A MECHANISM TO REDUCE WASTE DUE TO VOLTAGE DIPS IN NARROW FABRIC LOOMS

A dissertation submitted to the
Department of Electrical Engineering, University of Moratuwa
in partial fulfillment of the requirements for the
Degree of Master of Science

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Abstract

Like any other industry, apparel industry too tries to minimize their product cost by reducing production waste. Voltage fluctuations and power failures are two of the most concerning factors affecting the production. Even though these voltage fluctuations & voltage failures affect different kinds of looms at different degrees, its effect on the weaving looms which manufacture elastics is severe. As a narrow fabric elastic manufacturer it has been faced difficulties in minimizing the number of joints in the fabric (tape), which is a direct consequence of the same.

There are no research papers or commercial devices found to minimize the fabric joints in case of voltage dips or short period voltage interruptions. The significance of the proposed system is its ability to sense the voltage dips/sags or interruption with the fast AC to DC converter and take decisions intelligently to suit the situation prevailed, e.g. whether to let the machine run or stop depending on the time elapsed.

The brain of the controller 0" isa '--peripheral interface controller (PIC) and is programmed as assembly language. MPLAB Software compiles assembly to hex codes and the required sequence of signals is generated from PIC. This signal is sent to control unit of the loom via the DPDT relay to hold down the control. switches to perform the controller operations of the looms within a 3 second period during the short-time voltage variations such as interruptions and dips.

Numerous other applications are possible with this system in other industries too. One is in the rubber extruder and another is mixing mill in manufacturing rubber tires.

DECLARATION

The work submitted in this dissertation is the result of my own investigation, except where otherwise stated.

It has not already been accepted for any degree, and is also not being concurrently submitted for any other degree.

UOM Verified Signature

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Date 21.01.2011

I endorse the declaration by the candidate.

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CONTENTS

List of tables

List of figures

Chapter 1

Introduction

1.1 Background

Apparel industry requires to provide efficient and on time service to the customers with no compromise on the quality of goods being delivered. One major determinant of the quality of the narrow fabric elastics is the number of joints of one tape per unit length which is predetermined.

The textile industry is an amalgam of related industries which uses variety of natural & synthetic materials. Among the machines which are used in apparel industry the machine type that it has been chosen to carry out my project is a narrow fabric weaving loom. However this can be implemented to other machinery in different industries with small changes.

Current loom capacity in the factory is 120 (100nos of single deck and 20 nos of double deck). Each single deck loom can be produced 10 tapes and 20 by double deck looms which leads to an average daily production of 0.4 million meters.

Narrow fabric manufacturers face difficulties in reducing the number of joints in the continuous fabric tapes. Since there is a particular number of joints that the narrow fabric can have which is of course pre-specified by the customer. any instance which exceeds the same will lead to heighten the factory production waste since it will not be accepted by the customer. The study helped in identifying following reasons as the causes of waste generation.

1. Voltage variation
2. power interruption
3. Machine break downs
4. Quality problems
5. Yarn breakages
6. Generator change over & vice versa
7. Process problems and many more

1.2 Motivation

The company categorizes its total waste initially as controllable & uncontrollable waste. One major contributing factor for uncontrollable wastes is the voltage variations which last less than 3 seconds.

As an Engineer with a background of electrical installation the author selected this project to study the production waste generation activities and the mechanism that could be implemented to minimize it. This thesis proposes a new automated approach to detect the voltage variation and react accordingly. The brain of the controller is a peripheral interface controller (PIC).By using PIC the design was done with low cost comparatively. This device can be named as Short Period Voltage Dip Actuator (SPVDA) which helps automating the machines, leading to the following advantages.

1. No joints will be generated due to short period voltage variations(time less than 3 sec)
2. No waste generation due to consequence voltage variations
3. No re-processing time & hence man hours can be saved.
4. Reduce customer complaints
5. No waste generation during the power changeover and vice versa and many more.

- If the above voltage variation occurs successively within short periods causing to have two joints within 10 meters it has to be disposed as waste. Implementation of the new actuator helps to eliminate this problem.
- In the case of short period voltage variations such as voltage dips and momentary interruptions elastic tape damages can be seen and machine operators have to reconnect it after removing unwanted portions. Helps immensely in saving time, which results in higher productivity.

Block Diagram of the expected design of the controller

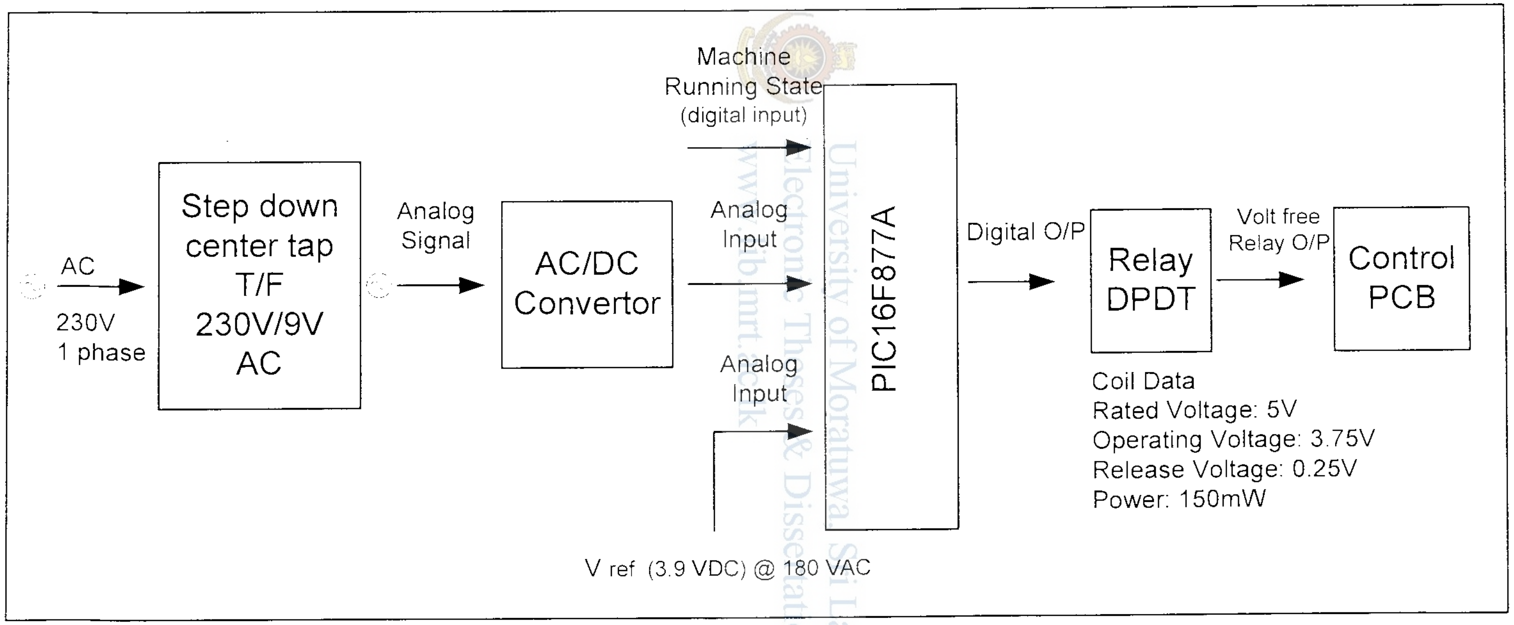


Figure 1- Sequence of Design

1.3 Goals

To achieve the final target the project work was broken further down to a set of goals, they are as follows.

1.3.1 Hardware Design

1.3.1.2 Selection of Relay (PCB driver)

Correct selection of the relay is very important because it drives the control PCB of the loom. Therefore several features need to be considered when choosing a relay such as switching rating, coil resistance, coil voltage, physical size & dielectric strength. As the relay was used for low voltage applications dielectric strength was not important. So that SPDT 5V DC/1A micro relay was selected. Features of the relay were.

- Coil rating = 5VDC ,90mA
- Coil resistance - 55 ohm
- Coil size - 1-1/32"x3/8"x1/4"

1.3.1.2 Selection of transistor (Relay Driver)

Selection of transistor was very critical because the relay was driven by transistor which was initially controlled by the PIC. Out of many transistors available in the market correct one needs to be selected. General purpose C1815, NPN transistor was chosen [4] base on the calculations done [10].

1.3.1.3 Selection of optocoupler

Optocoupler was used to isolate the signals for protection and safety between a safe and a potential hazardous or electrically noisy environment. The interfacing of the optocoupler between digital or analog signal needs to be designed properly for proper protection and operation.

1.3.1.4 Selection of Peripheral Interface (PIC)

This is the controller of the design. There are varieties of PICs in the market. So that the required controller with right features needs to be selected (PIC16F877A).

1.3.1 Software Development

Instructions to the PIC should be given in hex. If the instructions are given in assembly language, it needs to be converted to hex by MPLAB software, also there is a facility to program using C with C compiler.

1.3.2 Implementation

- Control circuit was designed and installed on board
- Power supply of 5V & 9V to the PIC and AC/DC converter separately.
- Programmed the PIC using MPLAS Software & Programmer.
- Checked the functionality of the PIC by a simulation in MPLAB and then incorporated PIC to the control circuit and checked functionality of all possible inputs.

1.4 Achievements in brief

Completion of literature survey, integrated the designing of Short Period Power Dip actuator. Series of theoretical calculations were done to calculate and find the required components such as on-line resistor, pull down resistor to protect the optocoupler, input voltage stability and base limiting resistor of the driver transistor(C1815) of the relay circuit.

Fast Precision AC/DC converter which was built by cascading two LM101A operational amplifiers. It was selected among the other converters which can be done the same job, because it was a full wave rectifier and the response time was less than 54ms. The converter was converted AC voltage to DC analog voltage and it was sent it to PIC AN0 pin as an analogue input signal.

Machine operating state signal was supplied to the RC5 pin of the PIC through the optocoupler CYN-17-1. It was used to isolate power side from the control side. Selected PIC 16F877A offers lot of features like, interrupt handling capacity, A/D module, timers apart from that digital inputs & outputs. Components were ordered after designing. It took time to find the PIC because the one it was initially planned was very rare in the local market to purchase (PIC16F870). Then PIC16F877 which was available in the market was purchased. PIC program was written in assembly language. It took time because it was needed to learn more about assembly language to develop the program [1]. Writing the program was time consuming too. Finally the program was developed and programmed in MPLAB, this was tested using MPLABSIM (MPLAB Simulator).

The PIC was debugged and programmed again. This was done many times until the correct program was obtained. Since PIC16F877A was flashed version, it could be programmed about 100,000 times without doing any damage to the PIC.

Chapter 2

Problem statement

2.1 Identification of machine states

Study about the machine operation and identifying problems was very useful to develop a system to minimize the effect due to the problem or problems. The weaving loom includes mainly three types of switches and two kinds of motors to run the loom. These are named as Tip switch, Stop switch, Start switch, Tip motor and main motor. Combinations of the operation of the switches and motors can be categorized in the table 2.1.

State	Raw power	Tip switch	Start switch	Stop switch	Tip motor	Main motor	Machine status
1	0	0	0	0	0	0	Stop
2	1	0	0	0	0	0	Stop
3	1	1	0	0	1	0	Tipping
4	1	0	1	0	0	0	Stop
5	1	1	1	0	0	1	Running
6	1	0	0	1	0	0	Stop
7	1	1	1	0	0	1	Running
8	0	0	0	0	0	0	Stop
9	1	0	0	0	0	0	Still Stop

Table 2.1-Combinations of machine states

State 4&6 can be explained that even though voltage is available machine is not able to run with Start switch itself. Tip switch is used to operate the machine at a moderate speed in order to setup or careful positioning of the moving parts in the machine. When Start switch is pressed with the Tip switch simultaneously & the machine can be run at its maximum set speed. The Stop switch is used to stop the machine and state 8 is very similar to the situation where power interruptions can be happened during the machine running. By seeing states 8 and 9 this situation can be identified as similar as to short period interruption or voltage dip situation and shutdown the machine. In the instance if the mechanism is developed to keep holding the two switches Stop and Tip simultaneously during the voltage variation or short period interruption (time t<3second) operation of the machine can be continued without having any production losses.

2.2 Behavior of the machine controller to the voltages

For the weaving machines electrical power for the controller starts from external transformer which is fitted into the machine. External transformer is capable of generating three levels of voltages. Those are 48, 27 & 18VAC and is fed into the weaving machine control PCB. The main motor contactor was energized by 48VAC through the internal relay system of the machine to control PCB and rest of the voltages (18VAC & 27VAC) were accommodated for the functions of balance activities of the control panel such as break, stop motions & other control circuits etc). The machines were operating with the CEB power and anytime voltage variations & interruptions can be happened. This will cause to stop the machine operations and consequently generate waste. So that investigations were done to find the behaviors of the machine controller and related motor contactor during the voltage variations. Trials were done with variac and experimental results were tabulated as following tables. 2.2 and 2.3.

AC I/P	% of Volt	48V AC	27V AC	17V AC	COMMENTS ON CONTROL PCB
230V	100	47.1	26.5	17.5	Control functions of the machine PCB is ok
225V	98	45.9	25.9	17.15	Do
220V	96	44.9	25.35	16.8	Do
215V	93	43.8	24.7	16.3	Do
210V	91	42.7	24.12	16	Do
205V	89	41.7	23.58	15.6	Do
200V	87	40.6	22.96	15.2	Do
195V	85	39.8	22.5	14.9	Card functions are satisfactory up to this point
190V	83	38.99	21.84	14.45	Internal relays start to vibrate but card stays on condition
185V	78.4	38.06	21.25	14.1	More noise but card functions are stable
180V	78	36.94	20.66	13.72	Noise disappeared and the Power failure indicator LED (red) is ON and the card functions are stopped

Table 2.2 - Behavior of Machine Controller to different Voltage Levels

Behaviors of the component for the different voltage levels

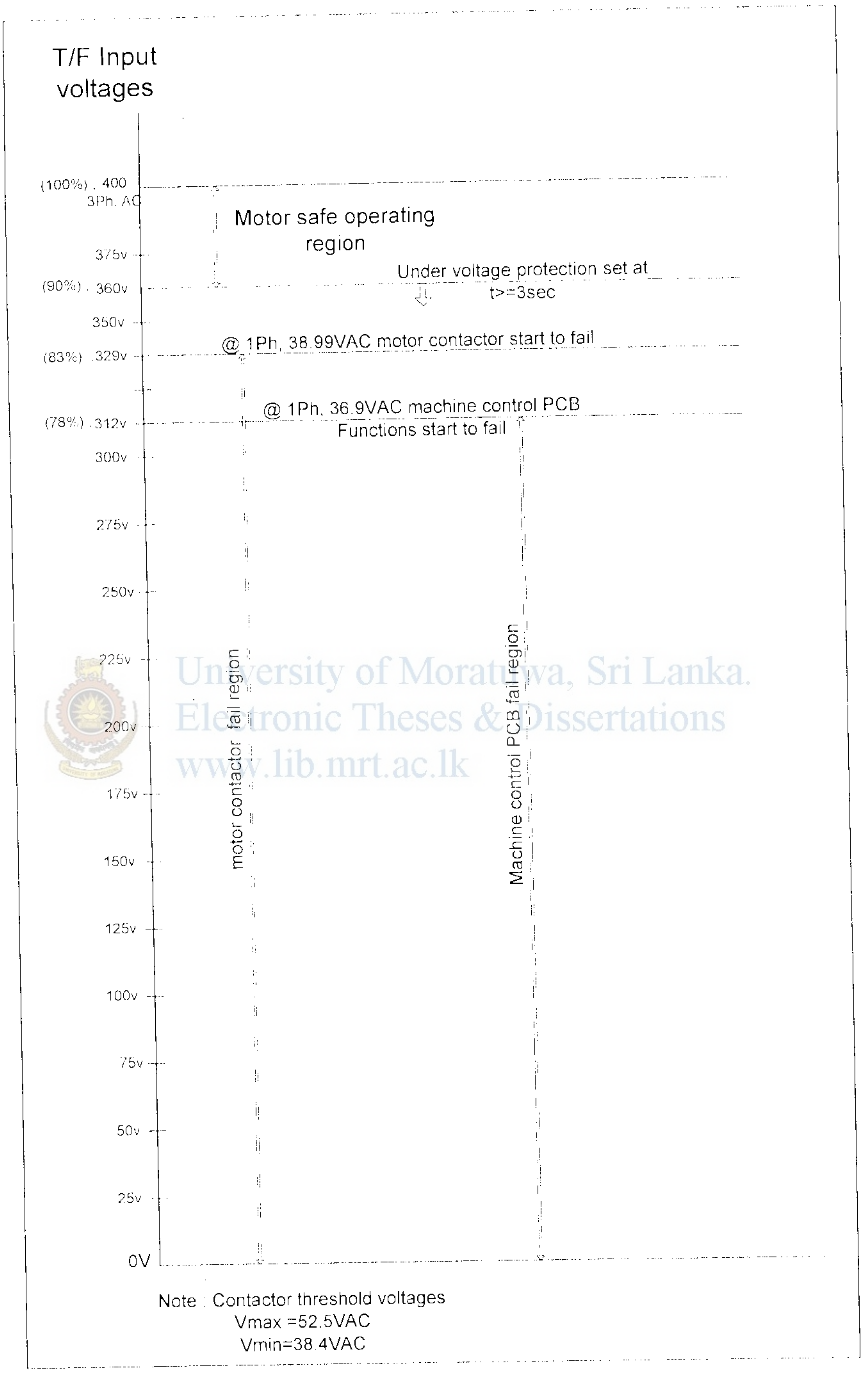


Table 2.3 – Behavior of other component to different Voltage Levels

As per the above results operation of the main motor contactor fails at 83% of single phase voltage, because of that voltage is less than the minimum threshold voltage (Appendix-E) of the coil (38.4VAC).The machine controller PCB functions were disabled when the voltage reaches at 78% of single phase voltage, because of low control voltage of the PCB and de-energized the internal relays of the PCB. As a result of that main motor contactor would be de-energized and shut down the machine operation. The basic operation of the machine controller is explained by figure 2.1.

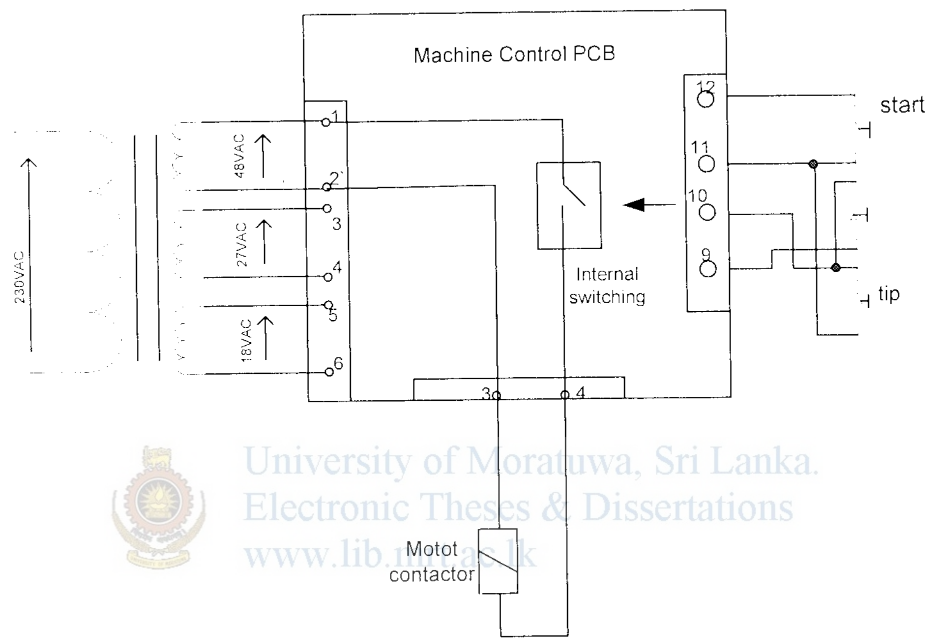


Figure 2.1-Schematic diagram for machine controller

2.3 Identification of the Problem

Due to the voltage variations production waste was generated significantly. Therefore the project was focused on minimization of waste due to voltage variations such as voltage dips. According to the survey was done there was a commercial device developed in UK was called high voltage traction capacitor device [8]. This device can be used to power the electrical devices in the case of voltage drops or in absence of power. But it is still in the development stage and also cost is high. Therefore still there is no any low cost mechanism to overcome this problem. But battery powered UPSs are one of perfect solutions. On average power consumption per loom is 1.5kW and plant capacity is 120 looms. Therefore at lease 180 kW UPS units are required to run the full capacity of the plant. But due to high capital cost it is not viable. Apart from the high capital cost following disadvantages were there.

- Frequent maintenance cost
- Fairly large space required
- Toxic waste
- Heat dissipation

Another one was fly wheel UPSs. This gives lot of advantages compared to the above. But the disadvantage is capital cost which is very much higher than the regular UPS systems.

In this research it was found approximately 50% of the power failures were less than 3 seconds and generated waste was 6% of the total waste. Therefore weaving looms in the Textile industry is very sensitive to the voltage variations and power quality problems and get stopped immediately. As a result of it, stop marks can be seen on the fabric tapes. It is the damage that can not be accepted by the customers.

2.3.1 Stop mark

The defect "stop mark" in the fabric tape was found on a continuous fabric due to the variation in tension building up along the yarn path from the yarn beam to elastic tape in case of machine stop.

The raw material (yarn) is wrapped on the aluminum beam which is about 40-70 kg loaded to the machine creel. The beam can be rotated freely with their center bearings and movement is controlled by the tension balance weights .If there is a sudden power failure or voltage variations happen free motion can be taken placed due to momentum of the beam. Therefore it causes a tension variation along the tapes. As a result of this a stop mark can be created. If there is a possibility to reset the machine within 3 seconds stored energy of the beam is enough to maintain the tension of the tape and creating stop mark can be minimized.

2.3 Objective of the project

The expectation of the projects was to reduce the waste and down time during the voltage variation. Since it finally affects the total revenue that can be generated from the plant.

This will require development of a new control system which should be facilitated to keep the machine start switches hold down during the voltage variations.

The new design involves digital control principles for practical implementation of control algorithms in a microcontroller unit (MCU). The following areas need to be focused.

- How to detect voltage variations which effecting to the machine operation?
- What hardware components to be sourced and what to be produced to make the photo type design?
- Programming the microcontroller according to the control algorithm.
- How to obtain the experimental results?

Chapter 3

Hardware Design of the system

3.1 Microcontroller types for the application (MCU)

Single chip microcontroller device is ideal to control waste due to the voltage variations in many applications. The advantage of a MCU for the application is the MCUs program can be changed, revised by changing a few lines of text in the source code. This source code is then converted in to machine code by software compiler and is programmed into MCU.

The MC is a single chip computer. It operates as stored program machine that is it must be read its program code and data values from its memory in order to operate. Two common methods are used to accomplish this. One is called von Neumann architecture and has been employed in many MCUs. This method uses one data bus and memory space for both program code & data values. Saving cost but slowing down the code execution. The other approach is called Harvard architecture, separates the program code & data values into two memory structures allowing parallel loading of both at the same time. In this case data execution is essential therefore Harvard architecture can be selected during the selection of MCs.

3.2 Some related features of peripheral interface controller (PIC)

A microcontroller [2] differs from a microprocessor in many ways. First and most important is its functionality. In order to a microprocessor to be used, other components such as memory, or components for receiving and sending data must be added to it. On the other hand microcontroller is designed to be all of that in one. No other external components are needed for its applications other than an oscillator because all necessary peripherals are already build into it. Thus, it can be saved the time and space needed to construct devices.

3.3 Selection of Microcontroller unit (PIC)

Different types of Peripheral Interface Units (PICs) are available in the market. In this thesis PIC16F series was considered. Features that considered for the application are given in the following table 3.1.

Device	Program memory Single word instructions	Data memory SRAM (bytes)	I/O Pins	Operating speed (MHz)	10 Bit A/D Modules	Timers 8/16 Bits	I/O Ports
PIC16F84A	1024	68X8	13	20	-	1	2
PIC16F85	1024	128x8	15	20	4ch;8bit	1	2
PIC16F870	2048	128x8	22	20	5ch;8	3	3
PIC16F871	2048	128x8	33	20	8ch;8	3	4(A,B,C,D)
PIC16F86	2048	128X8	15	20	4ch;8bit	1	2
PIC16F873A	4096	192	22	20	5ch;8bit	2/1	3
PIC16F874A	4096	192	33	20	8ch:8bit	2/1	5
PIC16F876A	8192	368	22	20	5ch:8bit	2/1	3
PIC16F877A	8192	368	33	20	8ch:8bit	2/1	5

Table 3.1- PIC16F Device Features

According to the above comparison in PIC16F87XA series PIC16F877A has 8k instructions of program memory, 368 bytes of SRAM data memory, 33 I/0s, 5 Ports, 10 bit A/D modules, two 8 bit timers and many more. But it was required inputs & outputs for software development such as,

- Three Ports A,B and C
- Two Analog modules
- Two digital outputs
- One digital input

Therefore except PIC16F84A all the other Peripheral Interface Units can be used for the software development of this project. But on top of that priority must be given to the product which is available in the market due to the time constrain. PIC16F877A is one of the largest program memory capacity chip available in the local market. Therefore PIC16F877A [2,5] was selected as the controller of the proposed system.

Pin Diagram

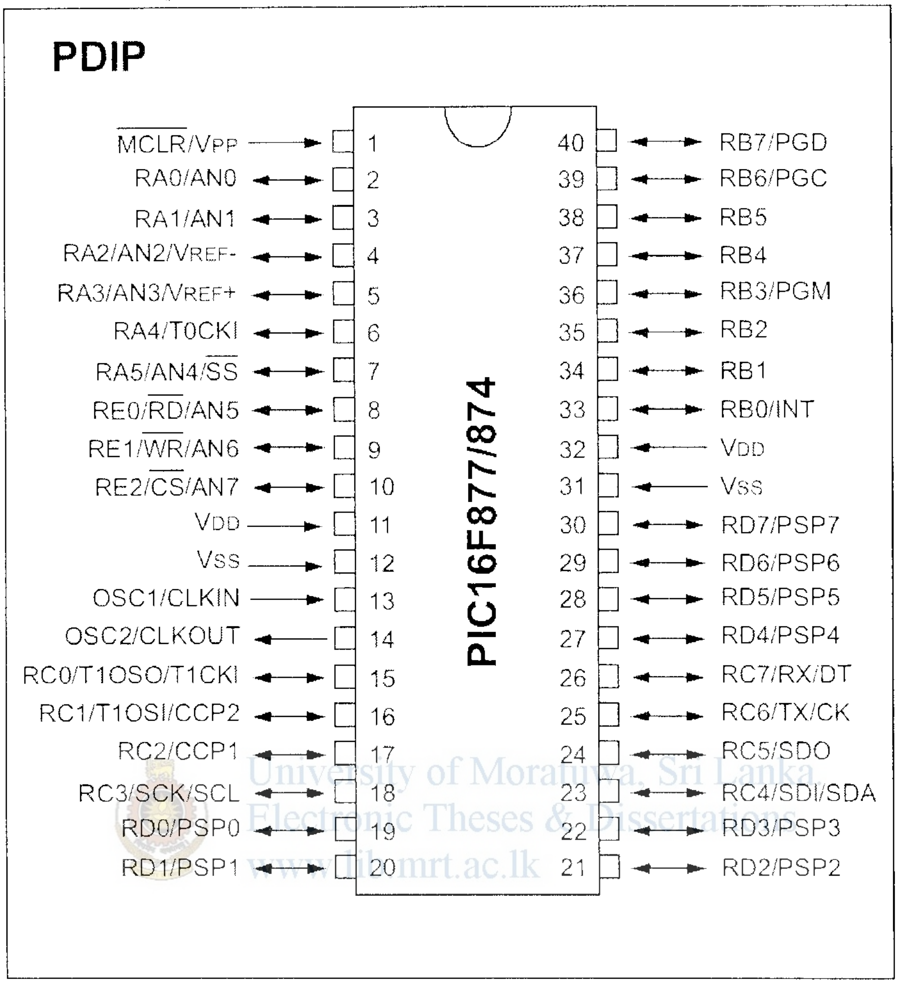


Figure 3.1 - PIC16F877 Pin Diagram

3.3.1 THE PIC16F887A BASIC FEATURES

- **Architecture**
  - Only 35 instructions to learn
  - All single-cycle instructions except branches
- **Operating frequency 0-20 MHz**
- **Precision internal oscillator**
  - Factory calibrated
  - Software selectable frequency range of 8MHz to 31KHz

- **Power supply voltage 2.0-5.5V**
  - Consumption: 220uA (2.0V, 4MHz), 11uA (2.0 V, 32 KHz) 50nA (stand-by mode)
- **Power-Saving Sleep Mode**
- **Brown-out Reset (BOR) with software control option**
- **33 input/output pins**
  - High current source/sink for direct LED drive
  - Software and individually programmable *pull-up* resistor
  - Interrupt-on-Change pin
- **8K ROM memory in FLASH technology**
  - Chip can be reprogrammed up to 100.000 times
- ***In-Circuit Serial Programming* Option**
  - Chip can be programmed even embedded in the target device
- **256 bytes EEPROM memory**
  - Data can be written more than 1.000.000 times
- **368 bytes RAM memory**
- **A/D converter:**
  - 08-channels
  - 10-bit resolution
- **3 independent timers/counters**
- **Watch-dog timer**
- **Analogue comparator module with**
  - Two analogue comparators
  - Fixed voltage reference (0.6V)
  - Programmable on-chip voltage reference
- **PWM output steering control**
- **Enhanced USART module**
  - Supports RS-485, RS-232 and LIN2.0
  - Auto-Baud Detect
- **Master Synchro nous Serial Port (MSSP)**
  - Supports SPI and I2C mode

3.3.2 PIN Assignment of PIC16F877A

Pin Name	DIP Pin#	PLCC Pin#	QFP Pin#	I/O/P Type	Buffer Type	Description
OSC1/CLKI	13	14	30	I	ST/CMOS(4)	Oscillator crystal or external clock input.
OSC1						Oscillator crystal input or external clock source input. ST buffer when configured in RC mode. Otherwise CMOS.
CLKI						External clock source input. Always associated with pin function OSC1 (see OSC1/CLKI, OSC2/CLKO pins).
OSC2/CLKOUT	14	15	31	O	—	Oscillator crystal or clock output.
OSC2						Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode.
CLKO						In RC mode, OSC2 pin outputs CLKO, which has 1/4 the frequency of OSC1 and denotes the instruction cycle rate.
$\overline{MCLR}$/VPP	1	2	18	I/P	ST	Master Clear (input) or programming voltage (output).
$\overline{MCLR}$						Master Clear (Reset) input. This pin is an active low RESET to the device.
VPP						Programming voltage input.
						PORTA is a bi-directional I/O port.
RA0/AN0	2	3	19		TTL	
RA0				I/O		Digital I/O.
AN0				I		Analog input 0.
RA1/AN1	3	4	20		TTL	
RA1				I/O		Digital I/O.
AN1				I		Analog input 1.
RA2/AN2/VREF-/CVREF	4	5	21		TTL	
RA2				I/O		Digital I/O.
AN2				I		Analog input 2.
VREF-				I		A/D reference voltage (Low) input.
CVREF				O		Comparator VREF output.
RA3/AN3/VREF+	5	6	22		TTL	
RA3				I/O		Digital I/O.
AN3				I		Analog input 3.
VREF+				I		A/D reference voltage (High) input.
RA4/T0CKI/C1OUT	6	7	23		ST	
RA4				I/O		Digital I/O – Open drain when configured as output.
T0CKI				I		Timer0 external clock input.
C1OUT				O		Comparator 1 output.
RA5/$\overline{SS}$/AN4/C2OUT	7	8	24		TTL	
RA5				I/O		Digital I/O.
$\overline{SS}$				I		SPI slave select input.
AN4				I		Analog input 4.
C2OUT				O		Comparator 2 output.

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 3.2 - Pin Assignment PIC877A

PIC877A Pin out Description(Continued)

Pin Name	DIP Pin#	PLCC Pin#	QFP Pin#	I/O/P Type	Buffer Type	Description
						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		TTL/ST(1)	
RB0				I/O		Digital I/O.
INT				I		External interrupt.
RB1	34	37	9	I/O	TTL	Digital I/O.
RB2	35	38	10	I/O	TTL	Digital I/O.
RB3/PGM	36	39	11		TTL	
RB3				I/O		Digital I/O.
PGM				I/O		Low voltage ICSP programming enable pin.
RB4	37	41	14	I/O	TTL	Digital I/O.
RB5	38	42	15	I/O	TTL	Digital I/O.
RB6/PGC	39	43	16		TTL/ST(2)	
RB6				I/O		Digital I/O.
PGC				I/O		In-Circuit Debugger and ICSP programming clock.
RB7/PGD	40	44	17		TTL/ST(2)	
RB7				I/O		Digital I/O.
PGD				I/O		In-Circuit Debugger and ICSP programming data.
						PORTC is a bi-directional I/O port.
RC0/T1OSO/T1CKI	15	16	32		ST	
RC0				I/O		Digital I/O.
T1OSO				O		Timer1 oscillator output.
T1CKI				I		Timer1 external clock input.
RC1/T1OSI/CCP2	16	18	35		ST	
RC1				I/O		Digital I/O.
T1OSI				I		Timer1 oscillator input.
CCP2				I/O		Capture2 input, Compare2 output, PWM2 output.
RC2/CCP1	17	19	36		ST	
RC2				I/O		Digital I/O.
CCP1				I/O		Capture1 input/Compare1 output/PWM1 output.
RC3/SCK/SCL	18	20	37		ST	
RC3				I/O		Digital I/O.
SCK				I/O		Synchronous serial clock input/output for SPI mode.
SCL				I/O		Synchronous serial clock input/output for I^2C mode.
RC4/SDI/SDA	23	25	42		ST	
RC4				I/O		Digital I/O.
SDI				I		SPI data in.
SDA				I/O		I^2C data I/O.
RC5/SDO	24	26	43		ST	
RC5				I/O		Digital I/O.
SDO				O		SPI data out.
RC6/TX/CK	25	27	44		ST	
RC6				I/O		Digital I/O.
TX				O		USART asynchronous transmit.
CK				I/O		USART 1 synchronous clock.
RC7/RX/DT	26	29	1		ST	
RC7				I/O		Digital I/O.
RX				I		USART asynchronous receive.
DT				I/O		USART synchronous 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 3.3 - Pin Assignment PIC877A

PIC877A Pin out Description (Continued)

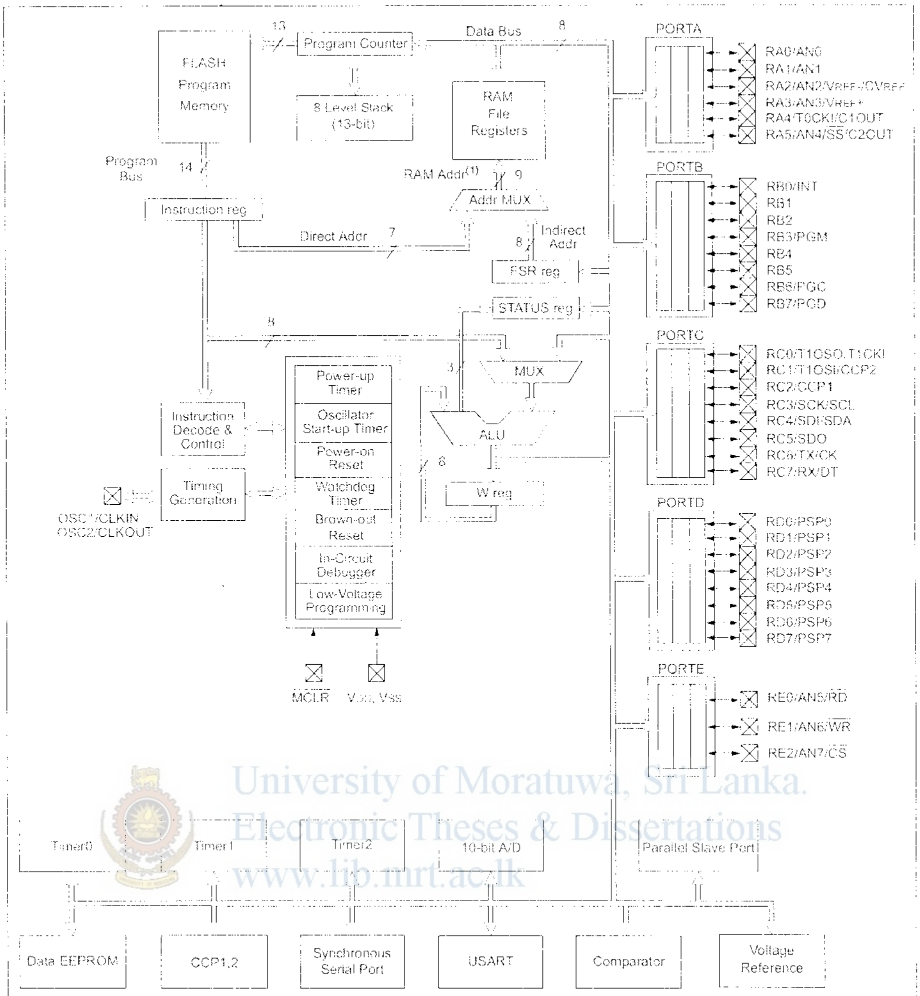
Pin Name	DIP Pin#	PLCC Pin#	QFP Pin#	I/O/P Type	Buffer Type	Description
						PORTD is a bi-directional I/O port or parallel slave port when interfacing to a microprocessor bus.
RD0/PSP0	19	21	38		ST/TTL(3)	
RD0				I/O		Digital I/O.
PSP0				I/O		Parallel Slave Port data.
RD1/PSP1	20	22	39		ST/TTL(3)	
RD1				I/O		Digital I/O.
PSP1				I/O		Parallel Slave Port data.
RD2/PSP2	21	23	40		ST/TTL(3)	
RD2				I/O		Digital I/O.
PSP2				I/O		Parallel Slave Port data.
RD3/PSP3	22	24	41		ST/TTL(3)	
RD3				I/O		Digital I/O.
PSP3				I/O		Parallel Slave Port data.
RD4/PSP4	27	30	2		ST/TTL(3)	
RD4				I/O		Digital I/O.
PSP4				I/O		Parallel Slave Port data.
RD5/PSP5	28	31	3		ST/TTL(3)	
RD5				I/O		Digital I/O.
PSP5				I/O		Parallel Slave Port data.
RD6/PSP6	29	32	4		ST/TTL(3)	
RD6				I/O		Digital I/O.
PSP6				I/O		Parallel Slave Port data.
RD7/PSP7	30	33	5		ST/TTL(3)	
RD7				I/O		Digital I/O.
PSP7				I/O		Parallel Slave Port data.
						PORTE is a bi-directional I/O port.
RE0/$\overline{RD}$/AN5	8	9	25		ST/TTL(3)	
RE0				I/O		Digital I/O.
$\overline{RD}$				I		Read control for parallel slave port.
AN5				I		Analog input 5.
RE1/$\overline{WR}$/AN6	9	10	26		ST/TTL(3)	
RE1				I/O		Digital I/O.
$\overline{WR}$				I		Write control for parallel slave port.
AN6				I		Analog input 6.
RE2/$\overline{CS}$/AN7	10	11	27		ST/TTL(3)	
RE2				I/O		Digital I/O.
$\overline{CS}$				I		Chip select control for parallel slave port.
AN7				I		Analog input 7.
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.

Table 3.4 - Pin Assignment PIC877A

3.3.3 Device block diagram



Device	Program FLASH	Data Memory	Data EEPROM
PIC16F874A	4K words	192 Bytes	128 Bytes
PIC16F877A	8K words	368 Bytes	256 Bytes

Note 1: Higher order bits are from the STATUS register.

Fig 3.2 - Internal architecture of PIC microcontroller

Above Figure 3-2 describe the device block diagram of the 16FPIC877A

3.3.4 Program memory organization

There are three memory blocks in each of thePIC16F87XA devices. The program memory and data memory has separate buses so that concurrent access can be occurred. The program memory can be read internally by user code The PIC16F87XA devices have a 13-bit program counter capable of addressing an 8K word x 14 bit program memory space. The PIC16F876A/877A devices have 8K words x 14 bits of Flash program memory, The below fig 3.3 is the memory allocations of the PIC16F877A.

Program memory map and stack

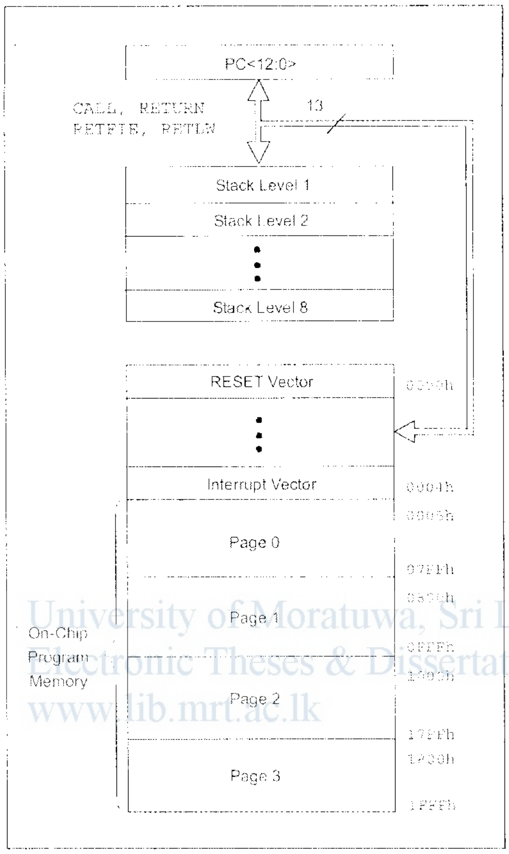


Fig 3.3 - Memory map

3.3.5 Data Memory Organization

The data memory is partitioned into multiple banks which contains the General Purpose Registers and the Special Function Registers. Bits RP1 (Status<6>) and RP0 (Status<5>) are the bank select bits. Each bank extends up to 7Fh (128 bytes). The lower locations of each bank are reserved for the Special Function Registers. Above the Special Function Registers are General Purpose Registers, implemented as static RAM. All implemented banks contain Special Function Registers. Some frequently used Special Function Registers from one bank may be mirrored in another bank for code reduction and quicker access.

RP1:RP0	Bank
00	0
01	1
10	2
11	3

Table 3.5 - Bank selection

3.3.6 Oscillator

Oscillator circuit is used to provide a micro controller with a clock. Clock is needed so that micro controller could be executed a program or program instructions.

3.3.6.1 Types of oscillators

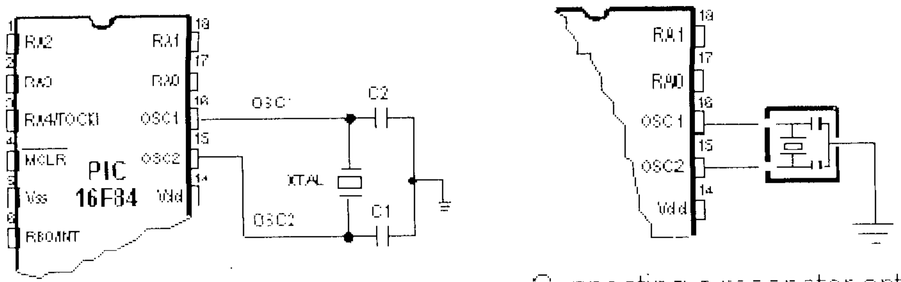
PIC16F877A can be worked with four different configurations of an oscillator. Since configurations with crystal oscillator and resistor-capacitor (RC) are the ones that are used most frequently. Microcontroller type with a crystal oscillator has in its designation XT, and a microcontroller with resistor-capacitor pair has a designation RC. This is important because during the time of purchasing a MC need to mention the type of oscillator. The user can program two configuration bits ((FOSC1 and FOSC0) to select one of these four methods.

- LP Low-Power Crystal
- XT Crystal/Resonator
- HS High-Speed Crystal/Resonator
- RC Resistor/Capacitor

3.3.6.2 XT Oscillator

Crystal oscillator is kept in metal housing with two pins where you have written down the frequency at which crystal oscillates. One ceramic capacitor whose other end is connected to the ground needs to be connected with each pin.

Oscillator and capacitors can be packed in joint case with three pins. Such element is called ceramic resonator and is represented in charts like the one below. Center pins of the element are the ground, while end pins are connected with OSC1 and OSC2 pins on the microcontroller. When designing a device, the rule is to place an oscillator nearer a microcontroller, so as to avoid any interference on lines on which microcontroller is receiving a clock. Following figures shows how to connect both oscillator options using a ceramic resonator is normally less expensive. This project 4MHz crystal oscillator has been used because it is the most accuracy one out of the others.



Connecting the quartz oscillator to give clock to a microcontroller

Connecting a resonator onto a microcontroller

Figure 3.4 - Oscillator connection

3.3.6.3 RC Oscillator

For timing insensitive applications, the "RC" device option offers additional cost savings. The RC oscillator frequency is a function of the supply voltage, the resistor (REXT) and capacitor (CEXT) values, and the operating temperature. In addition to this, the oscillator frequency will vary from unit to unit due to normal process parameter variation. Furthermore, the difference in lead frame capacitance between package types will also affect the oscillation frequency, especially for low CEXT values. The user also needs to take into account variation due to tolerance of external R and C components used. Figure 3.5 shows how the R/C combination is connected to the PIC16F87X.

RC Oscillator mode

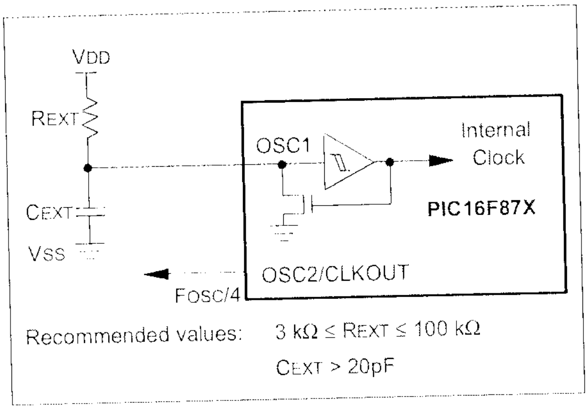


Figure 3.5 - RC Oscillator

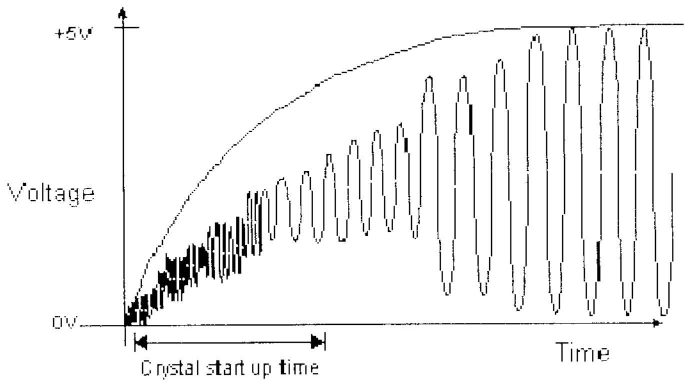
For the design purpose ceramic disc capacitors for the crystal oscillator of the PIC16F877A can be taken from the following table 3.6

Capacitor selection for crystal oscillator

Osc Type	Crystal Freq.	Cap. Range C1	Cap. Range C2
LP	32 kHz	33 pF	33 pF
	200 kHz	15 pF	15 pF
XT	200 kHz	47-68 pF	47-68 pF
	1 MHz	15 pF	15 pF
	4 MHz	15 pF	15 pF
HS	4 MHz	15 pF	15 pF
	8 MHz	15-33 pF	15-33 pF
	20 MHz	15-33 pF	15-33 pF

Table 3.6 - Capacitor selection

Following a supply, oscillator starts oscillating. Oscillation at first has an unstable period and amplitude, but after some period of time it becomes stabilized. The signal of an oscillator clock after receiving the supply of microcontroller is given below



Signal of an oscillator clock after receiving the supply of a microcontroller

Figure 3.6 - Oscillator clock signal

To prevent such inaccurate clock from influencing microcontroller's performance, we need to keep the microcontroller in reset state during stabilization of oscillator's clock. Diagram above shows a typical shape of a signal which microcontroller gets from the quartz oscillator.

3.3.7 High speed 10 bit A/D converter

The Analog-to-Digital (A/D) converter module has eight inputs for the PIC16F877A. The analog inputs charges a sample and hold capacitor. The output of the sampler and hold capacitor is the input into the converter. The converter then generates a digital result of this analog level via successive approximation. The A/D conversion of the analog input signal results in a corresponding 10 bit digital number. The A/D module has high and low voltage reference input that is software selectable to some combination of V_{DD}, V_{SS}, and RA2 or RA3.

A new feature for A/D converter is the addition of programmable acquisition time. This feature allows the user to select a new channel for conversion and to set the GO/DONE bit immediately. When the GO/DONE bit is set the selected channel is sampled for the programmed acquisition time before a conversion is actually started.

3.3.7.1 Ports

Term "port" refers to a group of pins on a microcontroller which can be accessed simultaneously, or on which we can set the desired combination of zeros and ones, or read from them an existing status. Physically, port is a register inside a microcontroller which is connected by wires to the pins of a microcontroller. Ports represent physical connection of Central Processing Unit with an outside world.

Microcontroller uses them in order to monitor or control other components or devices. Due to functionality, some pins have twofold roles. Selection of one of these two pin functions is done in one of the configuration registers.

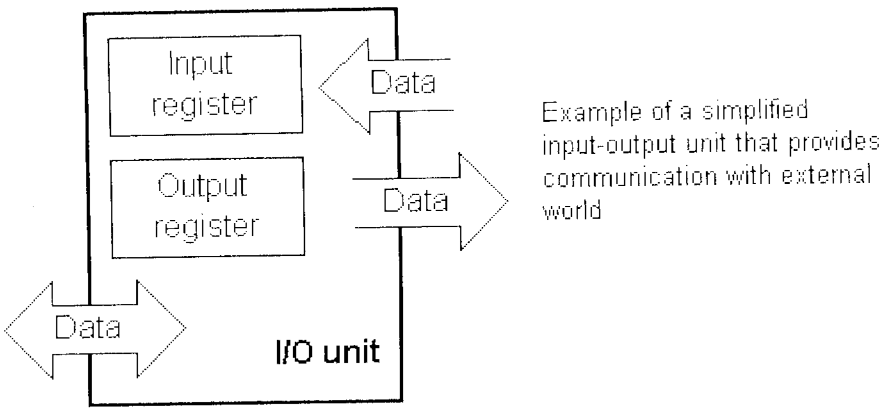


Figure 3.7 – I/O Unit

3.3.7.2 Input Output ports

Those locations It has just been added are called "ports". There are several types of ports input, output or bidirectional ports. When working with ports, first of all it is necessary to choose which port we need to work with, and then to send data to, or take it from the port.

In order to synchronize the operation of I/O ports with the internal 8-bit organization of the microcontroller, they are, similar to registers, grouped into five ports denoted by A, B, C, D and E. All of them have several features in common. When working with it the port acts like a memory location. Something is simply being written into or read from it, and it could be noticed on the pins of the microcontroller.

3.3.7.3 PORT and TRIS

For practical reasons, many I/O pins are multifunctional. Every port has its 'satellite', i.e. the corresponding TRIS register: TRISA, TRISB, TRISC etc. which determines the performance of port bits, but not their contents.

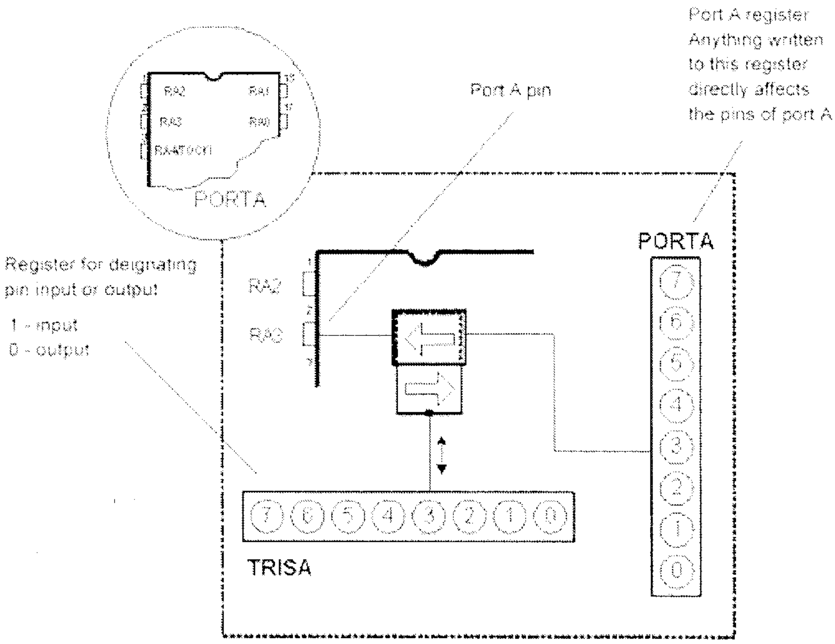


Figure 3.8-Port and Tris

All port pins can be designated as input or output, according to the needs of a device that's being developed. In order to define a pin as input or output pin, the right combination of zeros and ones must be written in TRIS register. If the appropriate bit of TRIS register contains logical "1", then that pin is an input pin, and if the opposite is true, it's an output pin. Every port has its proper TRIS register. Thus, port A has TRISA, and port B has TRISB. Pin direction can be changed during the course of work which is particularly fitting for one-line communication where data flow constantly changes direction. PORTA and PORTB state registers are located in bank 0, while TRISA and TRISB pin direction registers are located in bank 1.

3.3.8 TIMER TMR1

Timer TMR1 module is a 16-bit timer/counter, which means that it consists of two registers (TMR1L and TMR1H). It can be counted up 65.535 pulses in a single cycle, i.e. before the counting starts from zero. These registers can be read or written to at any moment. In case an overflow occurs, an interrupt is generated if enabled. The timer TMR1 module may operate in one of two basic modes, that is as a timer or a counter. Unlike the TMR0 timer, both of these modes have additional functions.

The TMR1 timer has following features:

- 16-bit timer/counter register pair;
- Programmable internal or external clock source;
- 3-bit prescaler;
- Optional LP oscillator;
- Synchronous or asynchronous operation;
- Timer TMR1 gate control (count enable) via comparator or T1G pin;
- Interrupt on overflow;
- Wake-up on overflow (external clock); and
- Time base for Capture/Compare function.

3.4 Phototransistor Opticoupler

The CNY17 contains a light emitting diode optically coupled to a photo-transistor. It is packaged in a 6-pinDIP package and available in wide-lead spacing option and lead bands option. Collector-emitter voltage is above 70 V. Response time,(tr), is typically 5 μs and minimum CTR is 40% at input current of 10 mA.

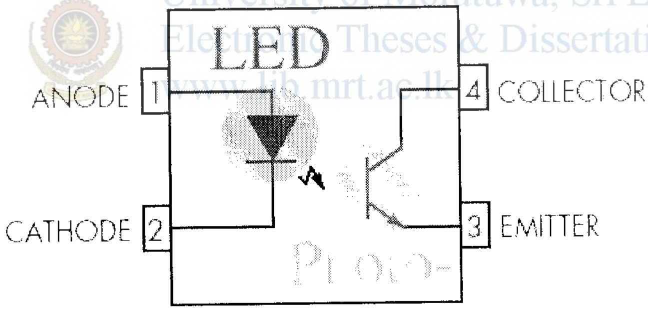


Figure 3.9-Optocoupler

It is most important to note that there is no direct electrical connection between the left side of the optocoupler and the right side. The left side is the connection to the outside world. Anything could be happened on that side. The right side is the delicate internal workings of our device.

The optocoupler will help prevent some kinds of electrical damage to the device. However, as with any engineering object, it has its limits. The LED part of the optocoupler is very much like the LEDs that anybody is familiar with. LEDs are tough and not easily damaged, however it is possible to burn them out. If the LED is made to pass too much current, it will be burnt out. The external resistor will be connected to anode to prevent the damage. Also, if lightning strikes the optocoupler a spark could possibly go across the terminals from left to right and this could cause damage to the device too

Absolute Maximum Ratings:

	Parameter	Symbol	Rating	Unit
Input	Peak forward current	I_{RM}	1	A
	Reverse voltage	V_R	6	V
	Power dissipation	P_D	70	mW
Output	Collector-emitter voltage	V_{CEO}	70	V
	Emitter-collector voltage	V_{ECO}	6	V
	Collector-base voltage	V_{CBO}	60	V
	Emitter-base voltage	V_{EBO}	6	V
	Collector current	I_C	50	mA
	Collector power dissipation	P_C	150	mW
	Total power dissipation	P_{tot}	200	mW
	Isolation voltage 1 minute	V_{iso}	5300	Vrms
		V_{iso}	7500	Vpk
	Operating temperature	T_{opr}	-55 to +100	^0C
	Storage temperature	T_{stg}	-55 to +125	^0C
	Soldering Temperature	T_{sol}	260	^0C

Table 3.7 - Optocoupler Parameters

Electrical Characteristics:

	Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Input	Forward voltage	VF	IF=20mA	-	1.2	1.4	V
	Peak forward voltage	VFM	IFM=0.5A	-	--	3.5	V
	Reverse current	R	VR=4V	-	-	10	µA
	Terminal capacitance	Ct	V=0,f=1kHZ	-	30	-	pF
Output	Collector dark current	ICEO	VCE=20V	-	-	0.1	µA
Transf Charac taristcs	Current transfer ratio	CTR	IF=10mA, VCE=5V	40	-	80	%
	Collector-emitter saturation voltage	VCE(sat)	IF=10mA ,Ic=2.5mA	-	0.1	0.4	V
	Isolation resistance	Riso	DC500V	$5x10^{10}$	10^{11}	-	ohm
	Floating capacitance	Cf	V=0 , f=1 MHZ	-	0.6	1.0	Pf
	Cut off frequency	T	Vcc=5V, Ic=2mA,RL=100ohm	-	80	-	kHz
	Response time (Rise)	Tr	Vce=2V,Ic=2mA	-	5	20	µs
	Response time (Fall)	tf	RL=100ohm	-	4	20	µs

Table 3.8 - Optocoupler Electrical Characteristics

3.5 Precision AC/DC Converter

Precision AC/DC Converter

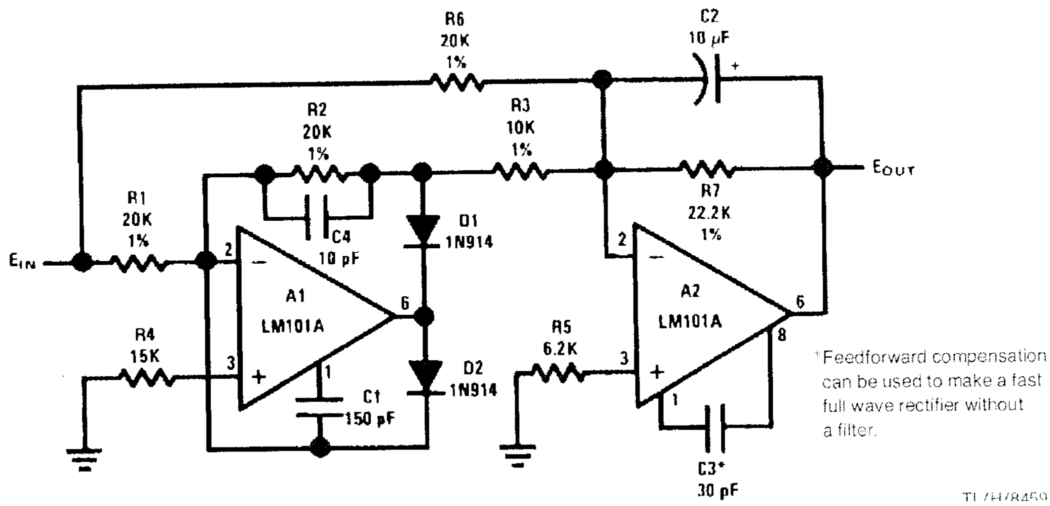


Figure 3.10 – Fast AC/DC Converter

This precision rectifier functions [3] somewhat different. The input signal is applied through R1to the summing node of an inverting operational amplifier. When the signal is positive, D1 is forward biased and develops an output signal across R2. As with any inverting amplifier, the gain is R2/R1. When the signal goes negative, D1 is non-conducting and there is no output. However, a negative feedback path is provided by D2. The path through D2 reduces the negative output swing to -0.7V, and prevents the amplifier from saturating.

Since* the LM101A is used as an inverting amplifier, feed forward compensation can be used. Feed forward compensation increases the slew rate to 10 V/ms and reduces the gain error at high frequencies. This compensation allows the half wave rectifier to operate at higher frequencies than the previous circuits with no loss in accuracy.

The addition of a second amplifier converts the half wave rectifier to a full wave rectifier. As is shown in Figure 3.10, the half wave rectifier is connected to inverting amplifier A2. A2sums the half waves rectified signal and the input signal to provide a full wave output. For negative input signals the output of A1 is zero and no current flows through R3. Neglecting for the moment C2, the output of A2 is $-\frac{R_7}{R_6} \times E_{IN}$

For positive input signals, A2 sums the currents through R3 and R6; and $E_{OUT} = R_7\left[\frac{E_{IN}}{R_3} - \frac{E_{IN}}{R_6}\right]$ If R_3 is 1/2 R_6, the output is $\frac{R_7}{R_6} \times E_{IN}$. Hence, the output is always the absolute value of the input.

Filtering, or averaging, to obtain a pure dc output is very easy to do. A capacitor, C2, placed across R7 rolls off the frequency response of A2 to give an output equal to the average value of the input. The filter time constant is R_7C_2, and must be much greater than the maximum period of the input signal. For the values given in Figure 3.10, the time constants about 0.22 seconds. This converter has better than1% conversion accuracy to above 100 kHz and less than1% ripple at 20 Hz. The output is calibrated to read the RMS value of a sine wave input.

As with any high frequency circuit some care must be taken during construction. Leads should be kept short to avoid stray capacitance and power supplies bypassed with 0.01 μF disc ceramic capacitors. Capacitive loading of the fast rectifier circuits must be less than 100pF or decoupling becomes necessary. The diodes should be reasonably fast and film type resistors used. Also, the amplifiers must have low bias currents.

3.6 Calculations of the components

3.6.1 Pull down resistor of the optocoupler (R_L) [9]

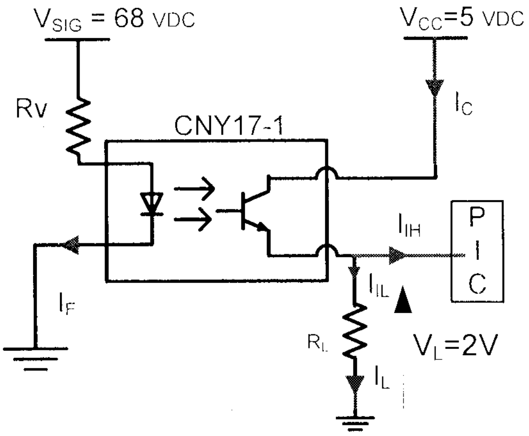


Figure 3.11 - Pull down Resistor

Supply voltage V_{CC} = 5V

Operating temperature = -55 to 100 ^{0}C

Typical CTR value selected as 100% at I_F = 10mA At -20 to + 60 ^{0}C

From the graph(see Optocoupler data sheet in appendix-G)

CTR undergoes a change in between +5% to -12%

Assuming a 10year service life period

allowances for additional CTR reduction = 20%

allowances for additional CTR safe value = -25%

Therefore CRT_{min} = 100% x(0.88)x(0.80)x(0.75)

= 52.8%

Referring the PIC Data sheet V_{IL} for the smith trigger input is 1V and V_{IH} is 4VDC

Max input low voltage to PIC(V_{IL}) = $V_{IL} \leq 1V$

Input low current (I_{IL}) = 1μA

I_{CEO} = 0.1μA

Therefore it is negligible , I_L = I_{IL}

For Max value of R_L

$$R_L \langle \frac{V_{IL}}{I_{IL}} = \frac{1V}{1\times10^{-6}} = 1M\Omega$$

Therefore Max R_L = 1 MΩ

For safety high state at output V_{IH}

$$V_{IH} \rangle \frac{V_{IH}}{I_L} = \frac{4V}{5.3mA} = 188.6\Omega$$

Resistance of the pull down resistor RL is vary between 1 MΩ $\langle R_L \langle 188.6\Omega$

Therefore Pull down resistor R_L can be selected as **1kΩ**

3.6.2 Current limiting resistor(Chopping resistor) (R_V) [9]

The R_L = 1k is selected and 20% safety is computed to the minimum V_{IH} in respect of the high state

$VIH = VIH \times 20\% = 2.4V$

This will then permit IC , IF and the chopping resistor RV at the input of the optocoupler to be determined.

$I_C = I_L \rangle \frac{2.4}{R_L} = 2.4mA$, Where R_L=1kΩ

$$I_F \rangle \frac{2.4mA}{CTR} = \frac{2.4}{0.53} = 4.5\text{ mA}$$

Where Forward voltage of the IR diode VF=1.2V

$$R_V \rangle \frac{V_{CC}-V_F}{4.5mA} = \frac{68-1.2}{4.5\times10^{-3}}$$

$R_V \rangle 14.8k\Omega$

Therefore Chopping resistor can be selected as **15kΩ**

R_L	1kΩ
R_V	15kΩ

Table 3.9 – Resistors of the optocoupler circuit

3.6.3 Current limiting resistor (R_b) and Transistor (Tr) [10]

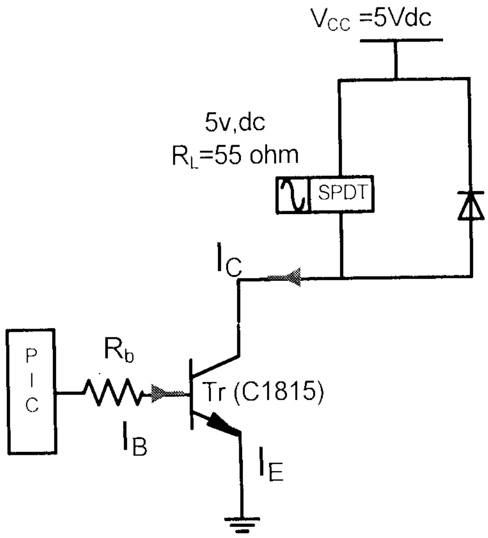


Figure 3.12 – Current limiting resistor at RB1

(a) Selection of transistor

Resistance of the relay coil = 55 ohm

Max current out from the PIC (I_{PIC}) = 25 mA

Supply voltage V_{CC} = 5V

Transistor at saturation I_C is max when $V_{CE}=0$, $R_{CE}=0$

Therefore Load current I_C at transistor saturation $= \frac{V_{CC}}{R_L} = \frac{5}{55}$

$= 91mA$

Therefore transistor must have $I_{C(max)} \rangle 91mA$

$$\min h_{EF} \rangle \frac{5 \times I_{C\cdot load}}{Max(Current(I_{PIC}))}$$

$$\min h_{FE} \rangle \frac{5 \times 91mA}{25mA} \rangle 18.2$$

Therefore **C1815, NPN** transistor was selected as min h_{EF} = 70 and I_C(max) = 150mA

(b) Selection of current limiting resistor R_B

$$R_B = \frac{V_S \times h_{FE}}{5 \times I_C}$$ where V_S is supply voltage of the PIC

For this application supply voltage of the PIC and transistor circuit is same. So that $V_S = V_{CC}$ and above formula can be re-arranged as

$$R_B = 0.2 \times h_{FE} \times R_L$$

$$= 0.2 \times 70 \times 55 = 770 \text{ ohm}$$

Therefore Current limiting resistor RB was selected as 820 ohm

(C) Current limiting resistor R1 output port RB2

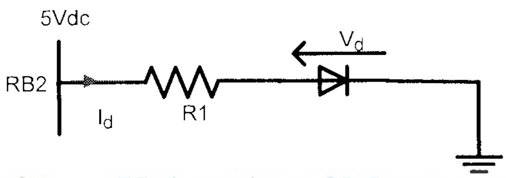


Figure 3.13 – Current limiting resistor at RB2

For safe operation Id=15mA and Vd =1.7V

Output voltage of the PIC = 5V

Therefore Id $= \frac{5 - Vd}{R1} = \frac{5 - 1.7}{R1}$

Limiting resistor R1 = 220 0hm

Chapter 4

Software Design of the system

4.1 Introduction

The ability to communicate is of great importance in any field. However, it is only possible if both communication partners know the same language, i.e follow the same rules during communication. Using these principles as a starting point, we can also define communication that occurs between microcontrollers and man. Language that microcontroller and man use to communicate is called "assembly language". The title itself has no deeper meaning, and is analogue to names of other languages, ex. English or French. More precisely, "assembly language" is just a passing solution. Programs written in assembly language must be translated into a "language of zeros and ones" in order for a microcontroller to understand it. "Assembly language" and "assembler" are two different notions. The first represents a set of rules used in writing a program for a microcontroller, and the other is a program on the personal computer which translates assembly language into a language of zeros and ones. A program that is translated into "zeros" and "ones" is also called "machine language".

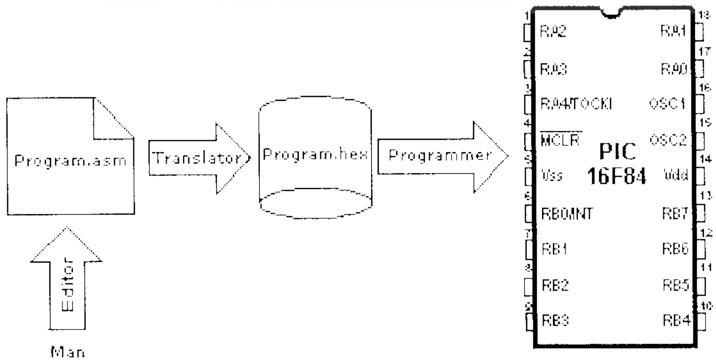


Figure 4.1-The process of communication between a man and a microcontroller

Physically, "**Program**" represents a file on the computer disc (or in the memory if it is read in a microcontroller), and is written according to the rules of assembler or some other language for microcontroller programming. Man can understand assembler language as it consists of alphabet signs and words. When writing a program, certain rules must be followed in order to reach a desired effect. A Translator interprets each instruction written in assembly language as a series of zeros and ones which have a meaning for the internal logic of the microcontroller.

4.2 Method

Before writing the assembly codes it is convenient to draw a flow chart for the whole program. The mechanism develop to recover the production waste (SPPDA) of the weaving machine using embedded microcontroller is developed as per the flow chart in figure 4.2. Practical testing was done in the factory at Biyagama.

4.3 Algorithm

The algorithm used for developing embedded programming as follows

- Implement the microcontroller based integrated control system
- The permissible values obtained from practical test and results were entered as reference value in microcontroller unit.
- Start the machine at rated condition.
- Competition are made between measured values with reference value.
- If $V_{measured} \leq V_{ref}$ then generate signal to operate the relay where $V_{measured}$ and V_{ref} are connected to AN0 and AN1 respectively.
- If time $t \geq 3\,\mathrm{sec}$ & $V_{measure} < V_{ref}$ stop the relay function and shut down the machine.
- Prototype model is developed and tested on a machine. The microcontroller base control system (SPPDA) respond to all types of voltage variations perfectly specified by and reenergized the relay after the specified time delay (3second) .

4.3.1 Software development flowchart

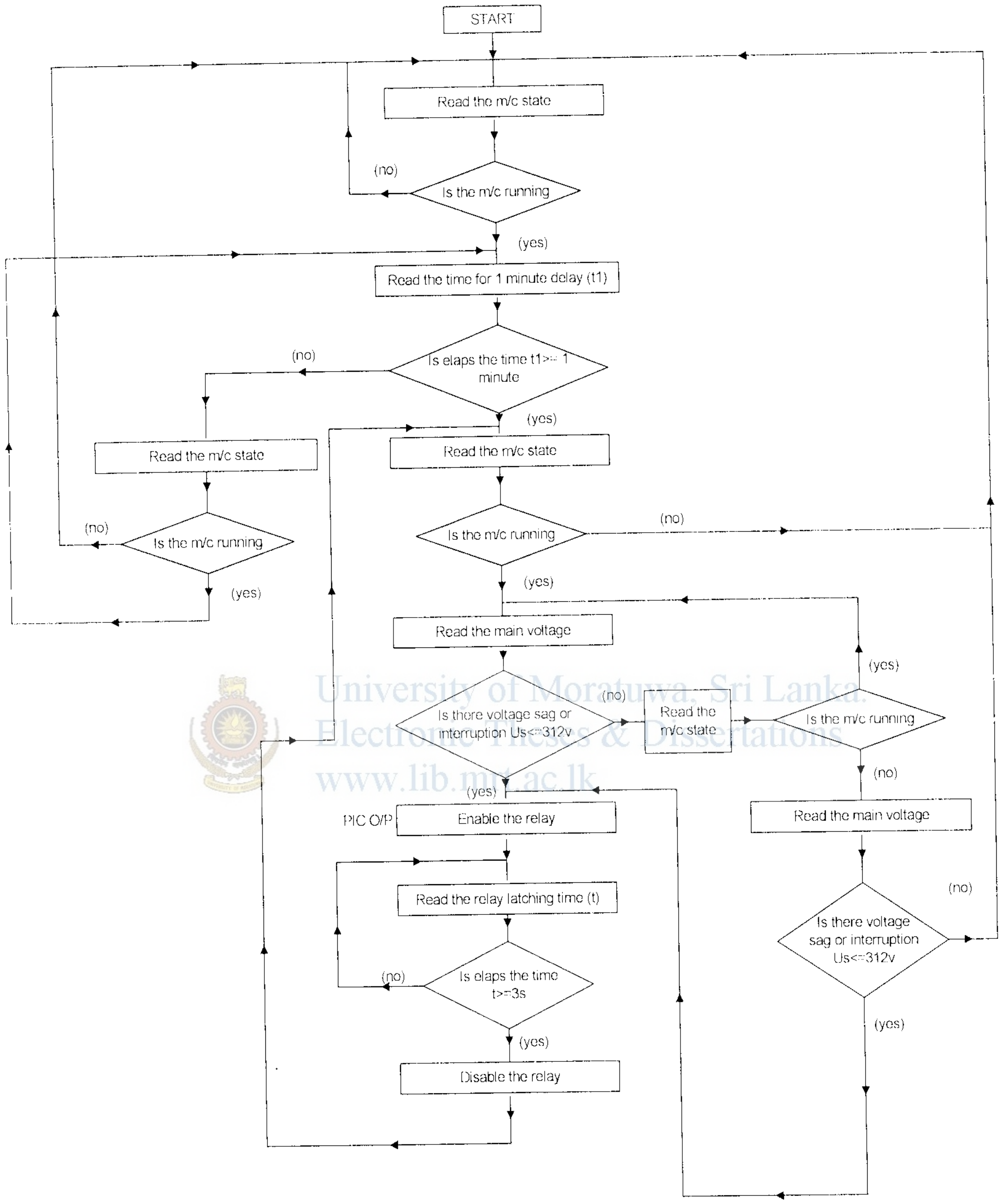


Figure 4.2 – Flow chart for software development

4.4 Resolution and Time Calculation

4.4.1 Resolution of the Analog signal

Speed of the crystal used for the PIC	=4 MHz
Time period per instruction	=1 μsecond
Machine controller functions fail voltage	=180VAC
Reference voltage at pin AN0	=5VDC
Voltage at the pin AN1	$= \frac{5 \times 180}{230} = 3.9VDC$
Required bits for the A/D conversion	=10 bits
Voltage resolution	$= \frac{5}{(2^{10} - 1)} \approx 5\text{ mV/Div}$

Therefore resolution of the analogue conversion is 5mV/Div

4.4.2 Acquisition time for the Analog module

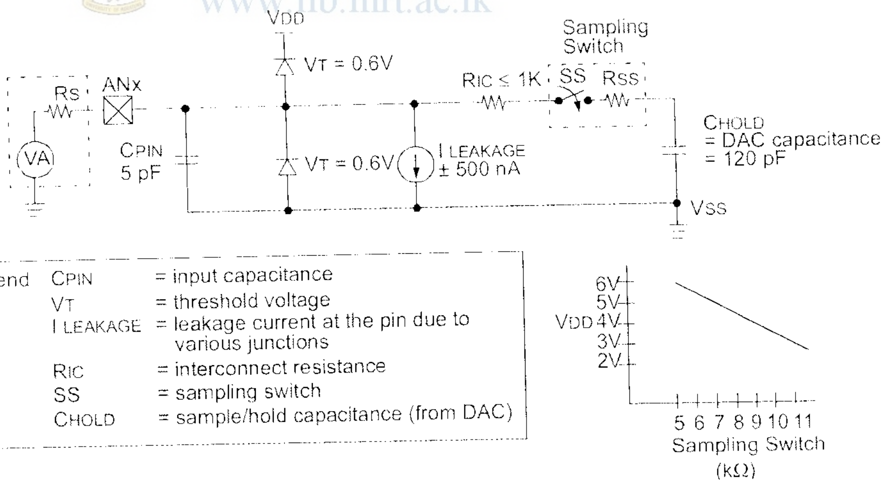


Figure 4.3 – Analog module for Acquisition time

As per the above figure 4.3 Acquisition time TACQ = Amplifier setting time

+Hold capacitor charging time

+Temperature coefficient

TACQ=TAMP+TC+TCOFF

$$=2\mu s+TC+[Temp-25^0C](0.05\mu s/^0C)$$

$$TC=C_{HOLD}(R1C+Rss+Rs)\ln(1/2047)$$

As per the Figure 4.3 resistors and capacitor values for the equivalent circuit to calculate acquisition time related to analog input AN0 and AN1are respectively as follows. The Rs value which is output resistance of the input circuit of the analog input AN0 is approximately zero because output impedance of the OP amp is negligible. When AN1 is considered two possible values can be considered which are at half preset (3.9V) and at full preset.

(a) Rs 0Ω , R1C=1kΩ , Rss=7kΩ from the graph of fig 4.3 at 5V

(b) Rs 22kΩ , R1C=1kΩ and Rss=7kΩ @5VDC and CHOLD=120pF

(c) Rs=100kΩ , R1C=1kΩ and Rss=7kΩ @5VDC and CHOLD=120pF

According to the above equation calculated TACQ at AN0 is 10.55μs and offset value of the pre-define general purpose register for the acquisition delay in the waiting loop in the program is 254 and likewise TACQ at AN1 is 30.6μs and offset value is 248. But maximum Rs value could be taken as 100kΩ at full preset position. So that calculated TACQ at AN1 is 103μs and related offset value is 231.when the assumptions are taking to calculate the Rs some errors can be happened. Therefore safe value for the offset can be selected as 231 to get highest acquisition time.

4.4.3 Basic operation of the program

1) AC/DC converter monitor present voltage level in the main supply which is supplied to the analog input AN0 at pin5 of the microcontroller portA and it could be varied in between 0V to 5V during the voltage variation or interruption.
2) Reference analog voltage 3.9VDC which is the threshold voltage level of the woven machine controller is applied to the AN1 at pin no3 in port A
3) As usual V_{DD} and V_{SS} of the microcontroller are connected to 0VDC and 5VDC respectively.
4) The machine run state is monitored by the optcoupler circuit which is connected to digital input RC5 at pin no 24 in portC.

5) Crystal oscillator 4Mhz oscillator is connected to the CLKOUT & CLKIN to perform the internal timing requirement. And all inputs that are used are pull down externally while turning on all internal pull ups of the unused inputs to avoid voltage floating

6) RB1 and RB2 in portB were used as outputs of the controller . RB1 is assigned to indicator LED and relay which is informed machine controller to keep the machine running once the voltage back to normal is driven by the out put RB2 of portB.

Once the controller is powered digital signal at pin 24(RC5) is checked whether the machine is running. If the machine is in running condition program continues its testing throughout one minute time and turn on LED. Because it needs the stability of the machine. If the condition is correct, it is being checked the machine state to confirm status of running .If the condition is not fulfilled the program will be commenced from the initial start.

Once the above conditions are fulfilled program of the microcontroller checks the voltage of AN0 at the pin2 of portA and ensure it is above or below the reference voltage of AN1 at pin 3 (3.9VDC). If the result of the competition is positive, '0' bit of the status register is set as "one "because no borrow bit is required. If not it is set as "zero". So that output RB1 at pin 34 is set as digital out 1 or 0 by the program.

Once the digital out put appears at RB1 pin numbers, 10,11,12 pins of the machine controller in fig 4.4 which are relevant to the Start, Tip and Stop switches of the machine are connected through the DPDT relay and de-energize after 3 seconds.

The meaning of connecting above points resembles starting the machine at the beginning. When the machine is started, Start and Tip switches are simultaneously kept in the holding stage. This action is done by microcontroller by connecting above three points. The machine controller holds this through the relay volt free contact and releases it after 3 seconds because stored energy in the tensioned yarn beams release their energy to relax the yarns which are between beams and machine as explained in chapter 2 section 2.3.1.

4.5 Schematic circuit diagram

(a) Control circuit for the microcontroller base SPVDA

(b)Power circuit for the AC/DC converter and microcontroller

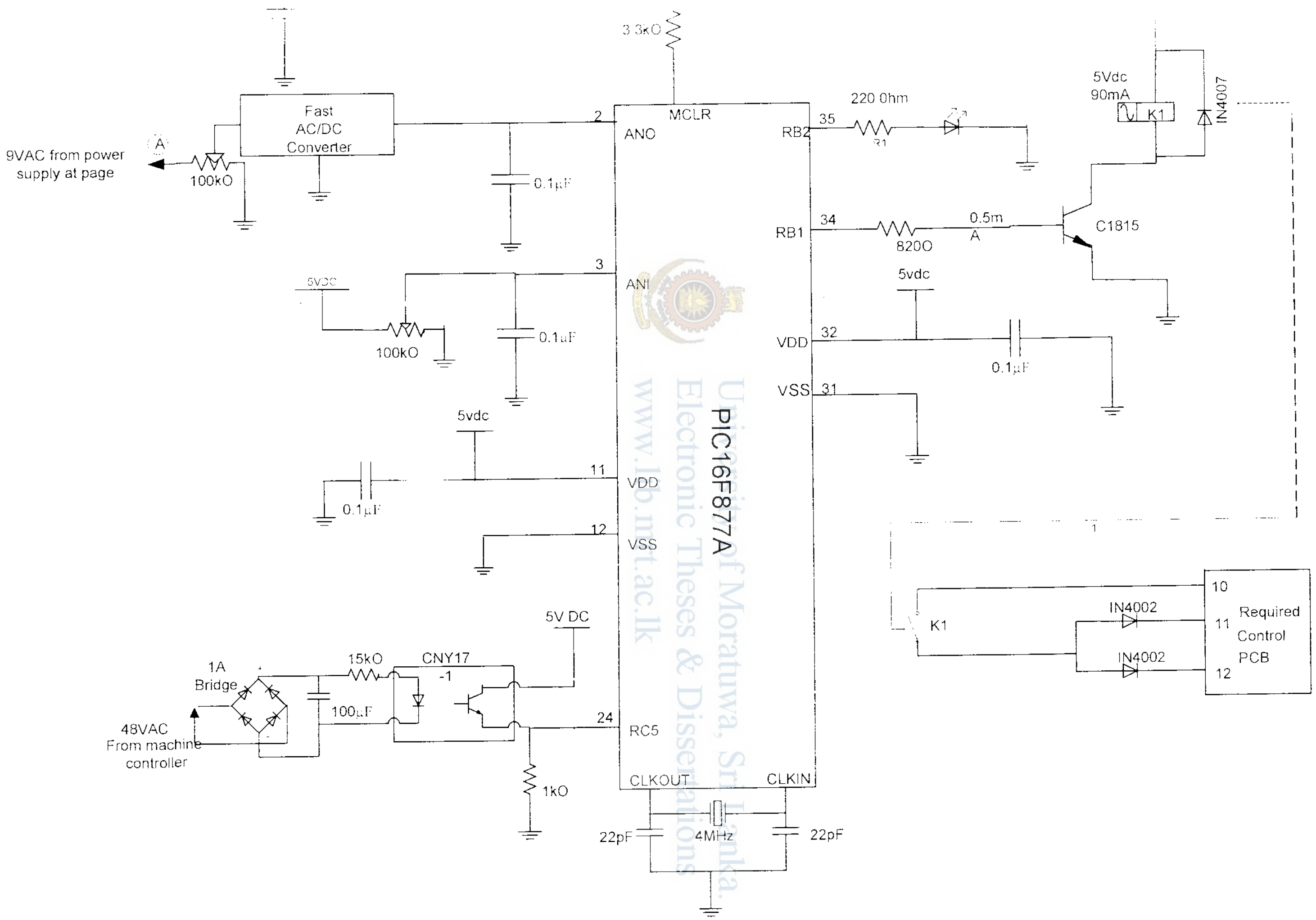


Figure 4.4 - Control circuit for the microcontroller

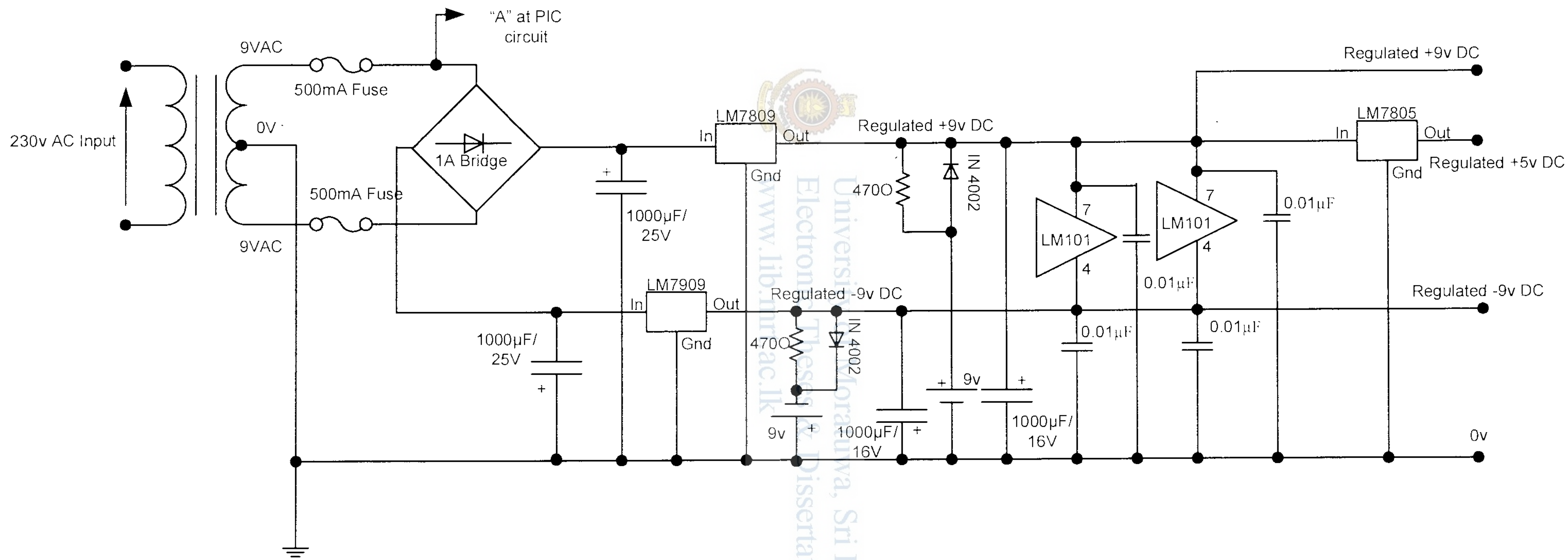


Figure 4.5 - Power circuit of the AC/DC converter

In order to provide DC power supply to the micro controller and fast AC to DC converter separate 5V and 9V power supply were used. AC step down center tapped transformer with full bridge rectification, smoothing capacitors and high frequency filtering capacitors were used for each DC supply. Since the output DC voltage levels have to be constant LM 7805, LM7809 and LM7909 regulators were used in 5V,9V and -9V supply circuit respectively as shown the figure 4.5. In addition to the above regulators two 9VDC rechargeable batteries were used to supply power to the circuit during the voltage interruptions.

4.5.1 Some photographs of the implemented Short Period Voltage Dip Actuator

Figure 4.6 - External appearance of the designed microcontroller bases circuit

Figure 4.7 - designed microcontroller bases circuit in the machine control unit

4.5.2 Machine controller circuit diagram

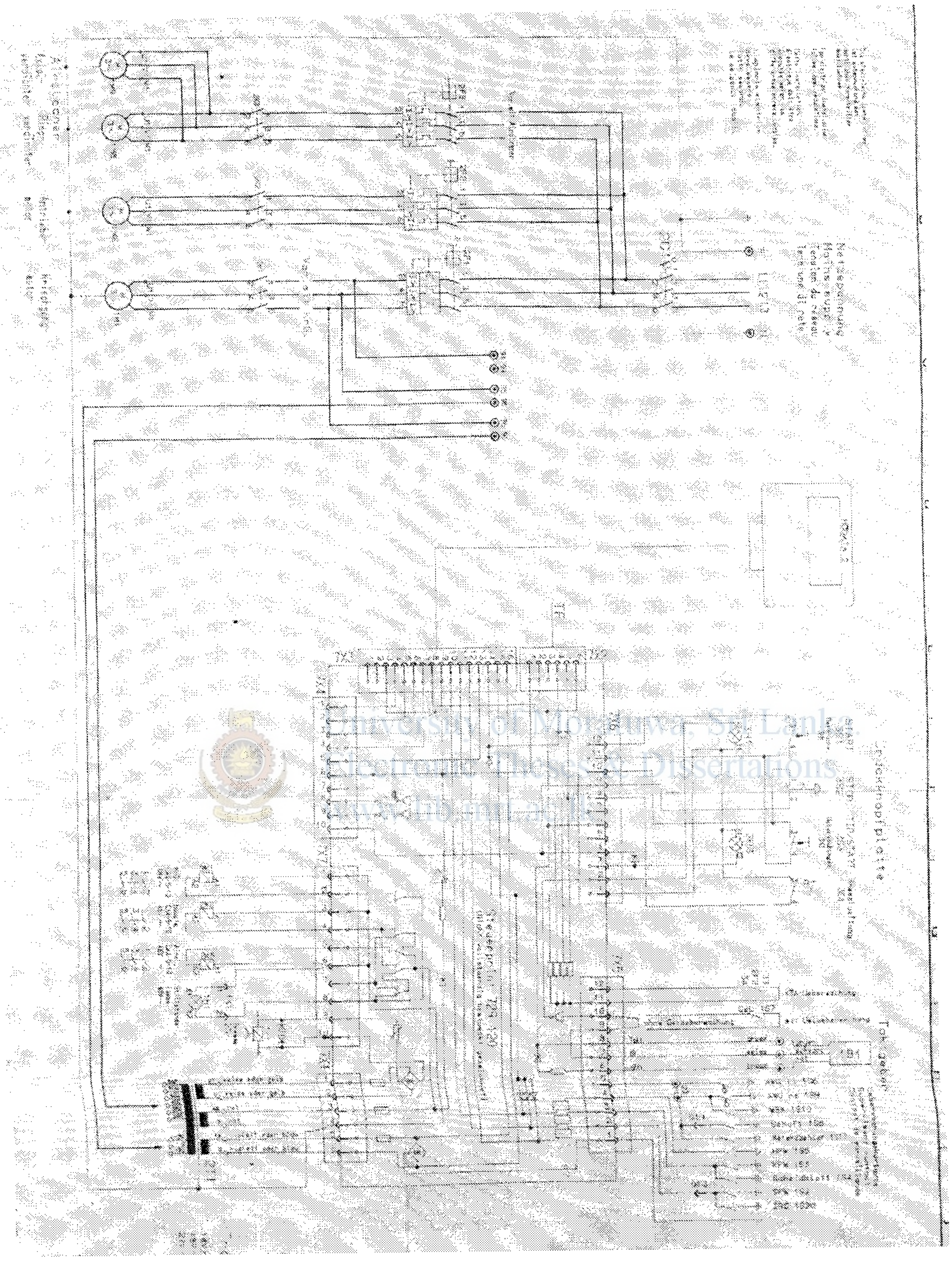


Figure 4.8 -Weaving loom main control unit circuit diagram

Chapter5

Statistical analysis of data

5.1 Category of waste

Data As described in the chapter1 there are two categories of waste which are controllable and uncontrollable waste. Since the solid waste contributing major portion of waste generated in the process, it is very important to analyze the information of solid waste in order to make decision in the company. The waste figure of the weaving department can be shown as below.

Solid waste analysis in year 2008 in kg

	2008											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Controllable												
Yarn waste	533	578	430	281	554	407	818	638	652	767	521	620
Quality Improvement	847	709	863	514	882	789	1325	1045	1292	1100	938	950
Beam Gating	121	88	70	60	41	80	86	110	115	89	95	88
Alteration	332	231	245	115	332	188	385	275	441	348	318	352
Ware House	291	169	218	55	211	301	288	254	189	193	222	198
Uncontrollable												
Bad Raw Material	13	25	29	65	54	39	48	53	92	32	27	39
Power cut	425	300	295	198	395	388	422	401	375	359	425	482
Maintenance	502	535	381	346	650	743	463	369	379	411	266	295
Mini Bulk	200	205	325	179	255	195	184	204	232	245	211	182
Total	3264	2840	2856	1813	3374	3130	4019	3349	3767	3544	3023	3206

Table 5.1 - Solid waste data in year 2008

Percentage waste of different categories in year 2008

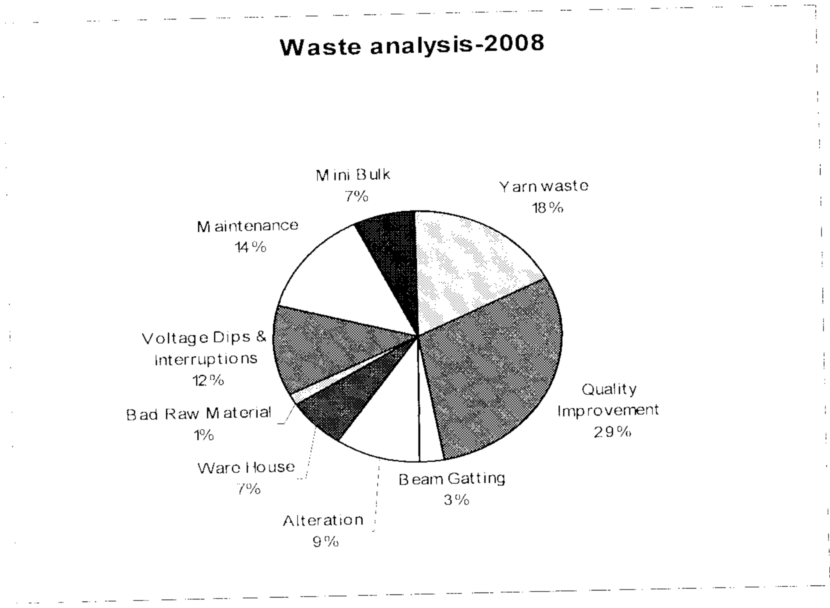


Figure 5.1 – Waste Analysis

5.2 Monitoring of results

Voltage Dips Analysis Report					
Date	Time	M/C Run	M/C Stop	t< 3Sec	t>3Sec
12.08.2009	9.11am	X		X	
13.08.2009	12.17 pm	X		X	
13.08.2009	07.30 pm	X		X	
15.08.2009	11.15 am		X		X
15.08.2009	11.45 am		X		X
17.08.2009	1.35 pm	X		X	
19.08.2009	11.05 am	X		X	
20..08.2009	3.05 am	X		X	
21.08.2009	10.05 am	X		X	
22.08.2009	4.15 am		X		X
24.08.2009	8.31 am		X		X
24.08.2009	12 noon	X		X	
27.08.2009	4.00 pm		X		X
27.08.2009	7.40 pm	X		X	
29.08.2009	1.45 am		X		X
29.08.2009	2.55 am	X		X	
29.08.2009	4.10 am		X		X
30.08.2009	7.30 am	X		X	
30.08.2009	9.10 am	X		X	
30.08.2009	1.58 pm	X		X	
01.09.2009	11.52 pm		X		X
02.09.2009	6.20 am	X		X	
02.09.2009	10.23 pm	X		X	
06.09.2009	3.00 pm	X		X	
07.09.2009	8.05 am		X		X
07.09.2009	8.00 pm	X		X	
09.09.2009	11.10 pm	X		X	
10.09.2009	7.40 am	X		X	
10.09.2009	2.00 pm	X		X	
11.09.2009	8.00 am		X		X

Table 5.2-Power failure analysis report

The model unit in figure 4.6 microcontroller base Short Period Voltage Dip Actuator was installed to the weaving machine and monitored and recorded the results during the period from 12th Aug 2009 to 11th Sept 2009. The results were tabulated as per the above table 5.2.

Reference to the table 5.2 approximately out of 30 voltage failures 16 can be managed to run the loom within a period of one month. It is approximately 50% of total waste due to voltage failures. Therefore referring the table 5.2 and figure 5.1 percentage of waste due to voltage dip is approximately 6% of the overall waste. Therefore approximately 2234 kg of mixed product can be saved by installing this controller.

5.3 Analysis of time waste

There are two kinds of machines, these are single and double deck. Each single deck machine includes 10 weaving heads and 20 for the double deck machines. The most significant part of the voltage failure is removing damages and reconnecting tapes (Tagging). In average time taking for the whole process per single tape would be 5second.

(a) Single deck100 machines

Tagging time		-	5 sec/tape
Tagging time for 100 looms		-	100x10x5 sec
Average voltage failures per month	t<3sec	-	20 nos
Therefore total loss time		-	20x100x10x5 sec
		-	27 hrs/month

(b) Double deck 20 machines

Tagging time		-	5 sec/tape
Tagging time foe 20 looms		-	20x20x5 sec
Average voltage failures per month	t<3sec	-	20 nos
Therefore total loss time		-	20x20x20x5 sec
		-	11 hrs/month

Therefore total loss time per year due to voltage dips less than 3 sec is approximately 456 hours .This is equivalent to Rs 1.9 million per month due to total capacity of 0.4 million meters per day production. So that annual time loss is approximately equivalent to Rs 23.2 million.

5.4 Analysis of production waste

According to the table1 .

Overall mixed production waste in all categories	= 38185kg
Overall mixed production waste due to voltage failures	= 4465kg
Overall waste percentage due to voltage failures	= 12%
After installing SPPDA waste percentage	= 6%
Therefore equivalent waste due to voltage dips approximately	= 2232 kg/year
This is equivalent approximately per year	= Rs2.4 million
So that overall estimated annual saving after installing SPPDA	**=Rs 25.6million**

5.5 Budgetary Requirement

One of the objectives on this project is to design an economical device to minimize production waste due to voltage failures less than 3sec. The estimated cost for the whole project is as follows

Cost for the components	= Rs3000
Cost for the printed board	= Rs 800
Cost of assembly	= Rs 500
Total cost per unit	= Rs 3300
Estimated cost for 120 units	= Rs 516,000

Total Estimated cost is approximately 2% of the annual saving

Pay back period would be approximately = 8 days

By considering this SPVDA will be installed for the weaving machines in the weaving department, it will be saved at least Rs 25 million.

Chapter 6

Experimental Results and Conclusion

6.1 Testing at site

The new controller was temporally set up at site and a power analyzer model Fluke 1735 was used to take the normal current and voltage Vs time readings during short period interruptions. The machine was given the starting signal and was allowed to run as of normal operation after setting up the new controller and power analyzer .The testing was done for three successive interruptions. The motor current before & after the voltage interruptions were recorded under the short period interruptions as shown in Figure 6.1.

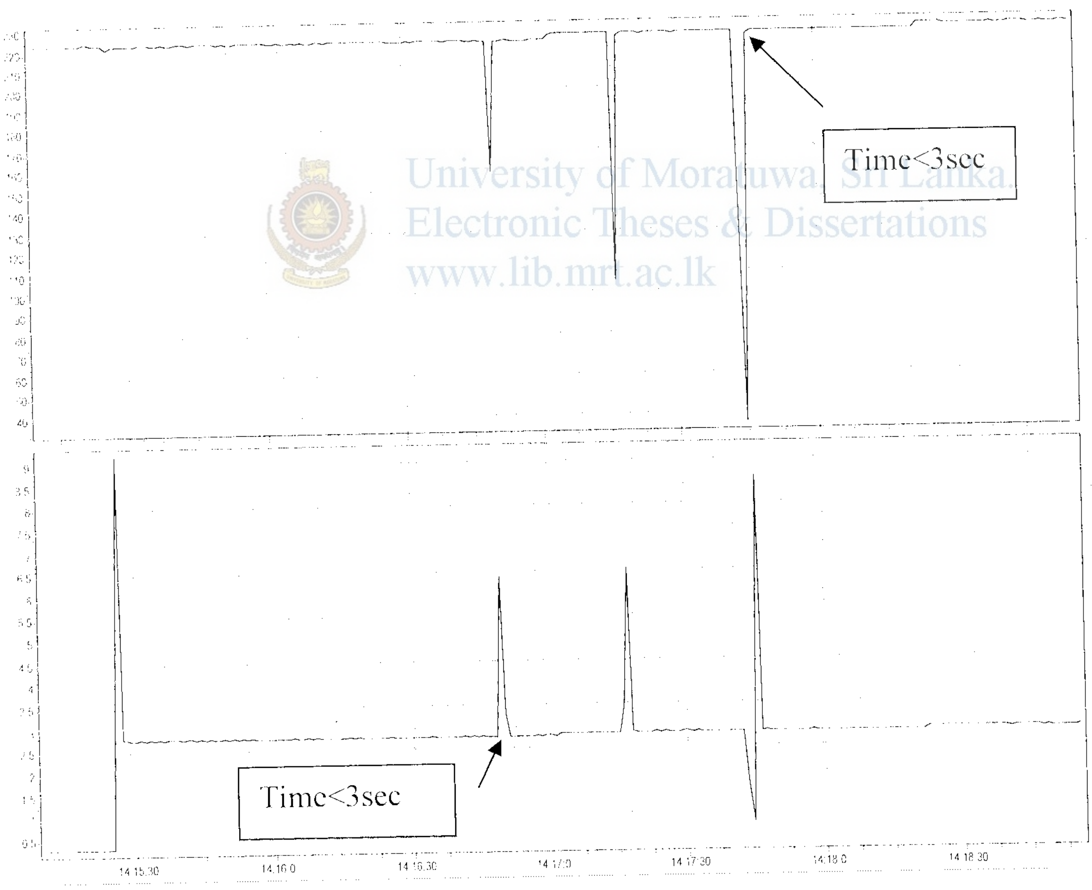


Figure 6.1-Motor Current Variation for momentary interruptions

As the supply voltage to the induction motor decreases the motor speed decrease. Depending on the size and the duration of the voltage dip. the motor speed may recover to its normal value as the voltage amplitude recovers. If the voltage dip magnitude and or duration exceed certain limits the motor would be taken out of the system by the machine controller or protection [6].

In this case if the dip or short period interruption is less than 3sec the motor would be taken out from the machine and consequence restarting must be done. As shown in the Fig. 6.1 during and after the interruption current rises to 2.5 to 3.7 times its normal value during the time less than 3 seconds. Under this scenario the current does not reach higher values for long enough time to trigger any of the motor's protection systems [6]. Fig 6.1 shows that machine operation was not effected by the momentary or voltage dips within time 3 second.

6.2 Conclusion

In this thesis it has been proposed a new approach for reducing waste through automation. The core innovation was triggered to reduce an excessive waste generation due to voltage variations or short period interruptions. It has been used micro controller and other related components to perform this task.

This device can be applied to any application that needs to operate safely during predefine time and voltage levels. The practical results obtained from the application shows that it has no effect to the motor and have a benefit to the organization.

The device was built & integrated with the machine controller to demonstrate the concept. The system was built up with very few pre-made components in an attempt to better understand the technology limits, cost and conditions of building the controller. In doing so it has been noticed the difficulties of the system operation with the number of features and components in the polluted power environment. Therefore the probability of the system working correctly, being the product of all its parts probabilities of working properly.

The new device was built considering all the possible power pollution causes that could be effected to proper operation of the device and mitigation actions were taken during the design stage and while testing.

The developed micro controlled base controlled can be set to operate at different time spans. The controller timing was set at 3 seconds maximum for the weaving looms. According to the results collected during one month period approximately 50% of voltage problems can be categorized as short period interruptions or voltage dips. Therefore production waste due to this reason could be recovered by doing small modification at low cost.

According to the Fig 5.1 in cheaper 5 waste due to the voltage problems was 12%. The results were based on average waste figures taken during a period of one year. After installing this new controller, It could be reduced approximately up to 6%. It is equivalent to 2232 kg per year of product saving and 456 hours per year of loss time saving. In terms of financial terms annual saving would be approximately Rs 23.4 million.

Another advantage is rejection of the batches due to high number of joints could be minimized and as a result of customer complains and reprocessing will be reduced.

References:

[1] Programming the PIC microcontroller with MBasic-Chapter 4.

[2] Website, http://www.microcgip.com/pic16f87xa datasheet.

[3] National Operational Amplifiers data book - Section 1.

[4] http://www.lldatasheet.com/datasheet-pdf/30084/TOSHIBA/C1815.html .

[5] PIC micro Mid-Range MCU Family Reference Manual

[6] M.Teresa Correia de Barros, Andria Leiria "Journal of Induction Motor Response to Voltage Dips", International Conference on Power Systems Transients-IPST 2003 in New Orleans, USA.

[7] Juan C. Gomez, " Behavior of Induction motor due to voltage sag and short interruptions" IEEE Transactions on power delivery, Vol. 17, no 2, April 2002

[8] Magazine of Engineering & Technology-IET.

[9] Website, http://www.vishay.com/docs/83741/83741.pdf

[10] Website, http://www.kpsec.freeuk.com/trancirc.htm

ASSEMBLY CODES OF THE PROGRAM

Program	Short Period Voltage Dip Actuator
Microcontroller	PIC 16F877A
Crystal Frequency	4 MHz
Author	H.K.L Gamini

" This part of the program includes defining registers "

```
porta            equ    0x05   ;Register definition using "equ" directive
portb            equ    0x06
portc            equ    0x07
trisa            equ    0x85
trisb            equ    0x86
trisc            equ    0x87
option_reg       equ    0x81
adcon0           equ    0x1f
adcon1           equ    0x9f
dly_count_lsb    equ    0x40
t1con            equ    0x10
time_count_1min  equ    0x26
pir1             equ    0x0c
time_count_3s    equ    0x27
voltage          equ    0x28
adres_msb        equ    0x1e
uv_setting       equ    0x23
status           equ    0x03
flag_register    equ    0x20
tmr1l            equ    0x0e
tmr1h            equ    0x0f
```

"This part of program includes defining variables "

```
#define         mc_runing_flag          flag_register,2
#define         uv_flag                 flag_register,3
```

"This part of the program includes macros "

```
                INCLUDE "p16f877a.inc"
                LIST
bank0           macro                   ;Selection of bank0
                bcf         status,5
                bcf         status,6
                endm
bank1           macro                   ;Selection of bank1
                bsf         status,5
                bcf         status,6
                endm
start_adc       macro                   ; Start A/D convention
                bsf         adcon0,2
                endm
off_adc         macro                   ; Stop A/D Module
                bcf         adcon0,0
                endm
                org         0x000  ;assign the starting address of a program
                call        sys_init
start           bcf         portb,2
                bcf         t1con,0
                clrf        time_count_1min
                call        mc_state
                btfss       mc_runing_flag
                goto        start
                call        timer1_on
one_min_delay   call        mc_state
                btfss       mc_runing_flag
                goto        start
                btfss       pir1,0
                goto        one_min_delay
```

```
            bcf         pir1,0
            incf        time_count_1min,1
            btfss       time_count_1min,6
            goto        one_min_delay
            bcf         t1con,0
            bsf         portb,2
after_1_min call        mc_state
            btfss       mc_runing_flag
            goto        start
volt_loop   call        read_voltage
            btfss       uv_flag
            goto        runing_volt
            bcf         uv_flag
relay_on    bsf         portb,1
            call        timer1_on
            movlw       0x00
            movwf       time_count_3s
thr_sec_delay btfss     pir1,0
            goto        thr_sec_delay
            bcf         pir1,0
            incf        time_count_3s,1
            btfss       time_count_3s,2
            goto        thr_sec_delay
            btfss       time_count_3s,1
            goto        thr_sec_delay
            bcf         t1con,0
            bcf         portb,1
            goto        after_1_min
runing_volt call        mc_state
            btfss       mc_runing_flag
            goto        what_failure
            goto        volt_loop
what_failure call       read_voltage ; check the type of failure
            btfss       uv_flag
```

```
                goto        start
                goto        relay_on
read_voltage    clrf        voltage
                movlw       b'01000001' ; clock ;channel 0;module on
                movwf       adcon0
                call        read_adc
                movfw       adres_msb
                movwf       voltage

"This part includes selection of clock and AD ON"
read_uv_setting movlw       b'01001001' ;clock (FOSC/8) ;ch1.module on
                movwf       adcon0
                call        read_adc
                clrf        uv_setting
                movfw       adres_msb
                movwf       uv_setting ;save the uv setting
check_volt      bcf         uv_flag
                movfw       uv_setting
                subwf       voltage,0
                btfsc       status,0 ;Is there a uv
                return      ;no
                bsf         uv_flag  ;yes
                return
mc_state        clrwdt      ;Reset watch dog timer
                bcf         mc_runing_flag
                btfsc       portc,5
                bsf         mc_runing_flag
                return
read_adc        call        wait    ; For acquisition delay
                start_adc   ;Start A/D conversion
adc_loop        btfsc       adcon0,2    ;Is end of conversion
                goto        adc_loop
                off_adc     ;0ff A/D Module
                return
```

"This part includes acquisition delay "

```
wait            movlw   0xE7        ;acquisition delay
                movwf   dly_count_lsb
wait_loop       clrwdt
                incfsz  dly_count_lsb
                goto    wait_loop
                return
timer1_on       clrf    tmr1h
                clrf    tmr1l
                movlw   b'00110101'
                movwf   t1con
                return
```

" This part includes configuration of portb as inputs and outputs "

```
sys_init        bank1
                movlw   b'11111001' ;configer portb(input/output)
                movwf   trisb
```

"This part includes configuration of porta as A/D port "

```
                movlw   b'00110000'  ;configer porta(A/D port)/ A/D
                                      result format
                movwf   adcon1
```

" This part includes configuration of portc as digital input "

```
                movlw   b'11111111'   ;configure portc inputs
                movwf   trisc
                movlw   b'01010100'   ;portb pull-up enable
                movwf   option_reg
                bank0
                clrf    adres_msb     ;initialy clear A/D result register
                bcf     adcon0,7      ;A/d conversion clock select
                bsf     adcon0,6      ;A/d conversion clock select
                bcf     portb,1       ;initialy OFF the relay
                call    read_uv_setting ;Read under voltage setting
                return
                END
```

Transistor Datasheet:

TOSHIBA 2SC1815

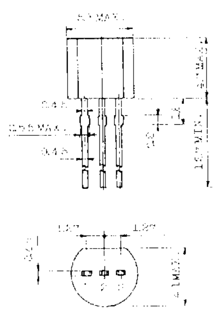
TOSHIBA TRANSISTOR SILICON NPN EPITAXIAL TYPE (PCT PROCESS)

2SC1815

AUDIO FREQUENCY GENERAL PURPOSE AMPLIFIER APPLICATIONS.
DRIVER STAGE AMPLIFIER APPLICATIONS.

- High Voltage and High Current
  : V_{CEO} = 50V (Min.), I_C = 150mA (Max.)
- Excellent h_{FE} Linearity
  : $h_{FE(2)}$ = 100 (Typ.) at V_{CE} = 6V, I_C = 150mA
  : h_{FE} (I_C = 0.1mA) / h_{FE} (I_C = 2mA) = 0.95 (Typ.)
- Low Noise : NF = 1dB (Typ.) at f = 1kHz
- Complementary to 2SA1015 (O, Y, GR class)

Unit in mm



1. EMITTER
2. COLLECTOR
3. BASE

JEDEC	TO-92
EIAJ	SC-43
TOSHIBA	2-5F1B

Weight : 0.21g

MAXIMUM RATINGS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	RATING	UNIT
Collector-Base Voltage	V_{CBO}	60	V
Collector-Emitter Voltage	V_{CEO}	50	V
Emitter-Base Voltage	V_{EBO}	5	V
Collector Current	I_C	150	mA
Base Current	I_B	50	mA
Collector Power Dissipation	P_C	400	mW
Junction Temperature	T_j	125	°C
Storage Temperature Range	T_{stg}	−55~125	°C

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	TEST CONDITION	MIN.	TYP.	MAX.	UNIT
Collector Cut-off Current	I_{CBO}	V_{CB} = 60V, I_E = 0	—	—	0.1	μA
Emitter Cut-off Current	I_{EBO}	V_{EB} = 5V, I_C = 0	—	—	0.1	μA
DC Current Gain	$h_{FE(1)}$ (Note)	V_{CE} = 6V, I_C = 2mA	70	—	700	
	$h_{FE(2)}$	V_{CE} = 6V, I_C = 150mA	25	100	—	
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	I_C = 100mA, I_B = 10mA	—	0.1	0.25	V
Base-Emitter Saturation Voltage	$V_{BE(sat)}$	I_C = 100mA, I_B = 10mA	—	—	1.0	V
Transition Frequency	f_T	V_{CE} = 10V, I_C = 1mA	80	—		MHz
Collector Ouput Capacitance	C_{ob}	V_{CB} = 10V, I_E = 0, f = 1MHz	—	2.0	3.5	pF
Base Intrinsic Resistance	$r_{bb'}$	V_{CE} = 10V, I_E = −1mA f = 30MHz	—	50	—	Ω
Noise Figure	NF	V_{CE} = 6V, I_C = 0.1mA f = 1kHz, R_G = 10kΩ	—	1.0	10	dB

Note : h_{FE} Classification O : 70~140 Y : 120~240 GR : 200~400 BL : 350~700

961001EAA2

1997-04-10 1/3

Appendix – C

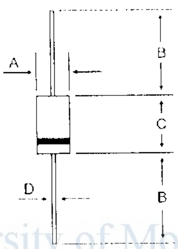
Silicon Rectifier Diode Datasheet :

MOSPEC 1N4001 THRU 1N4007

GENERAL PURPOSE SILICON RECTIFIER
VOLTAGE RANGE 50 TO 1000 Volts Current 1 Ampere

FEATURES
- Low cost construction
- Low forward voltage drop
- Low reverse leakage
- High forward surge current capability
- High temperature soldering guaranteed 260 °C/10 seconds, 0.375"(9.5 mm) lead length at 5 lbs(2.3kg) tension

DO-41



DIM	MILLIMETERS	
	MIN	MAX
A	2.00	2.70
B	25.40	---
C	4.20	5.20
D	0.70	0.90

MECHANICAL DATA
- Case : Transfer Molded Plastic
- Epoxy: UL94V-O rate flame retardant
- Terminals : Solderable Per MIL-STD-202 Method 208
- Polarity : Color band denotes cathode end
- Mounting position: Any
- Weight : 0.012 ounce, 0.33 gram (approx)

MAXIMUM RATINGS AND ELECTRICAL CHARATERISTICS
- Rating at 25 °C ambient temperature unless otherwise specified
- Single phase half wave, 60Hz, resistive or inductive load.
- For capacitive load derate current by 20 %

Characteristic	Symbol	1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	200	400	600	800	1000	V
RMS Reverse Voltage	$V_{R(RMS)}$	35	70	140	280	420	560	700	V
Average Rectifier Forward Current Per Leg T_C=125 °C	$I_{F(AV)}$	1.0							A
Non-Repetitive Peak Surge Current (Surge applied at rate load conditions halfware, single phase, 60Hz)	I_{FSM}	30							A
Maximum Instantaneous Forward Voltage (I_F =1.0 Amp T_C = 25 °C)	V_F	1.1							V
Maximum Instantaneous Reverse Current (Rated DC Voltage, T_C = 25 °C) (Rated DC Voltage, T_C = 100 °C)	I_R	5.0 50							uA
Typical Junction Capacitance (Reverse Voltage of 4 volts & f=1 MHz)	C_J	15							pF
Typical Thermal Resistance	$R_{\theta JA}$	50							°C/W
Operating and Storage Junction Temperature Range	T_J , T_{stg}	-65 to +175							°C

1N4001 thru 1N4007

FIG-1 FORWARD CURRENT DERATING CURVE

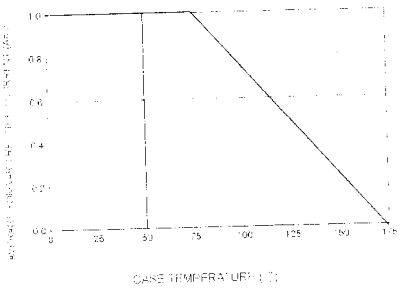


FIG-2 TYPICAL FORWARD CHARACTERISITICS

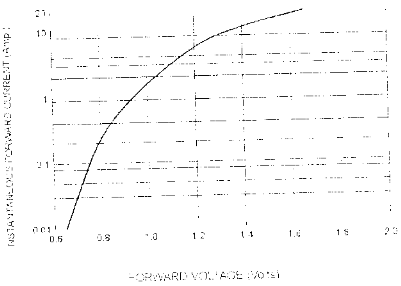


FIG-3 TYPICAL REVERSE CHARACTERISTICS

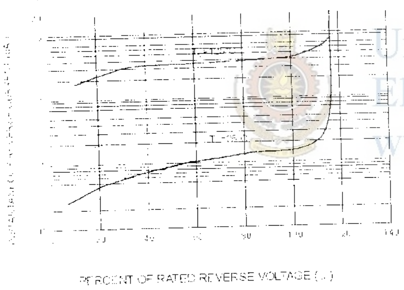


FIG-4 TYPICAL JUNCTION CAPACITANCE

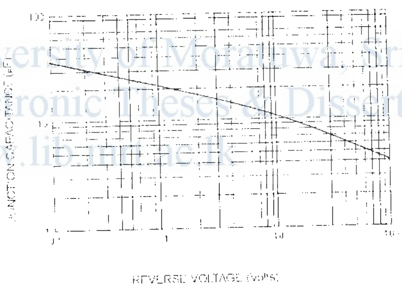
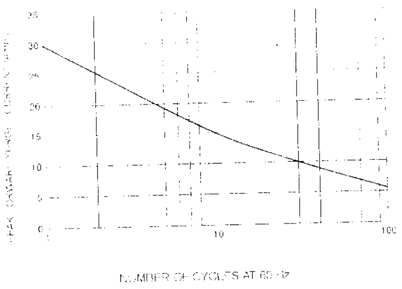


FIG-5 PEAK FORWARD SURGE CURRENT



PCB Relay Datasheet:

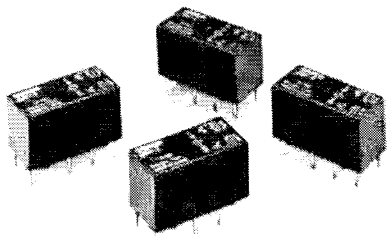
OMRON

PCB Relay G5V-2

Miniature Relay for Signal Circuits

- Wide switching power of 10 µA to 2 A.
- High dielectric strength coil-contacts: 1,000 VAC; open contacts: 750 VAC.
- Conforms to FCC Part 68 requirements.
- Ag + Au clad bifurcated crossbar contacts and fully sealed for high contact reliability.
- New 150-mW relays with high-sensitivity.

RoHS Compliant Refer to pages 16 to 17 for details.



FCC

Ordering Information

Classification	Contact form	Contact type	Contact material	Enclosure ratings	Model
Standard	DPDT	Bifurcated crossbar	Ag + Au-Alloy	Fully sealed	G5V-2
High-sensitivity					G5V-2-H1

Note: When ordering, add the rated coil voltage to the model number.
Example: G5V-2 12 VDC
Rated coil voltage

Model Number Legend

G5V - □ - □ □ VDC
1 2 3

1. **Contact Form**
   2: DPDT
2. **Classification**
   H1: High-sensitivity
3. **Rated Coil Voltage**
   3, 5, 6, 9, 12, 24, 48 VDC

Specifications

■ Coil Ratings

Standard Models

Rated voltage		3 VDC	5 VDC	6 VDC	9 VDC	12 VDC	24 VDC	48 VDC
Rated current		166.7 mA	100 mA	83.3 mA	55.6 mA	41.7 mA	20.8 mA	12 mA
Coil resistance		18 Ω	50 Ω	72 Ω	162 Ω	288 Ω	1,152 Ω	4,000 Ω
Coil inductance (H) (ref. value)	Armature OFF	0.04	0.09	0.16	0.31	0.47	1.98	7.23
	Armature ON	0.05	0.11	0.19	0.49	0.74	2.63	10.00
Must operate voltage		75% max. of rated voltage						
Must release voltage		5% min. of rated voltage						
Max. voltage		120% of rated voltage at 23°C						
Power consumption		Approx. 500 mW						Approx. 580 mW

Note:
1. The rated current and coil resistance are measured at a coil temperature of 23°C with a tolerance of ±10%.
2. Operating characteristics are measured at a coil temperature of 23°C.
3. The maximum voltage is the highest voltage that can be imposed on the relay coil.

105

High Sensitivity Models

		3 VDC	5 VDC	6 VDC	9 VDC	12 VDC	24 VDC	48 VDC
Rated voltage		3 VDC	5 VDC	6 VDC	9 VDC	12 VDC	24 VDC	48 VDC
Rated current		50 mA	30 mA	25 mA	16.7 mA	12.5 mA	8.33 mA	6.25 mA
Coil resistance		60 Ω	166.7 Ω	240 Ω	540 Ω	960 Ω	2,880 Ω	7,680 Ω
Coil inductance (H) (ref. value)	Armature ON	0.18	0.46	0.70	1.67	2.90	6.72	20.1
	Armature OFF	0.57	0.71	0.97	2.33	3.99	9.27	26.7
Must operate voltage		75% max. of rated voltage						
Must release voltage		5% min. of rated voltage						
Max. voltage		180% of rated voltage at 23°C						150% of rated voltage at 23°C
Power consumption		Approx. 150 mW					Approx. 200 mW	Approx. 300 mW

Note: 1. The rated current and coil resistance are measured at a coil temperature of 23°C with a tolerance of +10%.
2. Operating characteristics are measured at a coil temperature of 23°C.
3. The maximum voltage is the highest voltage that can be imposed on the relay coil.

■ Contact Ratings

Item	Standard models	High sensitivity models
Load	Resistive load (cosφ = 1)	
Rated load	0.5 A at 125 VAC; 2 A at 30 VDC	0.5 A at 125 VAC; 1 A at 24 VDC
Contact material	Ag + Au-clad	
Rated carry current	2 A	
Max. switching voltage	125 VAC, 125 VDC	
Max. switching current	2 A	1 A
Max. switching power	62.5 VA, 60 W	62.5 VA, 24 W
Failure rate (reference value) (See note.)	0.01 mA at 10 mVDC	

Note: P level: $\lambda_{60} = 0.1 \times 10^{-6}$/operation
This value was measured at a switching frequency of 120 operations/min and the criterion of contact resistance is 50 Ω. This value may vary depending on the switching frequency and operating environment. Always double-check relay suitability under actual operating conditions.

■ Characteristics

Item	Standard models	High sensitivity models
Contact resistance (See note 1.)	50 mΩ max.	100 mΩ max.
Operate time	7 ms max.	
Release time	3 ms max.	
Max. operating frequency	Mechanical: 36,000 operations/hr Electrical: 1,800 operations/hr (under rated load)	
Insulation resistance (See note 2.)	1,000 MΩ min. (at 500 VDC)	
Dielectric strength	1,000 VAC, 50/60 Hz for 1 min between coil and contacts 1,000 VAC, 50/60 Hz for 1 min between contacts of different polarity 750 VAC, 50/60 Hz for 1 min between contacts of same polarity	1,000 VAC, 50/60 Hz for 1 min between coil and contacts 1,000 VAC, 50/60 Hz for 1 min between contacts of different polarity 500 VAC, 50/60 Hz for 1 min between contacts of same polarity
Impulse withstand voltage	1,500 V (10 x 160 μs) between coil and contacts (conforms to FCC Part 68)	
Vibration resistance	Destruction: 10 to 55 to 10 Hz, 0.75-mm single amplitude (1.5-mm double amplitude) Malfunction: 10 to 55 to 10 Hz, 0.75-mm single amplitude (1.5-mm double amplitude)	
Shock resistance	Destruction: 1,000 m/s² (approx. 100G) Malfunction: 200 m/s² (approx. 20G)	Destruction: 1,000 m/s² (approx. 100G) Malfunction: 100 m/s² (approx. 10G)
Endurance	Mechanical: 15,000,000 operations min. (at 36,000 operations/hr) Electrical: 100,000 operations min. (at 1,800 operations/hr)	
Ambient temperature	Operating: –25°C to 65°C (with no icing)	Operating: –25°C to 70°C (with no icing)
Ambient humidity	Operating: 5% to 85%	
Weight	Approx. 5 g	

Note: The above values are initial values.
Note: 1. The contact resistance was measured with 10 mA at 1 VDC with a voltage drop method.
2. The insulation resistance was measured with a 500-VDC megohmmeter applied to the same parts as those used for checking the dielectric strength.

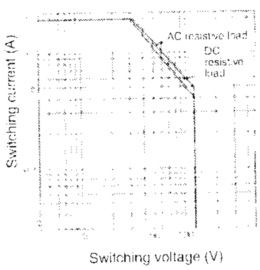
■ Approved Standards

UL478, UL1950, UL508 (File No. E41515)/CSA C22.2 No.0, No.14 (File No. LR31928)

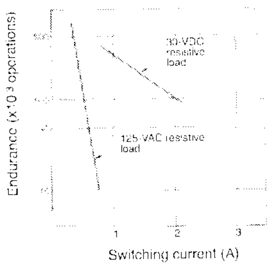
Contact form	Coil ratings	Contact ratings	
		G5V-2	G5V-2-H1
DPDT	3 to 48 VDC	0.6 A, 125 VAC (general use) 0.6 A, 110 VDC (resistive load) 2 A, 30 VDC (resistive load)	0.5 A, 125 VAC (general use) 0.2 A, 110 VDC (resistive load) 1 A, 24 VDC (resistive load)

Engineering Data

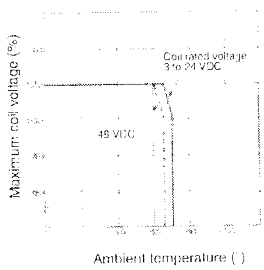
Maximum Switching Power
G5V-2



Endurance
G5V-2

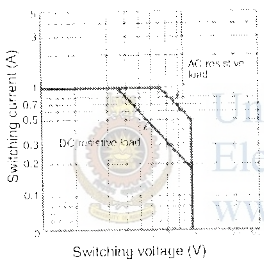


Ambient Temperature vs. Maximum Coil Voltage
G5V-2

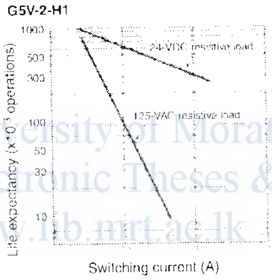


Note: The maximum coil voltage refers to the maxi-mum value in a varying range of operating power voltage, not a continuous voltage.

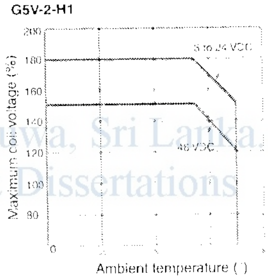
G5V-2-H1



G5V-2-H1



G5V-2-H1



Note: The maximum coil voltage refers to the maxi-mum value in a varying range of operating power voltage, not a continuous voltage.

Appendix – E

Contactor Relay Threshold voltages:

3RH1 contactor relays, 4- and 8-pole

Contactor	Type	3RH11

Rated control supply voltages (the 10th and 11th position of the order number must be changed)

AC operation

Coils for AC 50 and 60 Hz

Rated control supply voltage U_s V AC 50/60 Hz[1]	Control supply voltage at V AC 60 Hz	Option
24	--	B0
42	--	D0
48	--	H0
110	--	F0
220	--	N2
230	--	P0
400	--	V0

For Japan[2]

V AC 50/60 Hz	V AC 60 Hz	Option
100	110	G6
200	220	N6
400	440	R6

For USA and Canada[3]

V AC 50 Hz	V AC 60 Hz	Option
110	120	K6
220	240	P6

DC operation

Rated control supply voltage U_s V DC	Option
12	A4
24	B4
42	D4
48	W4
60	E4
110	F4
125	G4
220	M4
230	P4

1) Coil operating range [illegible]

2) Coil operating range at 50/60 Hz: 0.85 to 1.1 x U_s, at 60 Hz: 0.8 to 1.1 x U_s

3) Coil operating range [illegible]

Operational Amplifier Datasheet :

National Semiconductor

December 1994

LM101A/LM201A/LM301A Operational Amplifiers

General Description

The LM101A series are general purpose operational amplifiers which feature improved performance over industry standards like the LM709. Advanced processing techniques make possible an order of magnitude reduction in input currents, and a redesign of the biasing circuitry reduces the temperature drift of input current. Improved specifications include:

- Offset voltage 3 mV maximum over temperature (LM101A/LM201A)
- Input current 100 nA maximum over temperature (LM101A/LM201A)
- Offset current 20 nA maximum over temperature (LM101A/LM201A)
- Guaranteed drift characteristics
- Offsets guaranteed over entire common mode and supply voltage ranges
- Slew rate of 10V/μs as a summing amplifier

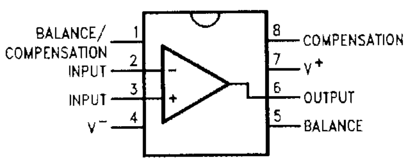
This amplifier offers many features which make its application nearly foolproof: overload protection on the input and output, no latch-up when the common mode range is exceeded, and freedom from oscillations and compensation with a single 30 pF capacitor. It has advantages over internally compensated amplifiers in that the frequency compensation can be tailored to the particular application. For example, in low frequency circuits it can be overcompensated for increased stability margin. Or the compensation can be optimized to give more than a factor of ten improvement in high frequency performance for most applications.

In addition, the device provides better accuracy and lower noise in high impedance circuitry. The low input currents also make it particularly well suited for long interval integrators or timers, sample and hold circuits and low frequency waveform generators. Further, replacing circuits where matched transistor pairs buffer the inputs of conventional IC op amps, it can give lower offset voltage and a drift at a lower cost.

The LM101A is guaranteed over a temperature range of −55°C to +125°C, the LM201A from −25°C to +85°C, and the LM301A from 0°C to +70°C.

Connection Diagrams (Top View)

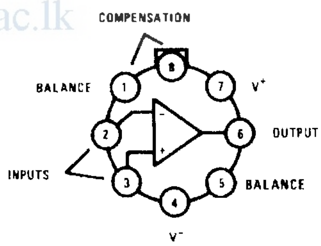
Dual-In-Line Package



TL/H/7752-4

Order Number LM101AJ, LM101J/883*, LM201AN or LM301AN
See NS Package Number J08A or N08A

Metal Can Package

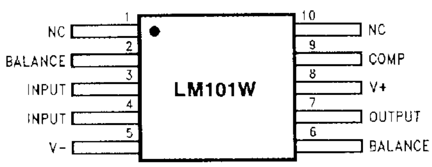


TL/H/7752-2

Note: Pin 4 connected to case.

Order Number LM101AH, LM101AH/883*, LM201AH or LM301AH
See NS Package Number H08C

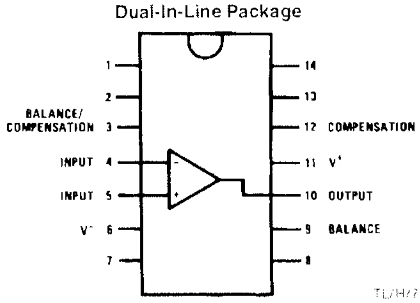
Ceramic Flatpack Package



TL/H/7752-4

Order Number LM101AW/883 or LM101W/883
See NS Package Number W10A

Dual-In-Line Package



TL/H/7752-3

Order Number LM101AJ-14/883*
See NS Package Number J14A

*Available per JM38510/10103

Absolute Maximum Ratings

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

	LM101A/LM201A	LM301A
Supply Voltage	±22V	±18V
Differential Input Voltage	±30V	±30V
Input Voltage (Note 1)	±15V	±15V
Output Short Circuit Duration (Note 2)	Continuous	Continuous
Operating Ambient Temp. Range	−55°C to +125°C (LM101A) −25°C to +85°C (LM201A)	0°C to +70°C
T_J Max		
H-Package	150°C	100°C
N-Package	150°C	100°C
J-Package	150°C	100°C
Power Dissipation at T_A = 25°C		
H-Package (Still Air)	500 mW	300 mW
(400 LF/Min Air Flow)	1200 mW	700 mW
N-Package	900 mW	500 mW
J-Package	1000 mW	650 mW
Thermal Resistance (Typical) θ_{jA}		
H-Package (Still Air)	165°C/W	165°C/W
(400 LF/Min Air Flow)	67°C/W	67°C/W
N Package	135°C/W	135°C/W
J-Package	110°C/W	110°CmW
(Typical) θ_{jC}		
H-Package	25°C/W	25°C/W
Storage Temperature Range	65°C to +150°C	−65°C to +150°C
Lead Temperature (Soldering, 10 sec.)		
Metal Can or Ceramic	300°C	300°C
Plastic	260°C	260°C
ESD Tolerance (Note 5)	2000V	2000V

Electrical Characteristics (Note 3) $T_A = T_J$

Parameter	Conditions		LM101A/LM201A			LM301A			Units
			Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	T_A = 25°C, $R_S \leq$ 50 kΩ			0.7	2.0		2.0	7.5	mV
Input Offset Current	T_A = 25°C			1.5	10		3.0	50	nA
Input Bias Current	T_A = 25°C			30	75		70	250	nA
Input Resistance	T_A = 25°C		1.5	4.0		0.5	2.0		MΩ
Supply Current	T_A = 25°C	V_S = ±20V		1.8	3.0				mA
		V_S = ±15V					1.8	3.0	mA
Large Signal Voltage Gain	T_A = 25°C, V_S = ±15V V_{OUT} = ±10V, $R_L \geq$ 2 kΩ		50	160		25	160		V/mV
Input Offset Voltage	$R_S \leq$ 50 kΩ				3.0			10	mV
Average Temperature Coefficient of Input Offset Voltage	$R_S \leq$ 50 kΩ			3.0	15		6.0	30	μV/°C
Input Offset Current					20			70	nA
Average Temperature Coefficient of Input Offset Current	25°C ≤ $T_A \leq T_{MAX}$			0.01	0.1		0.01	0.3	nA/°C
	$T_{MIN} \leq T_A \leq$ 25°C			0.02	0.2		0.02	0.6	nA/°C

Electrical Characteristics (Note 3) $T_A = T_J$ (Continued)

Parameter	Conditions		LM101A/LM201A			LM301A			Units
			Min	Typ	Max	Min	Typ	Max	
Input Bias Current					0.1			0.3	μA
Supply Current	$T_A = T_{MAX}$, $V_S = \pm 20V$			1.2	2.5				mA
Large Signal Voltage Gain	$V_S = \pm 15V$, $V_{OUT} = \pm 10V$ $R_L \geq 2k$		25			15			V/mV
Output Voltage Swing	$V_S = \pm 15V$	$R_L = 10\ k\Omega$	±12	±14		±12	±14		V
		$R_L = 2\ k\Omega$	±10	±13		±10	±13		V
Input Voltage Range	$V_S = \pm 20V$		±15						V
	$V_S = \pm 15V$			+15, −13		±12	+15, −13		V
Common-Mode Rejection Ratio	$R_S \leq 50\ k\Omega$		80	96		70	90		dB
Supply Voltage Rejection Ratio	$R_S \leq 50\ k\Omega$		80	96		70	96		dB

Note 1: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

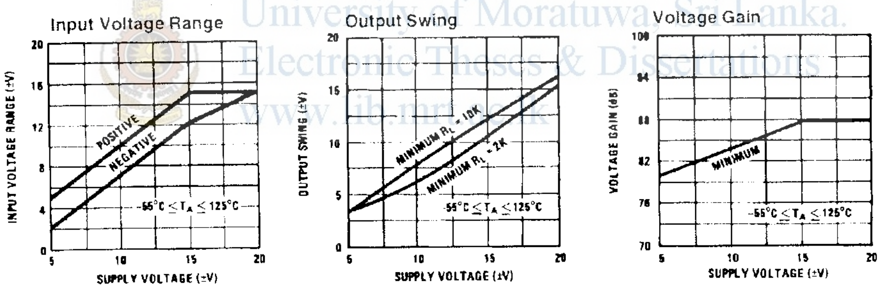
Note 2: Continuous short circuit is allowed for case temperatures to 125°C and ambient temperatures to 75°C for LM101A/LM201A, and 70°C and 55°C respectively for LM301A.

Note 3: Unless otherwise specified, these specifications apply for C1 = 30 pF, ±5V ≤ V_S ≤ ±20V and −55°C ≤ T_A ≤ +125°C (LM101A), ±5V ≤ V_S ≤ ±20V and −25°C ≤ T_A ≤ +85°C (LM201A), ±5V ≤ V_S ≤ ±15V and 0°C ≤ T_A ≤ +70°C (LM301A).

Note 4: Refer to RETS101AX for LM101A military specifications and RETS101X for LM101 military specifications.

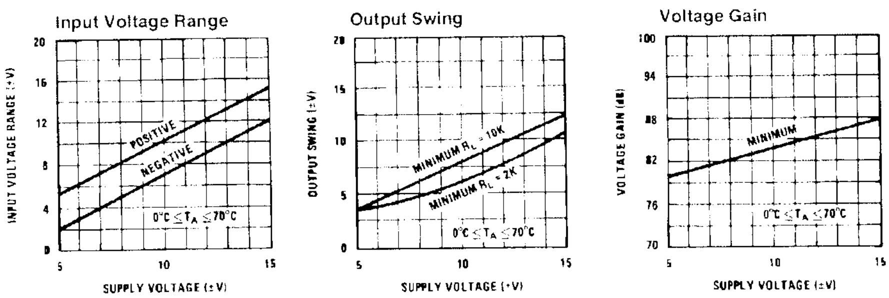
Note 5: Human body model, 100 pF discharged through 1.5 kΩ.

Guaranteed Performance Characteristics LM101A/LM201A



TL/H/7752-5

Guaranteed Performance Characteristics LM301A



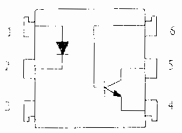
TL/H/7752-6

Optocoupler CNY17-1 Datasheet:

opto Global Supplier of Optoelectronic Solutions
ALL Product Lead Free, RoHs Compliant

CNY17-1
UL # E244343

Schematic:



For dimensions and pin-outs, see the last page of this document.

Features:

1. Current transfer ratio (CTR 40-80% at IF=10mA Vce=5V)
2. High isolation voltage between input and output (Viso = 5300Vrms, 7500Vpk).

Ordering:

Suffix to Standard Part Number

V = VDE Compliant
G = 10mm Lead Spread
S = Surface Mount Lead-form
T = Tape & Reel

Superior OPTO Part Number:

OPTO611

Absolute Maximum Ratings:

Parameter		Symbol	Rating	Unit
Input	Peak forward current	I_{FM}	1	A
	Reverse voltage	V_R	6	V
	Power dissipation	P_D	70	mW
	Collector-emitter voltage	V_{CEO}	70	V
Output	Emitter-collector voltage	V_{ECO}	6	V
	Collector-base voltage	V_{CBO}	60	V
	Emitter-base voltage	V_{EBO}	6	V
	Collector current	I_C	50	mA
	Collector power dissipation	P_C	150	mW
	Total power dissipation	P_{tot}	200	mW
Isolation voltage 1 minute		V_{iso}	5300	Vrms
		Viso	7500	Vpk
Operating temperature		T_{opr}	-55 to +100	°C
Storage temperature		T_{stg}	-55 to +125	°C
Soldering Temperature 10 seconds		T_{sol}	260	°C

Electrical Characteristics:

Parameter		Symbol	Conditions	MIN	TYP	MAX	Unit
Input	Forward voltage	VF	IF=20mA	–	1.2	1.4	V
	Peak forward voltage	VFM	IFM=0.5A	–	–	3.5	V
	Reverse current	IR	VR=4V	--	--	10	uA
	Terminal capacitance	Ct	V=0, f=1kHZ	–	30	--	pF
Output	Collector dark current	ICEO	VCE=20V	--	–	0.1	uA
Transfer characteristics	Current transfer ratio	CTR	IF=10mA, VCE=5V	40	--	80	%
	Collector-emitter saturation voltage	VCE(sat)	IF=10mA, Ic=2.5mA	--	0.1	0.4	V
	Isolation resistance	Riso	DC500V	5×10^{10}	10^{11}	--	ohm
	Floating capacitance	Cf	V=0, f=1MHZ	--	0.6	1.0	Pf
	Cut-off frequency	fc	Vcc=5V,Ic=2mA,RL=100ohm	--	80	--	kHz
	Response time (Rise)	tr	Vce=2V,Ic=2mA,RL=100ohm	–	5	20	us
	Response time (Fall)	tf			4	20	us

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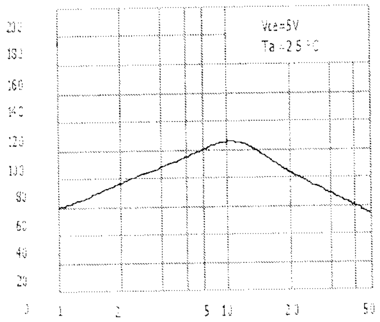
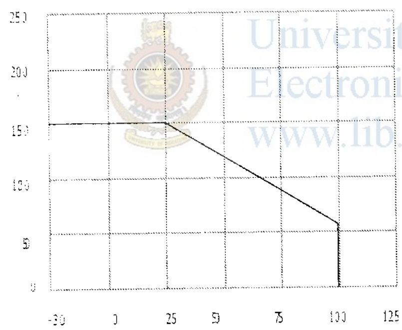
Fig. 1 Current Transfer Ratio
Vs. Forward Current



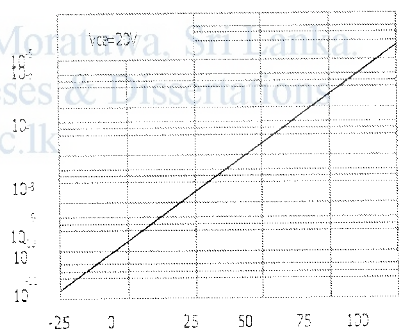
Forward current IF(mA)

Fig.2 Collector Power Dissipation
vs. Ambient Temperature



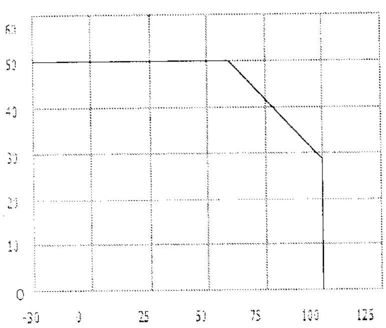
Ambient Temperature Ta(°C)

Fig.3 Collector Dark Current vs.
Ambient Temperature



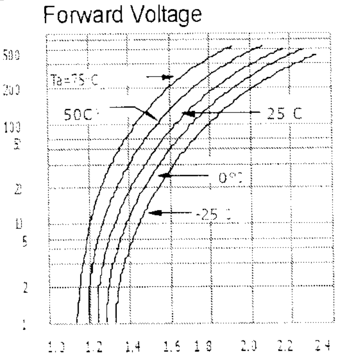
Ambient Temperature Ta(°C)

Fig.4 Forward Current vs.
Ambient Temperature



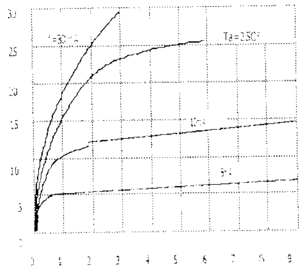
Ambient temperature Ta(°C)

Fig.5 Forward Current vs.
Forward Voltage



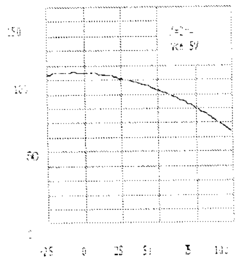
Forward Voltage VF(V)

Fig.6 Collector Current vs. Collector-emitter Voltage



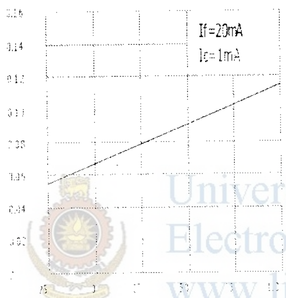
Collector-emitter Voltage V_{CE} (V)

Fig.7 Relative Current Transfer Ratio



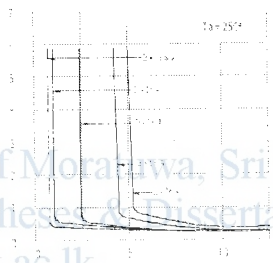
Ambient Temperature Ta(°C)

Fig.8 Collector-emitter Saturation Voltage vs. Ambient Temperature



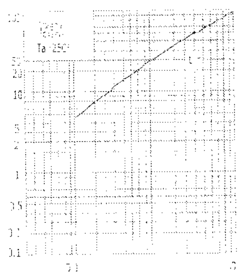
Ambient Temperature Ta(°C)

Fig.9 Collector-emitter Saturation Voltage vs. Forward Current



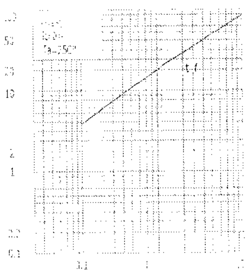
Forward Current IF(mA)

Fig.10 Response Time vs. Load Resistance



Load Resistance RL(Kohm)

Fig.11 Response Time vs. Load Resistance



Load Resistance RL(Kohm)

Photo graphs of the machine in production: