CHARACTERIZATION OF DAC

oleh

Shukri b Korakkottil Kunhi Mohd

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ABSTRACT

This dissertation presents about characterization of Digital-to-Analog Converter (DAC). It is included a theory, problem facing, problem solving, characterization techniques, results and lastly conclusion. DAC chip used here for characterization process was ICM7363 Quad 12 bit from IC Microsystems (ICmic). ICM7363 is a serial digital input type of DAC. In order for the DAC to work properly, serial data input, clock signal, chip select signal and clear signal are needed. 8051 microcontroller board was built for data generation and as well as all the signal needed in order to activate the DAC. In this project 8051 microcontroller circuit were combined with DAC circuit and a set of switches. There are 17 switches available. One of these switches used as a test functionality switch. Function of this switch is to indicate whether the DAC is working or not. Other 16 switches used as data input of DAC. 8051 microcontroller was programmed to read the condition of all those switches and then generate signals to the DAC. DAC is then producing an analog output that is proportional with digital input value. The program was written in assembly language. This program was then compiled and burnt into ROM. Program start running whenever supply is connected. The output produced by the DAC is then can be measured and characterized. Measuring tool used here is digital mutimeter. From the output, DAC parameters such as resolution, accuracy, offset error, full-scale error, differential non-linearity, integral non-linearity, full scale range, settling time, maximum conversion rate and signal-to-noise ratio can be characterize. Resolution of the DAC is shown by plotting a histogram of the output. Typical output value for adjacent input is 0.01V. This is the DAC resolution. DNL and INL of DAC are shown by plotting a graph of the output. From here, ideal value and measured value can be compared. DNL and INL are approximately 1LSB for intermediate voltage that is around 2V and 3V. It is more than 1LSB when it comes to bigger voltage. Actually there is no certain quantitative value to describe this. Other parameters result such as full scale range is 4.68V, offset error is 0.010V and gain error is 93.6%. This measurement can be performed by applying an appropriate data input. The value can be shown quantitatively. From measurement, we conclude that this DAC is a very high resolution and accuracy. The project shows a good result and succeeds to achieve its objective.

ABSTRAK

Laporan ini membentangkan berkenaan mempercirikan penukar digital ke analog (DAC). Ia termasuk teori, masalah yang dihadapi, cara menyelesaikan masalah, kaedah pencirian dan keputusan pencirian dan akhir sekali adalah kesimpulan. DAC yang difokuskan disini adalah model ICM7363 kuad 12 bit daripada IC Microsystem (ICmic). ICM7363 adalah dari jenis yang menggunakan input digital secara siri. Untuk mengaktifkan DAC ini, isyarat seperti data input sesiri, isyarat jam, isyarat pemilihan cip, dan isyarat jelas diperlukan. Dalam projek ini, litar mikropengawal 8051 dibina. Tujuan pembinaan litar mikropengawal ini adalah untuk menjana isyarat data sesiri dan juga isyarat lain yang diperlukan bagi mengaktifkan DAC. Litar yang dibina dalam projek ini menggabungkan litar 8051 mikropengawal, litar DAC dan juga litar suis. Terdapat 17 suis yang digunakan untuk masukan data dan isyarat ujian. Keadaan ujian adalah dimana suis ujian 'ON'. Ini adalah bertujuan untuk menunjukkan DAC berfungsi atau tidak. 8051 mikropengawal diprogramkan untuk membaca status keadaan suis dan kemudian menjana isyarat kepada DAC. Program ditulis dan kemudian dimasukkan ke ROM yang terdapat di dalam 8051 mikropengawal. Program bermula sebaik sahaja sumber disambung. Keluaran yang dihasilkan oleh DAC kemudiannya boleh diukur dan dicirikan. Keluaran DAC diukur dengan menggunakan multimeter. Daripada nilai keluaran ini, beberapa parameter DAC seperti resolusi, kejituan, ralat pengimbangan, ralat skala penuh, perbezaan tak linear (DNL), kamilan tak linear (INL), julat skala penuh, masa selesai, kadar penukaran maksima dan nisbah isyarat ke hangar (SNR) boleh dicirikan. Resolusi DAC dapat ditunjukkan dengan memplot histogram bagi nilai keluaran DAC. Nilai keluaran DAC bagi input bersebelahan dapat ditunjukkan disini. DNL dan INL bagi DAC ini dapat ditunjukkan dengan memplot graf untuk isyarat keluaran DAC. Dari graf, nilai yang diukur dan nilai unggul dapat dibandingkan. Resolusi, DNL, dan INL adalah nilai yang biasa diperolehi dan ini dapat dilihat dari histogram dan graf. Tiada nilai kuantitatif tertentu untuk parameter ini. Parameter lain seperti julat skala penuh, ralat pengimbangan dan ralat pekali dapat dperolehi dengan data masukan sepatutnya. Nilai-nilai ini dapat ditunjukkan secara kuantitatif. Daripada pengukuran, didapati DAC ini beresolusi dan kejituan yang tinggi.Projek menunjukkan keluaran yang memuaskan dan berjaya mencapai objektif.

ACKNOWLEDGEMENT

Thanks to Allah for giving me strength and allow me to complete my final year project. Without HIS permission, this project could never been completed. During the process, I learned a lot about IC (integrated circuit) chip and how to operate them. Most of acknowledgement that I must give here goes to my supervisor Prof Madya Dr. Othman Sidek for his guidance in this project. Special thanks also to Dr. Tun Zainal Azni Zulkifli as my co-supervisor for giving me a full support in order to run this project. Without him, present study could have been possible and I would never goes this far. It is his patience and gentle manner that driven me to focus in this project.

I also want to express my gratitude to Universiti Sains Malaysia for giving me a chance to complete my study so that I will become a better person soon. Without the university, all the ambition could never be achieved.

Along the way, I would like to thanks to Associate Prof. Dr. Zaid B. Abdullah for his explanation about (Digital-to-Analog Converter) DAC application. I would also like to thank to technician Mr. Khairul Anuar Abdul Razak at Microprocessor Laboratory, Mr. Amir Hamid and Mr. Azhar Zabidin at Mechatronic Laboratory and lastly Mr. Elias Zainuddin at PCB (Printed Circuit Laboratory) Laboratory for their contribution in this project.

Finally to all my family members, my friends and those who are involved in this project directly or indirectly. I would like to express my appreciation to all of them for the cooperation, support and encouragement.

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CHAPTER 1

INTRODUCTION

Digital-to-Analog Converter (DAC) is a device that converts a digital code (usually binary code) to an analog signal (usually voltage). In electronic, DAC is a link between world of transducer that usually work with analog value and digital data collection. An analog to digital converter (ADC) performs reverse operation (Hoeschele, 1994). Electrical signal from transducer which is an analog form and proportional to the phenomena being measured is then converted to digital by ADC for computational or decision making purposes. This computed digital value is then converted back to an analog form using DAC to perform action by driving an actuator or other equipment. Digital circuits and digital techniques have become widely used nowadays in almost all area of life such as computers, robots, entertainments and others. With the growth of digital systems, there is also an increase in use of ADC and DAC to perform the conversion (Tocci, 2001).

1.1 DAC Application

There is various application of DAC such as in audio visual system and also in signal processing. In audio system, signal from microphone or sound source is an analog form. This signal is then converted to digital for the purpose of storage or processing where it is then converted back to an analog signal for playback. In personal computer, this function usually done in a sound card and nowadays there are external devices that perform this function externally in order to improve the sound quality. In visual system, video signal stored in a computer is in digital form. This signal must be converted to an analog form in order for it to be displayed on an analog computer. Generally the purpose of analog and digital conversion is for signal processing, computing and decision making so that an action can be perform. An analog signal that is convert to digital value for the purpose of computing or processing so that it can perform action when convert back to analog (Tocci, 2001).

1.2 Basic Digital-to Analog Converter Function

Digital-to-analog Converter (DAC) is a device that converts data from digital representation into analog representation as shown in **Figure 1.1**. DAC convert a signal from state one and zero into signal that have numbered of states.

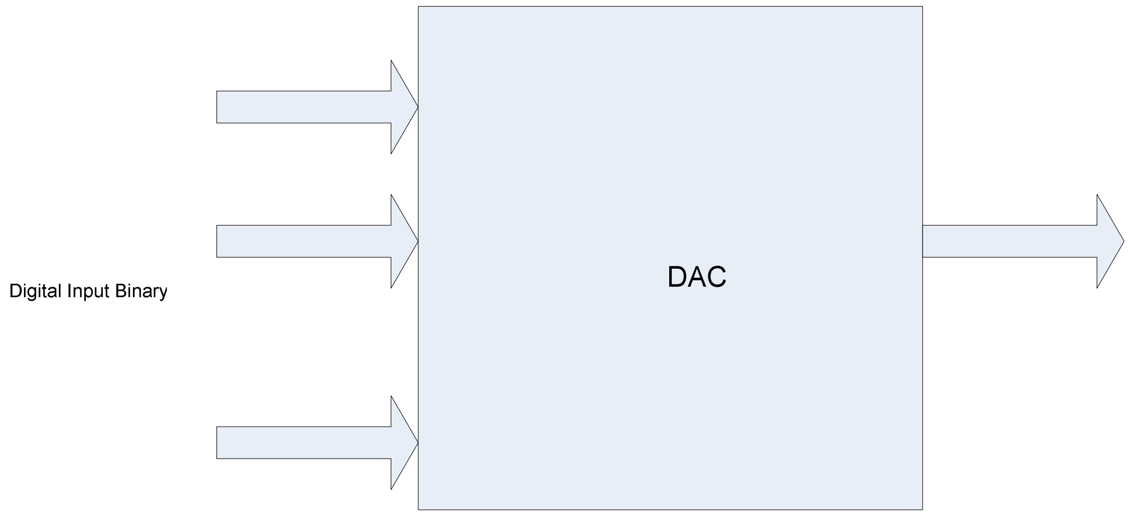

Figure 1.1: Block diagram of Digital-to-Analog Converter

Generally, digital input value converts into an analog value using the following equation (Plassche, 1994):

$$V_{out} = \sum_{m=0}^{n-1} B_m 2^m R_{ref} \qquad (1.1)$$

Where;

V_{out} is analog output value

R_{ref} is a reference value

Note that equation 1.1 represents an n-bit converter. B_{n-1} represents the Most Significant Bit (MSB) of the converter and B_0 is the Least Significant Bit (LSB). The factor 2^m indicates binary bit. Not all DAC devices produce a voltage as its output. There are DAC available that produce current as its output and in this case, above formula cannot be used (Rudy Van Plassche, 1994).

1.3 Digital/Analog Representation and System

Digital representation is the quantity that is represented by symbols called digit. Digital representations are discrete in nature and there is no ambiguity when reading the value of a digital quantity. Digital devices are a device that works with digital value such as DAC. A digital system is a combination of devices designed to manipulate logical information or physical quantities that are represented in digital form or quantities that only can take discrete values. Analog representation is a quantity represented by a voltage, current, or meter movement that is proportional to the value of an item being measured. Analog quantity can vary over continuous range of values. An analog device is a device that works with analog representation such as ADC and DAC. An analog system contains devices that manipulate quantities that are represented in an analog form. In analog systems, the quantities can vary over a continuous range of values (Tocci, 2001).

1.4 Objectives

There are varieties of DAC available in store to meet various applications requirement. Most system can be implemented using any type of DAC. However, sometime certain systems need certain requirements to guarantee its function and this becomes a problem for the designers to choose which device suitable for it. The choice of conversion device always not simple and there is a need to know the device performance. Lack of knowledge of device performance can performed inability of the whole system to work properly.

Performance specifications or parameters for digital-to-analog converter chips included resolution, settling time, differential nonlinearity (DNL), integral nonlinearity (INL), power dissipation and special features. Resolution measure the number of discrete levels used to represent a signal and is usually defined in bits. Settling time is the time required for an output to reach a final value within the limit of a defined error band. The DNL error is the differences between the ideal values and measured output values. The INL error is the amount that a measured transfer function deviates from an ideal transfer function. It is defined in a straight line drawn from zero to full scale. Special features such as on-chip electrostatic discharge (ESD) protection.

This project will develop a way to characterize certain parameters of DAC so that designers have an idea which DAC to be use based on this parameter. DAC chosen here is ICM7363 which used serial digital input as its input code. So, certain parameters from this DAC will be characterized. This project also can be used as an IC (Integrated Circuit) tester to test other DAC which is in the same model. This project may also become a pioneer for other type of chip.

1.5 Project Methodology

Project methodology is as shown in the **Figure 1.2** below.

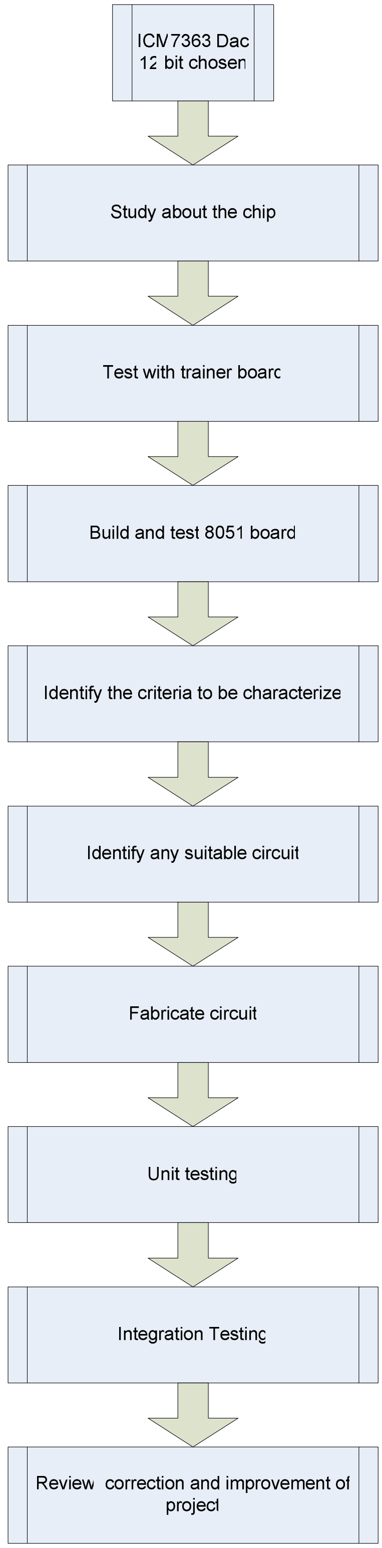

Figure 1.2: Project Methodology

1.6 Thesis Organization

Chapter one basically is about an introduction of DAC, its applications, basic DAC function and elaborates a little bit on analog and digital term. Common parameters for DAC as well as its definition are discussed in Chapter 2. After defining common DAC parameters, Chapter 3 will explained about DAC chosen to be characterized in this project that is ICM7363. All about ICM7363 operation as well as its PCB layout will be showed here. Chapter 4 will focused on 8051 microcontroller since it will be used to interface with ICM7363 DAC. All the schematic and how to build 8051 microcontroller circuit will be discussed here. Finally Chapter 5 will interface 8051 microcontroller with ICM 7363 DAC. All flowcharts on how to program the DAC and result of this interfacing project will be discussed here. Chapter 6 will conclude the project and there are appendices at the end of the dissertation.

CHAPTER 2

DAC PARAMETERS

DAC has certain parameter that is needed to be known by the system designer before it can be used. Lack of knowledge in the DAC parameters will affect the whole systems. This chapter will discussed common DAC parameters as well as its definition.

2.1 Resolution

Resolutions are normally given in bits. It indicates the smallest increment in the DAC output with correspond to 1 LSB (Least Significant Bit) input change. For example, 12 bit DAC equal to 2^{12} that is 4096 in decimal. In this case the resolution is 1/4096 of the output change.

2.2 Full Scale Range

Full Scale Range is a maximum output signal for the DAC and can be in current or voltage and this depend on type of the DAC whether it is a current output or voltage output.

2.3 Offset Error

Offset Error is a difference between an ideal and actual DAC output when zero digital code applied to the input.

2.4 Gain Error

Gain Error indicates how closely the analog output of a DAC matches its ideal value at full scale digital code applied to the input.

2.5 Voltage Reference Input Range

This indicates the minimum and maximum voltage that was used as the reference voltage for DAC.

2.11 Differential Nonlinearity (DNL)

DNL is the difference between an actual or measured output change and the ideal output change for a digital input change of 1 LSB (Hoeschele, 1994). It is measured by applying a ramp code to the input of DAC. The step between every pair of the adjacent codes should not exceed or below 1 LSB. In another words, DNL represents the error from 1 LSB for every step. **Figure 2.1** show an example of DNL for a three bit DAC.

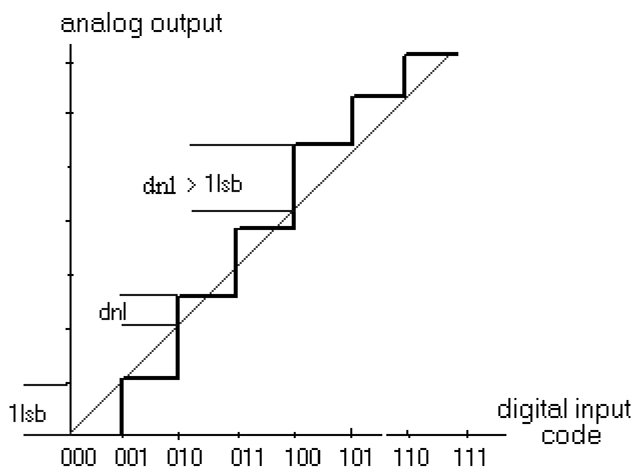

Figure 2.1: Example of Differential Nonlinearity

2.12 Integral Nonlinearity (INL)

INL is the maximum deviation of the output from an ideal straight line between zero and full scale points (Hoeschele, 1994). It shows how the output deviates from an ideal straight line. An example of INL for three bit DAC is as shown in **Figure 2.2**. It is measured in LSB.

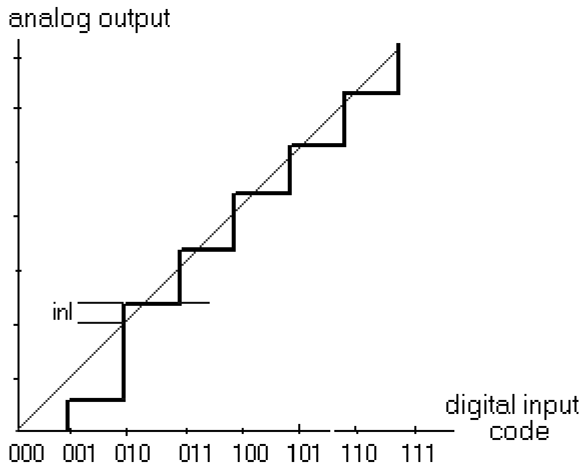

Figure 2.2: Example of Integral Nonlinearity

2.13 Settling Time

Settling time is a time required by output of the DAC to reach and remain about specified error band in its steady state or final value. It is measured from an input transition until the output was produced.

2.14 Maximum DAC Conversion Rate

Maximum DAC conversion rate is a maximum input signal frequency that the DAC can handle (Hoeschele, 1994). It is base on equation 2.1 below.

$$\text{Maximum DAC conversion rate} = 1/\text{Settling time} \qquad (2.1)$$

2.15 Signal-to-Noise Ratio (SNR)

This is the ratio of the analog output of a DAC when the input code is at full scale and the analog output of a DAC when the input code is set to zero. SNR is better when the value is bigger.

CHAPTER 3

ICM7363 DIGITAL TO ANALOG CONVERTER (DAC)

Digital-to-Analog Converter that will be characterized in this project is ICM7363 from IC Microsystems. Refer **Appendix A** for the datasheet of the DAC. This DAC is 12 bit Monotonic DAC and use resistor string architecture. It included a 1.25V reference voltage output. There are 4 DAC contained in a single chip. Each of this DAC can be driven individually by a different reference voltage and there is a gain of two at the output. The DAC used Serial Data Input for digital data input unlike other DAC normally used parallel input. All the digital input is CMOS/TTL compatible. Refer **Appendix B** for differences between CMOS and TTL. In this project 8051 Microcontroller is used to generate signal and serial data input for the DAC. For this chapter we will be focusing on DAC and 8051 Microcontroller will be discussed in detail in Chapter 4. ICM7363 has a serial data output for easy daisy-chaining applications.

3.1 ICM7363 Package and Pin Description

ICM7363 Package is as shown in **Figure 3.1** below. It is a 16 pin chip.

Figure 3.1: ICM7363 Package

Pin description of ICM7363 is as shown in **Table 3.1** below.

Table 3.1: Pin Description of ICM 7363

Pin	Notation	Description
1	V_{DD}	Supply Voltage (5V)
2	V_{OUTA}	DAC A Output
3	REF_A	Voltage Reference DAC A
4	V_{OUTB}	DAC B Output
5	REF_B	Voltage Reference DAC B
6	REFOUT	Output Voltage (1.25V)
7	$\overline{CLR}$	Clear Input / Reset DAC
8	SDI	Serial Data Input
9	SCK	Serial Clock Input
10	SDO	Serial Data Output
11	$\overline{CS}$	Chip Select
12	REF_C	Voltage Reference DAC C
13	V_{OUTC}	DAC C Output
14	REF_D	Voltage Reference DAC D
15	V_{OUTD}	DAC D Output
16	GND	Ground

3.2 Serial Interface and Logic

This section explained about on how the chip operates**. Figure 3.2** shows a serial interface signal diagram which is needed in order for the chip to function properly. It consists $\overline{CS}$, SDI and SCK signal. $\overline{CS}$ is a chip select signal used to initiate and terminate data transferring. SDI is a serial data input signal and SCK is serial clock input signal.

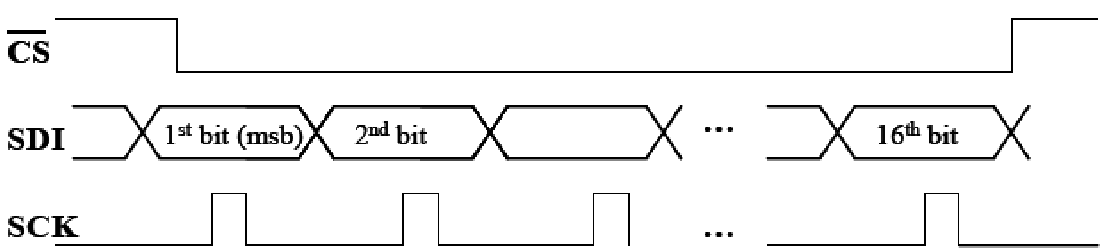

Figure 3.2: Interface Signals

Data is loaded ICM7363 using 4 wire serial interfaces. One that is not define in **Figure 3.2** is CLR (Clear Signal) used to reset DAC. Data is loaded in 16 bit which consists of 4 Most Significant Bit (MSB) address bit as control bits followed by 12 bits of data. From **Figure 3.2**, $\overline{CS}$ pin should initially be HIGH (SDI and SCK are ignored while $\overline{CS}$ is HIGH), while SCK pin should initially be held LOW. To start data transfer, $\overline{CS}$ is first brought LOW and this activate DAC serial interface. While $\overline{CS}$ is LOW, data is serially transferred to the DAC at each positive edge of SCK. 16 clock pulses are needed in order to transfer all the required 16 bit command and data. First transferred bit is MSB. After all 16 bit data has been transferred, $\overline{CS}$ needs to be brought back to HIGH. Transitions of $\overline{CS}$ from LOW to HIGH terminate data transferred and execute loaded command. Note that if there is more than 16 bit are transferred, only the last 16 bit will be considered. If less than 16 bit are transferred, the remaining bits are taken from previous communication session. T**able 3.2** shows the data format of ICM7363. **Table 3.3** list control commands of ICM7363 and its function.

Table 3.2: 16 bit Command and Data Format

Control Word				Digital Data											
Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
C3	C2	C1	C0	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0

Table 3.3: ICM 7363 Control Commands

C3	C2	C1	C0	Functions
0	0	1	0	Load Data into DAC A
0	1	0	1	Load Data into DAC B
1	0	0	0	Load Data into DAC C
1	0	1	1	Load Data into DAC D
1	1	1	0	Load Data into DAC A-D
1	1	1	1	No Operation

3.3 Reference Input and Output

Each DAC has its own reference input pin which can be driven from ground to V_{DD} – 1.5V. There is a gain of two in the output of DAC which means output of DAC is multiply by two. Output voltage of DAC can be calculated using equation 3.1.

$$Vout = 2 \times (V_{REFIN} \times D) / 2^n \quad (3.1)$$

Where:

V_{REFIN} is a voltage reference of DAC, D is a digital input code in decimal and n is a number of bits which in this case is 12 for ICM 7363. Example of calculation for digital input code of 001111111111B which means it is 1023 in decimal with 2.5V as its reference voltage.

$$Vout = 2 \text{ x } (2.5V \text{ x } 1023)/2^{12}$$
$$= 1.25V$$

3.4 Communication Interface Using 8051 Microcontroller

In this project, 8051 microcontroller is used to generate signals for this DAC so that the output produces from the DAC can be measured. **Figure 3.3** shows a block diagram of communication interface between 8051 Microcontroller and ICM7363.

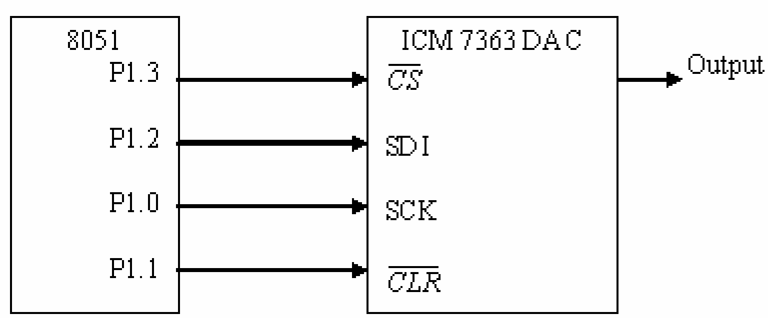

Figure 3.3: Communication Interface 8051 Microcontroller and ICM7363

3.5 ICM7363 Circuit Design And Fabrication

In order to operate the DAC, supply voltage used in this project is +5V. ICM7363 consists of four DAC in a single chip which means that it must have four test points in order to measure the output voltage. All these test points are connected using Header. In this project, each DAC is driven by an external reference voltage. This voltage is actually coming from supply but has been regulated to +2.5V using voltage divider circuit as shown in **Figure 3.4**. In the voltage divider, resistor value is calculated using equation 3.2.

$$Vout = \frac{R_2}{R_1 + R_2} Vin \tag{3.2}$$

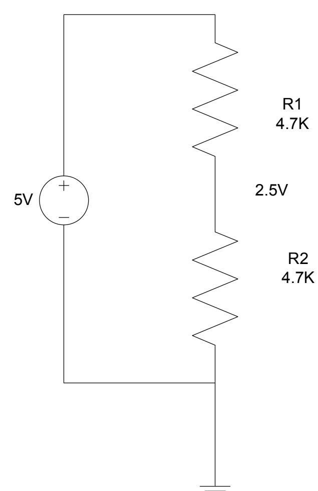

Figure 3.4: Voltage Divider

3.5.2 Layout of ICM7363 DAC Circuit

ICM7363 DAC board is built using PCB (Printed Circuit Board) fabrication. For this purpose there is a need to build its layout. Firstly schematic of circuit is designed by referring to **Appendix D** for the full circuit. Circuit in **Appendix D** integrates between DAC, switch, and 8051 microcontroller. However, individual circuits need to be built in order to test and check its functionality. All the circuit will be combined later. Single DAC circuit is as shown in **Figure 3.5** below. Layout of the circuit is then printed on the board.

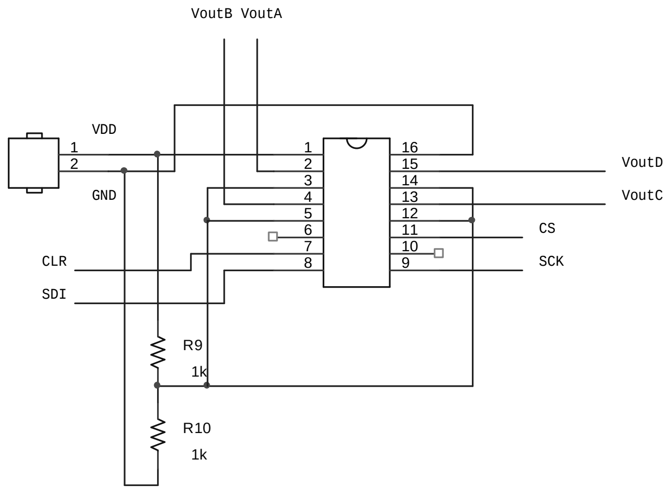

Figure 3.5: ICM7363 Circuit

Component needed to build ICM7363 circuit board are listed below in **Table 3.4**.

Table 3.4: List of ICM7363 Board Component

Component/Instrument	Amount
ICM7363 DAC	1
Header 2	4
4.7k Resistor	2

ICM7363 DAC is then soldered on the PCB board as well as voltage divider circuit and header. Unit testing is performed on the circuit using 8051 trainer board to ensure it is functioning properly.

3.6 Example of Application

Example of application using this DAC is on temperature sensing application. It is an alternative method without using an expensive ADC (Analog to Digital Converter). Block diagram of this application is as shown in **Figure 3.6**. Temperature sensor produce analog output and this output is comparing with analog output from DAC using comparator.

Whenever analog output from temperature sensor reach its maximum or minimum value, comparator will give signal to microcontroller and condition of temperature sensor can be known.

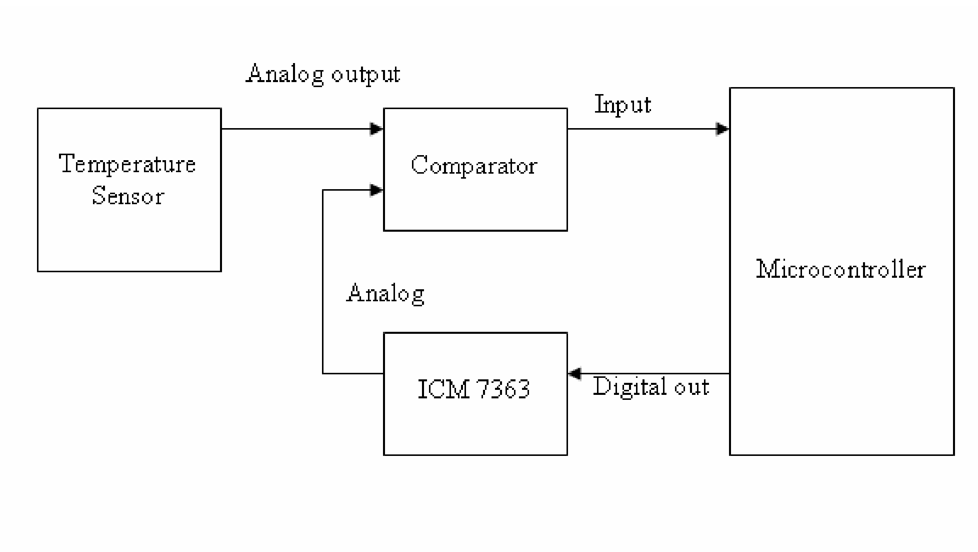

Figure 3.6: ICM 7363 Application

CHAPTER 4

8051 MICROCONTROLLER

Microcontrollers consists of fixed amount of RAM (Random Access Memory), ROM (Read Only Memory), I/O (Input/Output) ports and timer all in a single chip (Mazidi, 2000). **Figure 4.1** shows components available inside 8051 Microcontroller. Microcontrollers are widely used in an embedded system to do one task and one task only. An example of embedded system that use microcontroller is a printer. The task and only task of printer is to print. Microcontroller inside the printer used in order to control getting the data and printing it. 8051 microcontroller introduced by Intel Corporation had RAM, ROM, two timers, one serial port and four ports all on a single chip.

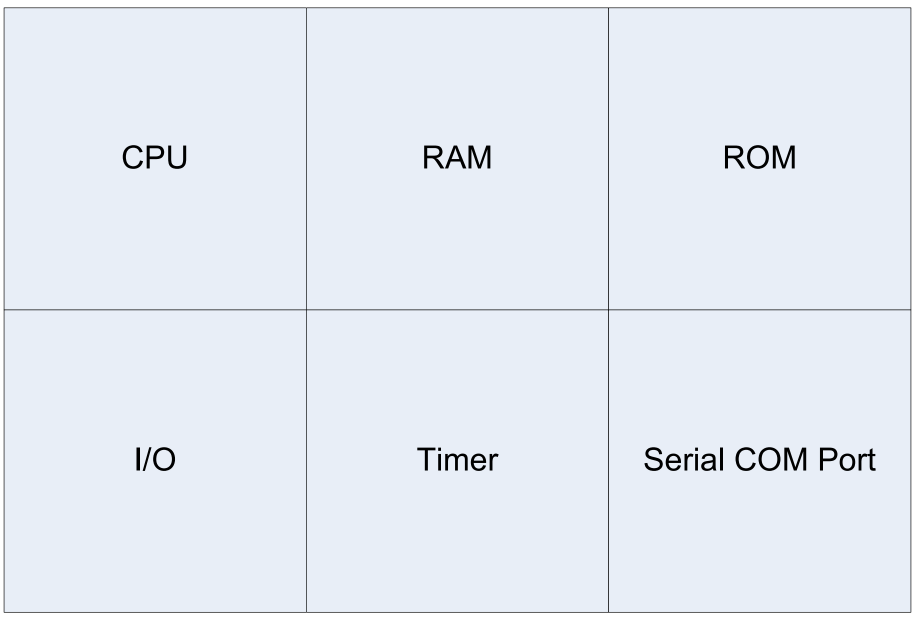

Figure 4.1: Component inside 8051 Microcontroller

4.1 Pin Description of the 8051 microcontroller

8051 microcontroller may come in different packages whether it is DIP (dual in line package) or SMT (surface mount technology). Both of them have 40 pins for various functions (Mazidi, 2000). **Figure 4.2** below show 8051 pin diagram. Pin V_{cc}, GND, XTAL1, XTAL2, RST, EA, and PSEN must be connected in order for the system to work.

Figure 4.2: 8051 Pin Diagram

Pin 40 (Vcc) used to provide supply voltage to the chip. Its value is +5V. Pin 20 (GND) act as ground pin. Pin 18 and 19 is XTAL1 and XTAL2 pin. 8051 microcontroller has an on chip oscillator but requires an external clock to run it (Mazidi, 2000). So, the quartz crystal oscillator is connected to XTAL1 and XTAL2 pin together with two capacitor of 33pF value as shown in **Figure 4.3**.

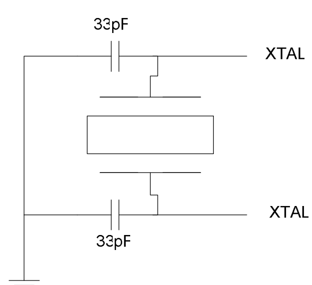

Figure 4.3: XTAL connection to 8051

Size of crystal frequency attached to the 8051 decides the speed at which 8051 timer run. The frequency of the timer is always 1/12 the frequency of the crystal attached to the 8051. In this project, we will use XTAL frequency of 11.0592 MHz Based on formula below:

$$ClockFrequncy = 1/12 \times CrystalFrequency \tag{4.1}$$

$$T = 1/ClockFrequncy \tag{4.2}$$

The clock period for this project is 1.085 µs.

Pin 9 (RST) is the RESET pin. It is an active high input. Once applying a high pulse to this pin, the microcontroller will reset and terminate all activities. All values in the register also will be lost. **Figure 4.4** show how to connect RST pin. The programmed will be restarted again once applying a high pulse to the RST pin. In order for the RESET input to be effective, it must have a minimum duration of 2 machine cycles. In this project 2 machine cycle equal to two times clock period that is 2.17 µs. Push button used as RESET switch in this project.

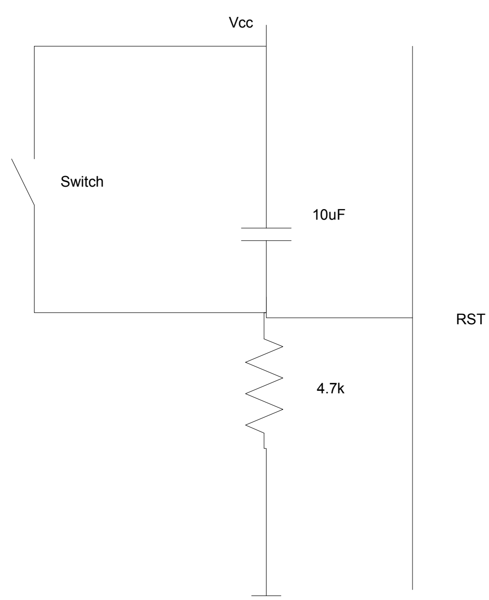

Figure 4.4: RESET Circuit

Pin 31 or EA pin must be connected to either Vcc or GND. EA stand for External Access. The 8051 family member such as 8751, come with on chip ROM. In this case, programmed code is stored in on chip ROM and EA must be connected to V_{cc}. For other family members that have no on chip ROM, programmed code is stored in an external ROM. So, in this case EA pin is connected to GND to indicate programmed code was stored externally. In this project, there is no ROM in the microcontroller used, so EA pin is connected to GND.

Pin 29 is a PSEN pin. PSEN stands for programmed store enable and this is an output pin. It is an output signal and must be connected to OE pin of an external ROM contained program code. PSEN used by 8051 to send signal in order to fetch program code from an external ROM. This only can be done when EA is connected to GND. If EA is connected to Vcc, PSEN cannot be activated.

Pin 30 is a ALE pin. ALE stands for Address Latch Enable and this is an output pin. Port 0 provides both address and data. So when port 0 is being used as data path, ALE pin is held LOW and when port 0 is being used as address path, ALE pin is held HIGH. The ALE pin is used for demultiplexing process between address and data by connect it to 74LS373 chip.

4.2 ROM (Read Only Memory)

ROM used here is UV-EPROM type that is UV erasable programmable ROM. Once the programmed burnt inside a ROM, the programmed can be erased using UV radiation. All UV-EPROM chips have a window on top of it. When this window exposed to UV radiation, the content in it will be erased. To program the chip, its content must be erased. Program code is loaded using programmer.

4.3 74LS373 D Latch

74LS373 used to extract the addresses from the P0 pins since this pins send both data and address. Whenever 8051 microcontroller want to use P0 as address bus, it will send HIGH to ALE pin. Else, if 8051 use P0 as data bus, ALE pin is brought LOW.

4.4 74LS138 Decoder

74LS138 decoder has 3 inputs and 8 outputs. Block diagram of 74LS138 decoder is as shown in **Figure 4.5**.

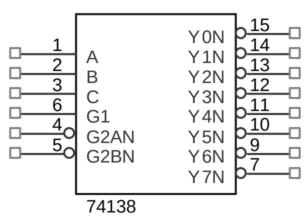

Figure 4.5: 74LS138 Block Diagram

Each Y output is connected to CS of chip for allowing control by 74LS138. Programmed address for ROM and 8255 were determined from here. Look at **Table 4.1** below.

Table 4.1: Range of Address for 8255 and ROM

IC chip	C	B	A												
	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
8255(Min)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
(Max)	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ROM (Min)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(Max)	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1

In this project, 8255 is connected to Y1. Y1 means 1 in decimal. So, based on **Table 4.1**, 001B equals to 1 in decimal. When 8255 connected to Y1 its range of address are from 2000H-2FFFH. ROM is connected to Y0. So, to determine address for ROM, 0 equal to 000B. From here we know that address range for ROM are from 0000H-0FFFH.

4.5 8255 Chip

8255 is a chip that can expand I/O port of 8051. It is a 40 pin chip and has three ports. These three ports can be programmed to be input or output. **Figure 4.6** shows pin position of 8255.

Figure 4.6: 8255 Chip

4.5.2 8255 Pin description

PA0-PA7, PB0-PB7 and PC0-PC7 as indicated in **Figure 4.6** can be programmed as all input or as all output. RD and WR pin connected to RD and WR pin 8051. The purpose of this pin is to read and write data to 8255. D0- D7 pin allow 8255 to send and receive data from 8051. RESET pin connected and once it activate, all ports of 8255 will be initialized as high. CS is connected to 74LS138. It is connected to allow controlled by 74LS138. A0 and A1 is to select specific ports. It is based on **Table 4.2** below:

Table 4.2: 8255 Ports Selection

A1	A0	Selection
0	0	Port A
0	1	Port B
1	0	Port C
1	1	Control Word
x	x	Not select

4.6 8051 Microcontroller Board

There is no on chip ROM in the 8051 microcontroller used in this project. So, the programmed code is stored in an external ROM. In order to connect this ROM, P2 and P0 will be used as address and data path. Therefore, the only I/O port left is P1. To expand this I/O port, 8255 is used. **Figure 4.7** shows a block diagram of 8051 microcontroller board for better understanding. Port 0 and port 2 is an address path from 8051 to ROM. As we know earlier, port 0 can be a data path or an address path. Therefore, 74LS373 latch used to extract from address from port 0. If it is an address, it can go through and if it is data, it is blocked from go through 74LS373 and the data will go into data bus. 8051 communicate with ROM and 8255 through data bus.

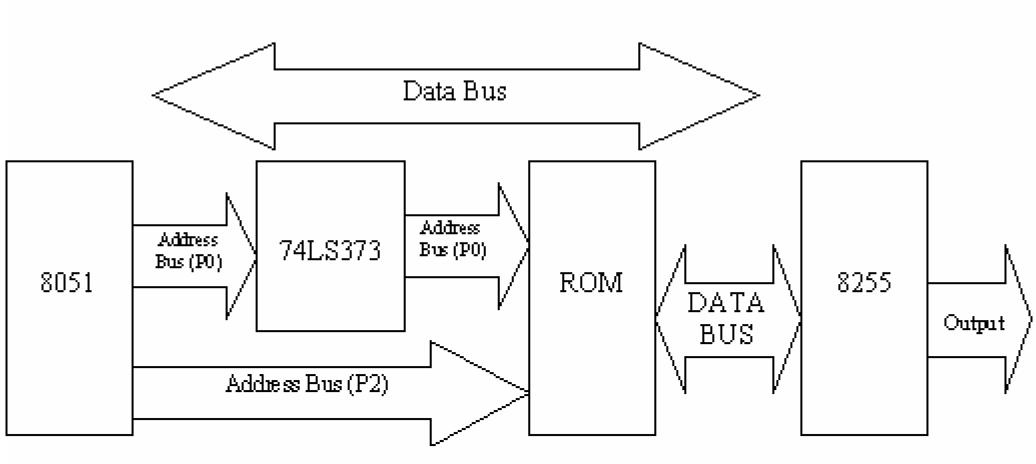

Figure 4.7: Block Diagram of 8051 Microcontroller Board

4.7 Fabrication of 8051 Microcontroller Board

In this project, 8051 Microcontroller Board will be built using PCB (Printed Circuit Board) fabrication. To fabricate PCB, there is a need to build its layout first. The process is actually similar as to build ICM 7363 Board which has been explained in **CHAPTER 3**. Before starting to build 8051 microcontroller board layout, schematic of 8051 Microcontroller board is needed. Refer to **Appendix C** for the schematic of 8051 microcontroller board. Once the layout is completed, it is then printed on PCB board and parts can be soldered on it. Component for 8051 Microcontroller Board are as shown in **Table 4.3**. This 8051 board is then combined with DAC board as in **Appendix D**.

Table 4.3: List of 8051 Microcontroller Board

Component	Amount Used
Header 2	1
Crystal	1
33pF Capacitor	2
8051 Microcontroller	1
Reset Switch	1
4.7k Resistor	1
10µF Capacitor	1
7414 Buffer	1
74LS138 Decoder	1