit that initializes the controller/driver after power on
- Internal oscillator with external resistors
- Low power consumption

Ordering Information

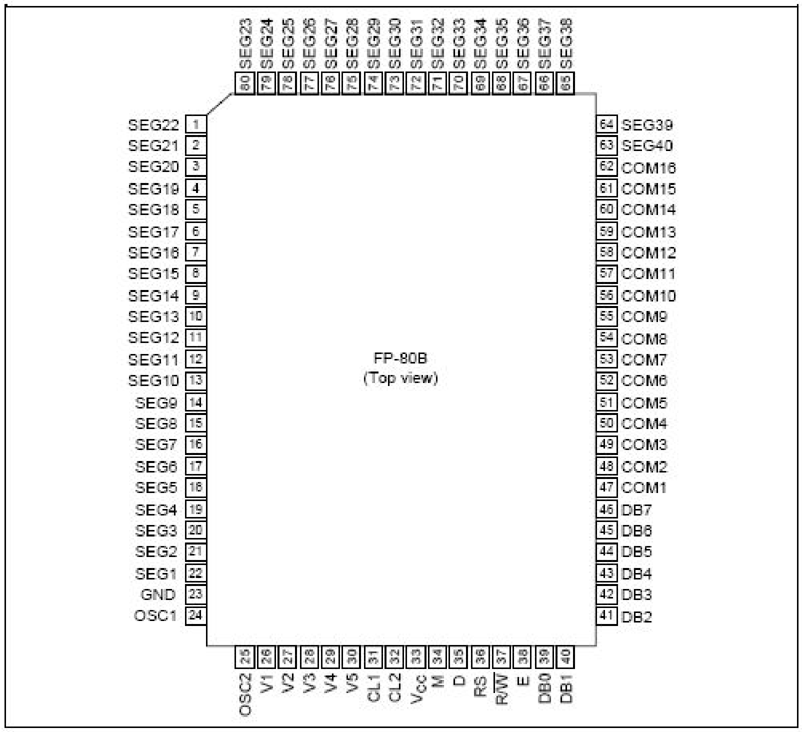
Type No.	Package	CGROM
HD44780UA00FS HCD44780UA00 HD44780UA00TF	FP-80B Chip TFP-80F	Japanese standard font
HD44780UA02FS HCD44780UA02 HD44780UA02TF	FP-80B Chip TFP-80F	European standard font
HD44780UBxxFS HCD44780UBxx HD44780UBxxTF	FP-80B Chip TFP-80F	Custom font

Note: xx: ROM code No.

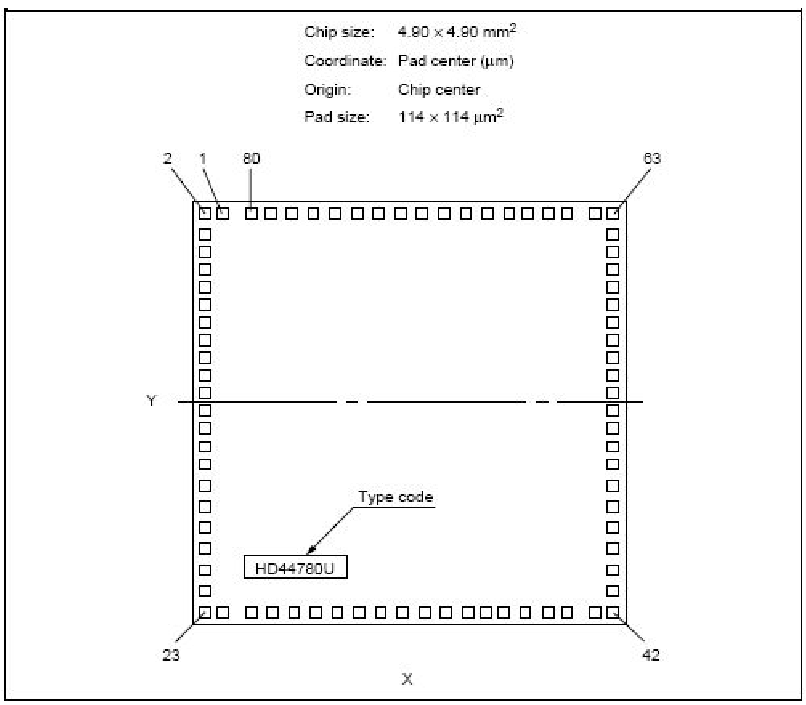
HD44780U Block Diagram



HD44780U Pin Arrangement (FP-80B)



HD44780U Pad Arrangement



APPENDIX G

PIC16F877 Microcontroller Data Sheet

MICROCHIP

PIC16F87X

28/40-Pin 8-Bit CMOS FLASH Microcontrollers

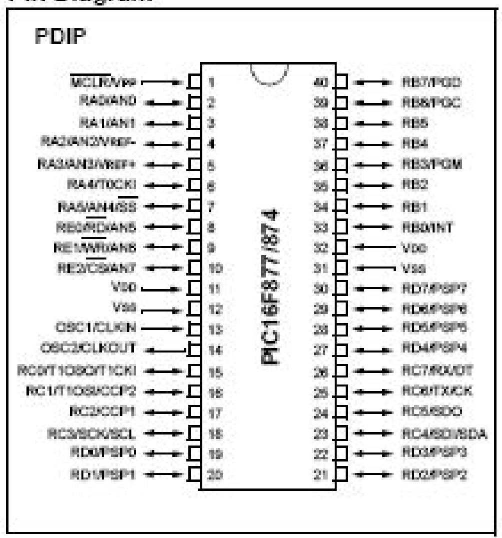
Devices Included in this Data Sheet:

- PIC16F873
- PIC16F874
- PIC16F876
- PIC16F877

Microcontroller Core Features:

- High performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program branches which are two cycle
- Operating speed: DC - 20 MHz clock input
DC - 200 ns instruction cycle
- Up to 8K x 14 words of FLASH Program Memory,
Up to 368 x 8 bytes of Data Memory (RAM)
Up to 256 x 8 bytes of EEPROM Data Memory
- Pinout compatible to the PIC16C73B/74B/76/77
- Interrupt capability (up to 14 sources)
- Eight level deep hardware stack
- Direct, indirect and relative addressing modes
- Power-on Reset (POR)
- Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code protection
- Power saving SLEEP mode
- Selectable oscillator options
- Low power, high speed CMOS FLASH/EEPROM technology
- Fully static design
- In-Circuit Serial Programming™ (ICSP) via two pins
- Single 5V In-Circuit Serial Programming capability
- In-Circuit Debugging via two pins
- Processor read/write access to program memory
- Wide operating voltage range: 2.0V to 5.5V
- High Sink/Source Current: 25 mA
- Commercial, Industrial and Extended temperature ranges
- Low-power consumption:
  - < 0.6 mA typical @ 3V, 4 MHz
  - 20 µA typical @ 3V, 32 kHz
  - < 1 µA typical standby current

Pin Diagram



Peripheral Features:

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during SLEEP via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - Capture is 16-bit, max. resolution is 12.5 ns
  - Compare is 16-bit, max. resolution is 200 ns
  - PWM max. resolution is 10-bit
- 10-bit multi-channel Analog-to-Digital converter
- Synchronous Serial Port (SSP) with SPI™ (Master mode) and I^2C™ (Master/Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection
- Parallel Slave Port (PSP) 8-bits wide, with external RD, WR and CS controls (40/44-pin only)
- Brown-out detection circuitry for Brown-out Reset (BOR)

Key Features PICmicro™ Mid-Range Reference Manual (DS33023)	PIC16F873	PIC16F874	PIC16F876	PIC16F877
Operating Frequency	DC - 20 MHz	DC - 20 MHz	DC - 20 MHz	DC - 20 MHz
RESETS (and Delays)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)
FLASH Program Memory (14-bit words)	4K	4K	8K	8K
Data Memory (bytes)	192	192	368	368
EEPROM Data Memory	128	128	256	256
Interrupts	13	14	13	14
I/O Ports	Ports A,B,C	Ports A,B,C,D,E	Ports A,B,C	Ports A,B,C,D,E
Timers	3	3	3	3
Capture/Compare/PWM Modules	2	2	2	2
Serial Communications	MSSP, USART	MSSP, USART	MSSP, USART	MSSP, USART
Parallel Communications	—	PSP	—	PSP
10-bit Analog-to-Digital Module	5 input channels	8 input channels	5 input channels	8 input channels
Instruction Set	35 instructions	35 instructions	35 instructions	35 instructions

TABLE 1-2: PIC16F874 AND PIC16F877 PINOUT DESCRIPTION

Pin Name	DIP Pin#	PLCC Pin#	QFP Pin#	I/O/P Type	Buffer Type	Description
OSC1/CLKIN	13	14	30	I	ST/CMOS(4)	Oscillator crystal input/external clock source input.
OSC2/CLKOUT	14	15	31	O	—	Oscillator crystal output. Connects to crystal or resonator in crystal oscillator mode. In RC mode, OSC2 pin outputs CLKOUT which has 1/4 the frequency of OSC1, and denotes the instruction cycle rate.
$\overline{\text{MCLR}}$/VPP	1	2	18	I/P	ST	Master Clear (Reset) input or programming voltage input. This pin is an active low RESET to the device.
						PORTA is a bi-directional I/O port.
RA0/AN0	2	3	19	I/O	TTL	RA0 can also be analog input0.
RA1/AN1	3	4	20	I/O	TTL	RA1 can also be analog input1.
RA2/AN2/VREF-	4	5	21	I/O	TTL	RA2 can also be analog input2 or negative analog reference voltage.
RA3/AN3/VREF+	5	6	22	I/O	TTL	RA3 can also be analog input3 or positive analog reference voltage.
RA4/T0CKI	6	7	23	I/O	ST	RA4 can also be the clock input to the Timer0 timer/counter. Output is open drain type.
RA5/$\overline{\text{SS}}$/AN4	7	8	24	I/O	TTL	RA5 can also be analog input4 or the slave select for the synchronous serial port.
						PORTB is a bi-directional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs.
RB0/INT	33	36	8	I/O	TTL/ST(1)	RB0 can also be the external interrupt pin.
RB1	34	37	9	I/O	TTL	
RB2	35	38	10	I/O	TTL	
RB3/PGM	36	39	11	I/O	TTL	RB3 can also be the low voltage programming input.
RB4	37	41	14	I/O	TTL	Interrupt-on-change pin.
RB5	38	42	15	I/O	TTL	Interrupt-on-change pin.
RB6/PGC	39	43	16	I/O	TTL/ST(2)	Interrupt-on-change pin or In-Circuit Debugger pin. Serial programming clock.
RB7/PGD	40	44	17	I/O	TTL/ST(2)	Interrupt-on-change pin or In-Circuit Debugger pin. Serial programming data.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as an external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured as general purpose I/O and a TTL input when used in the Parallel Slave Port mode (for interfacing to a microprocessor bus).
4: This buffer is a Schmitt Trigger input when configured in RC oscillator mode and a CMOS input otherwise.

TABLE 1-2: PIC16F874 AND PIC16F877 PINOUT DESCRIPTION (CONTINUED)

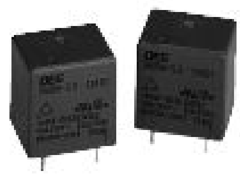
Pin Name	DIP Pin#	PLCC Pin#	QFP Pin#	I/O/P Type	Buffer Type	Description
						PORTC is a bi-directional I/O port.
RC0/T1OSO/T1CKI	15	16	32	I/O	ST	RC0 can also be the Timer1 oscillator output or a Timer1 clock input.
RC1/T1OSI/CCP2	16	18	35	I/O	ST	RC1 can also be the Timer1 oscillator input or Capture2 input/Compare2 output/PWM2 output.
RC2/CCP1	17	19	36	I/O	ST	RC2 can also be the Capture1 input/Compare1 output/PWM1 output.
RC3/SCK/SCL	18	20	37	I/O	ST	RC3 can also be the synchronous serial clock input/ output for both SPI and I^2C modes.
RC4/SDI/SDA	23	25	42	I/O	ST	RC4 can also be the SPI Data In (SPI mode) or data I/O (I^2C mode).
RC5/SDO	24	26	43	I/O	ST	RC5 can also be the SPI Data Out (SPI mode).
RC6/TX/CK	25	27	44	I/O	ST	RC6 can also be the USART Asynchronous Transmit or Synchronous Clock.
RC7/RX/DT	26	29	1	I/O	ST	RC7 can also be the USART Asynchronous Receive or Synchronous Data.
						PORTD is a bi-directional I/O port or parallel slave port when interfacing to a microprocessor bus.
RD0/PSP0	19	21	38	I/O	ST/TTL(3)	
RD1/PSP1	20	22	39	I/O	ST/TTL(3)	
RD2/PSP2	21	23	40	I/O	ST/TTL(3)	
RD3/PSP3	22	24	41	I/O	ST/TTL(3)	
RD4/PSP4	27	30	2	I/O	ST/TTL(3)	
RD5/PSP5	28	31	3	I/O	ST/TTL(3)	
RD6/PSP6	29	32	4	I/O	ST/TTL(3)	
RD7/PSP7	30	33	5	I/O	ST/TTL(3)	
						PORTE is a bi-directional I/O port.
RE0/$\overline{RD}$/AN5	8	9	25	I/O	ST/TTL(3)	RE0 can also be read control for the parallel slave port, or analog input5.
RE1/$\overline{WR}$/AN6	9	10	26	I/O	ST/TTL(3)	RE1 can also be write control for the parallel slave port, or analog input6.
RE2/$\overline{CS}$/AN7	10	11	27	I/O	ST/TTL(3)	RE2 can also be select control for the parallel slave port, or analog input7.
VSS	12,31	13,34	6,29	P	—	Ground reference for logic and I/O pins.
VDD	11,32	12,35	7,28	P	—	Positive supply for logic and I/O pins.
NC	—	1,17,28, 40	12,13, 33,34		—	These pins are not internally connected. These pins should be left unconnected.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as an external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured as general purpose I/O and a TTL input when used in the Parallel Slave Port mode (for interfacing to a microprocessor bus).
4: This buffer is a Schmitt Trigger input when configured in RC oscillator mode and a CMOS input otherwise.

APPENDIX H

SPDT Relay Data Sheet



SRUDH series

12 Amp Miniature Power PC Board Relay

Appliances, HVAC, Office Machines

UL File No. E82292
CSA File No. LR48471
TUV File No. R60271

Users should thoroughly review the technical data before selecting a product part number. It is recommended that user also seek out the pertinent approvals files of the agencies/laboratories and review them to ensure the product meets the requirements for a given application.

Features

- Small package, 12 Amp switching capcity.
- 1 Form A and 1 Form C contact arrangements.
- Immersion cleanable, sealed version available.
- Applications include appliance, HVAC, security system, garage opener control, emergency lighting.

Contact Data @ 20°C

Arrangements: 1 Form A (SPST-NO) and 1 Form C (SPDT).
Material: Ag Alloy.
Max. Switching Rate: 300 ops./min. (no load).
30 ops./min. (rated load).
Expected Mechanical Life: 10 million operations (no load).
Expected Electrical Life: 100,000 operations (rated load).
Minimum Load: 100mA @ 5VDC.
Initial Contact Resistance: 100 milliohms @ 1A, 6VDC.

Contact Ratings

Ratings: 12A @ 120VAC resistive,
10A @ 240VAC resistive,
10A @ 28VDC resistive.

4A @ 120VAC inductive (cosø= 0.4),
4A @ 28VDC inductive (L/R=7msec)

Max. Switched Voltage: AC: 240V.
DC: 28V.
Max. Switched Current: 12A.
Max. Switched Power: 2,400VA, 300W.

Initial Dielectric Strength

Between Open Contacts: 750VAC 50/60 Hz. (1 minute).
Between Coil and Contacts: 1,500VAC 50/60 Hz. (1 minute).
Surge Voltage Between Coil and Contacts: 3,000V (1.2 / 50µs).

Initial Insulation Resistance

Between Mutually Insulated Elements: 1,000M ohms min. @ 500VDCM.

Coil Data

Voltage: 6 to 48VDC.
Nominal Power: 360 mW except 48VDC coil (510mW)
Coil Temperature Rise: 35°C max., at rated coil voltage.
Max. Coil Power: 130% of nominal.
Duty Cycle: Continuous.

Coil Data @ 20°C

SRUDH				
Rated Coil Voltage (VDC)	Nominal Current (mA)	Coil Resistance (ohms) ± 10%	Must Operate Voltage (VDC)	Must Release Voltage (VDC)
6	60	100	4.50	0.60
9	40	225	6.75	0.90
12	30	400	9.00	1.20
24	15	1,600	18.00	2.40
48	10	4,500	36.00	4.80

Operate Data

Must Operate Voltage: 75% of nominal voltage or less.
Must Release Voltage: 10% of nominal voltage or more.
Operate Time: 15 ms max.
Release Time: 5 ms max.

Environmental Data

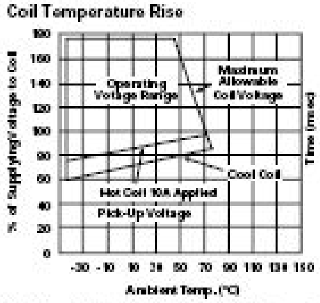
Temperature Range:
Operating: -30°C to +60°C
Vibration, Mechanical: 10 to 55 Hz., 1.5mm double amplitude
Operational: 10 to 55 Hz., 1.5mm double amplitude.
Shock, Mechanical: 1,000m/s² (100G approximately).
Operational: 100m/s² (10G approximately).
Operating Humidity: 20 to 85% RH. (Non-condensing).

Mechanical Data

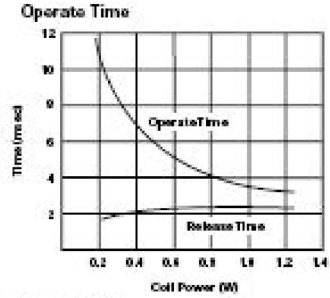
Termination: Printed circuit terminals.
Enclosure (94V-0 Flammability Ratings):
SRUDH-SS: Vented (Flux-tight) plastic cover
SRUDH-SH: Sealed plastic case
Weight: 0.42 oz (12g) approximately.

Reference Data

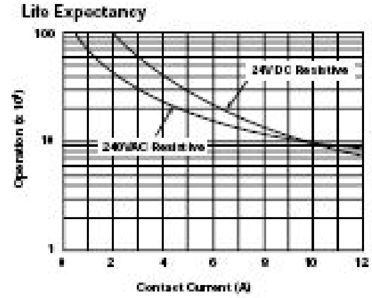
Coil Temperature Rise



Operate Time



Life Expectancy



Note: Rise data is based on the max. allowable temp. for E type insulation coil (115°C).

 Dimensions are shown for reference purposes only. Dimensions are in inches over (millimeters) unless otherwise specified. Specifications and availability subject to change. www.tycoelectronics.com Technical support: Refer to inside back cover.

Ordering Information

Typical Part Number ► SRUDH -SS -1 12 D M 1 ,000

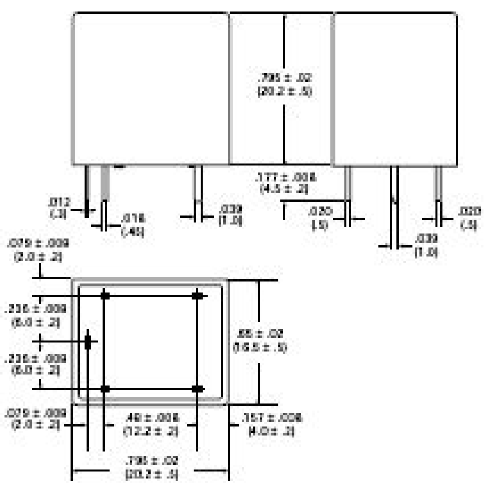
1. **Basic Series:**
   SRUDH = Miniature Power PC board relay.
2. **Enclosure:**
   SS = Vent (Flux-tight)* plastic cover.
   SH = Sealed, plastic case.
3. **Termination:**
   1 = 1 pole
4. **Coil Voltage:**
   06 = 6VDC 12 = 12VDC 48 = 48VDC
   09 = 9VDC 24 = 24VDC
5. **Coil Input:**
   D = Standard
6. **Contact Arrangement:**
   Blank = 1 Form C, SPDT M = 1 Form A, SPST-NO
7. **Contact Material:**
   1 = AgCdO
8. **Suffix:**
   ,000 = Standard model Other Suffix = Custom model

* Not suitable for immersion cleaning processes.

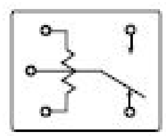
Our authorized distributors are more likely to maintain the following items in stock for immediate delivery.

SRUDH-SH-112D1,000 SRUDH-SH-112DM1,000
SRUDH-SH-124D1,000 SRUDH-SH-124DM1,000

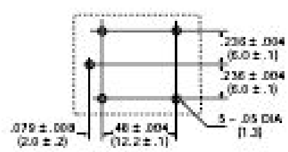
Outline Dimensions



Wiring Diagram (Bottom View)

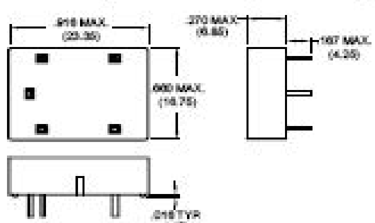


PC Board Layout (Bottom View)



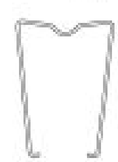
Socket

27E1064 socket is rated 10A @ 300VAC. UL Recognized for US and Canada. Designed to fit same suggested board layout as relay.



Hold-Down Spring

20C430 spring is designed to secure SRUDH relay in 27E1064 socket.



APPENDIX I

Optical Sensor Data Sheet

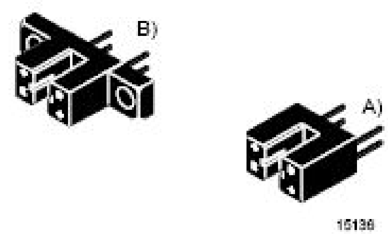
TCST110. up to TCST230.

Vishay Semiconduct

Transmissive Optical Sensor with Phototransistor Output

Description

This device has a compact construction where the emitting-light sources and the detectors are located face-to-face on the same optical axis. The operating wavelength is 950 nm. The detector consists of a phototransistor.

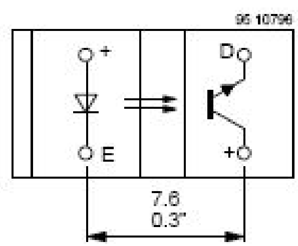


Applications

- Contactless optoelectronic switch, control and counter

Features

- Compact construction
- No setting efforts
- Polycarbonate case protected against ambient light
- 2 case variations
- 3 different apertures
- CTR selected in groups (regarding fourth number of type designation)



Top view

Order Instruction

Ordering Code	Resolution (mm) / Aperture (mm)	Remarks
TCST1103[A)]	0.6 / 1.0	No mounting flags
TCST2103[B)]		With two mounting flags
TCST1202[A)]	0.4 / 0.5	No mounting flags
TCST2202[B)]		With two mounting flags
TCST1300[A)]	0.2 / 0.25	No mounting flags
TCST2300[B)]		With two mounting flags

TCST110. up to TCST230.

Vishay Semiconductors

Absolute Maximum Ratings

Input (Emitter)

Parameter	Test Conditions	Symbol	Value	Unit
Reverse voltage		V_R	6	V
Forward current		I_F	60	mA
Forward surge current	$t_p \leq 10$ μs	I_{FSM}	3	A
Power dissipation	$T_{amb} \leq 25^\circ C$	P_V	100	mW
Junction temperature		T_j	100	°C

Output (Detector)

Parameter	Test Conditions	Symbol	Value	Unit
Collector emitter voltage		V_{CEO}	70	V
Emitter collector voltage		V_{ECO}	7	V
Collector current		I_C	100	mA
Collector peak current	$t_p/T = 0.5$, $t_p \leq 10$ ms	I_{CM}	200	mA
Power dissipation	$T_{amb} \leq 25^\circ C$	P_V	150	mW
Junction temperature		T_j	100	°C

Coupler

Parameter	Test Conditions	Symbol	Value	Unit
Total power dissipation	$T_{amb} \leq 25^\circ C$	P_{tot}	250	mW
Operating temperature range		T_{amb}	–55 to +85	°C
Storage temperature range		T_{stg}	–55 to +100	°C
Soldering temperature	2 mm from case, $t \leq 5$ s	T_{sd}	260	°C

Electrical Characteristics (T_{amb} = 25°C)

Input (Emitter)

Parameter	Test Conditions	Symbol	Min.	Typ.	Max.	Unit
Forward voltage	I_F = 60 mA	V_F		1.25	1.6	V
Junction capacitance	V_R = 0, f = 1 MHz	C_j		50		pF

Output (Detector)

Parameter	Test Conditions	Symbol	Min.	Typ.	Max.	Unit
Collector emitter voltage	I_C = 1 mA	V_{CEO}	70			V
Emitter collector voltage	I_E = 10 μA	V_{ECO}	7			V
Collector dark current	V_{CE} = 25 V, I_F = 0, E = 0	I_{CEO}			100	nA

Coupler

Parameter	Test Conditions	Type	Symbol	Min.	Typ.	Max.	Unit
Current transfer ratio	V_{CE} = 5 V, I_F = 20 mA	TCST1103, TCST2103	CTR	10	20		%
		TCST1202, TCST2202	CTR	5	10		%
		TCST1300, TCST2300	CTR	1.25	2.5		%
Collector current	V_{CE} = 5 V, I_F = 20 mA	TCST1103, TCST2103	I_C	2	4		mA
		TCST1202, TCST2202	I_C	1	2		mA
		TCST1300, TCST2300	I_C	0.25	0.5		mA
Collector emitter saturation voltage	I_F = 20 mA, I_C = 1 mA	TCST1103, TCST2103	V_{CEsat}			0.4	V
	I_F = 20 mA, I_C = 0.5 mA	TCST1202, TCST2202	V_{CEsat}			0.4	V
	I_F = 20 mA, I_C = 0.1 mA	TCST1300, TCST2300	V_{CEsat}			0.4	V
Resolution, path of the shutter crossing the radiant sensitive zone	I_{Crel} = 10 to 90%	TCST1103, TCST2103	s		0.6		mm
		TCST1202, TCST2202	s		0.4		mm
		TCST1300, TCST2300	s		0.2		mm

Switching Characteristics

Parameter	Test Conditions	Symbol	Typ.	Unit
Turn-on time	V_S = 5 V, I_C = 2 mA, R_L = 100 Ω (see figure 1)	t_{on}	10.0	μs
Turn-off time		t_{off}	8.0	μs

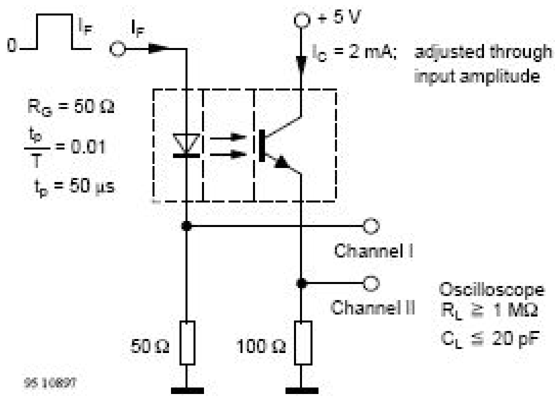
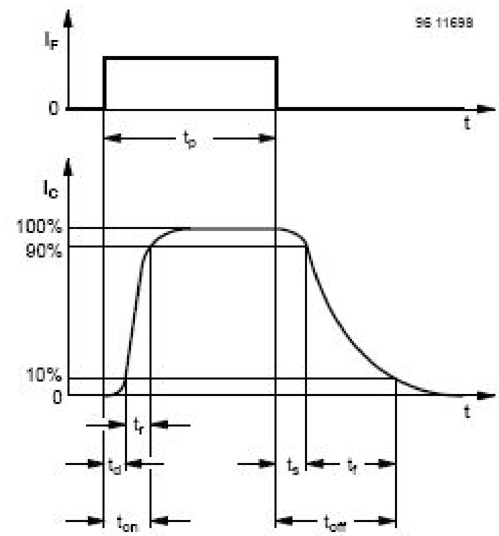


Figure 1. Test circuit, saturated operation



t_p	pulse duration	t_s	storage time
t_d	delay time	t_f	fall time
t_r	rise time	t_{off} (= t_s + t_f)	turn-off time
t_{on} (= t_d + t_r)	turn-on time		

Figure 2. Switching times

APPENDIX J

User Manual

Instructions for the Administrators

1. Open the rear door of the Bill-to-Coin Changer by unlocking it with the key included.
2. Refill each coin tube (blue pipes) for 25-cents, 1-peso, 5-peso, and 10-peso coins with 300 pieces of each coin type.
3. Close the rear door and lock it.
4. Plug-in the Bill-to-Coin Changer to a 220V socket.
5. Turn-on the switch in the left-bottom part in the rear.
6. When the *welcome* screen appears, ensure that the calibration value is equal to 15 or 16 by pressing "7".

Instructions for the Customers

1. Press "*" to view the number of coins in the coin bank to check if your desired denomination is still obtainable.
2. Insert the bill (P20.00, P50.00, or P100.00) in the feeder mouth properly.
3. Press "#" to start the transaction process.
4. When the bill is fed and the amount of bill is displayed in the screen, press "#" again.
5. Select the desired denomination by pressing "1" for 25-cents, "2" for 1-peso, "3" for 5-peso, or "4" for 10-peso coins.
6. Enter the number of pieces for the selected denomination then press "#" to accept.

7. Other denominations can still be selected by following step 4. Note that the value of your desired denominations must be equal to the value of the bill.
8. Press “#” to change the bill.
9. Wait for the *Transaction Successful* message.
10. Open the coin cargo door to get the dispensed coins.
11. Close the coin cargo door after getting the coins.