DESIGN AND CONSTRUCTION OF A FOUR (4) CHANNEL AUDIO MIXER AND SELECTOR

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2000/9780EE

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Dedication

I dedicate this project to Jesus, the One who has brought me thus far, to whom I owe my entire existence.

Declaration

I, ADELUMOLA Oluwasegun V.A., declare that work was done by me and has never been presented elsewhere for the award of a degree. I also hereby relinquish the copyright to the Federal University of Technology, Minna.

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(Name of external Examiner)

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Acknowledgement

I thank God, who is my All in All, all through my life, He has been the Master and King over my life helping, supporting, making ways for me and blessing me; Thank you Jesus. To my wonderful supervisor, Engr. Musa Abdullahi, (HOD, Elect/Compt Eng'ring dept.) I say a big thank you Sir, for your immense assistance and understanding through this period, you are a father indeed. To every lecturer who has imparted me with knowledge in one way or another, I say thank you, God bless you.

I must acknowledge the immense contribution of my parents, Pastor Joel Adelu and Mrs. Sarah Adelu through to this point of my life. My Siblings; Bola Oyewo, Christiana, Remilekun, and Oluwafemi Adelu, you are the best, your support, love and understanding is matchless. To my love, Omowumi Jegede, I say thank you for your support, love, encouragement, care and understanding. You made the journey worthwhile and much easier, God bless you.

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My Mummy, Mrs. Gadani only God can reward you for your love and support, a mother indeed you are. Dr and Mrs Benson, thank you so much. Nana Atta (my sister and friend) Gideon Ugbenyo, Segun Oyeleke (Apostle), Abraham Adejo, Ikechukwu Ubendu; space will not permit me to mention everyone; thank you all, God bless you so so so much.

Abstract

This project is based on the design and construction of an audio instrument. It involves the switching and mixing of four (4) audio channels. Each channel can be linked to a common output through a digital technique. The intensity of any selected channel(s) can be manually adjusted using a variable resistor. Also, the design incorporates a low-power audio amplifier for boosting the mixed channels. The result is linked to an output socket for expansion whereby additional devices such as a powered amplifier is connected. The digital selections of involved channel(s) to a common output greatly minimize or eliminate serious distortion associated with manual option. The design merely provides a simple, effective, and cheap audio process.

The basic concept of the design is the application of Complementary Metallic Oxide Semiconductor (CMOS) bilateral switches. Such switches are digitally controlled. Every channel is related to a two (2) button switch; one for switching ON and the other for switching OFF. Therefore, the overall design result is an economic electronic audio equipment.

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Chapter 1

1.0 Introduction

1.1 Introduction

Audio devices are based on signals with frequencies ranging from 2Hz to 20000Hz. The signals within this frequency range can be heard with the human ear [12]. The frequency range is used for any form of sound production; speech and or music. It is quite evident that audio mixers are common electronic audio devices. They are designed for increasing the strength and improving the overall quality of audio signals. They have other numerous applications for audio processing. This project involves one of such in form of both selecting and mixing of four audio channels. The device involves digital switching to minimise noise or distortion in the involved sound production. Mixing is done through four simple and readily available variable resistor circuits, one for each channel.

The project is based on Complementary Metallic Oxide Semi-conductor (CMOS) integrated circuits (ICs). Without doubts, the nice characteristics of the CMOS (zero quiescent current, rail-to-rail output swing and good noise immunity) make it the logic choice [16]. The logic provides reasonable compatibility, low power consumption, high flexibility and simplicity.

1.2 Aims and Objectives of the Project

The project is aimed at the design and construction of a 4-channel audio selector/mixer; it is however broken down into the following:

- Ability to identify the various components necessary and their alternatives for the design.
- Mix various (four) input signals while amplifying the output.
- Taking low level input signals and boosting their levels sufficiently with minimum noise and distortion.
- Relating various electronic components' functions.

1.3 Methodology

The project mainly involves the application of the 4066B and the 4013B integrated circuits. The first device (i.e. the 4066B IC) is used for digitally controlled switching. This device allows the flow of analogue signal through it in both directions with insignificant resistance. Four of such devices are used one for each involved audio channel that is incorporated into the design. The switching is attributed to 10W noise and distortion.

Moreover, the application of 4013B (a latching device) into the design is merely for controlling the involved digitally controlled analogue switches. Buttons are connected to the inputs of the device that allow the users to independently control or activate the latches. A latch is a device that serves as a temporary buffer memory, it is the most fundamental memory device used in digital electronics [17]. The outputs of the latches are connected to the analogue switch for control purpose.

The mixing involves a variable resistor for each audio channel adjustment of a particular resistor allows the current flowing into corresponding audio channel to be altered [14]. This operation results into desired variation of the strength of the involved audio signals.

In addition, the four audio channels are joined into a common terminal. The resulting signal is amplified by a low power amplifier. The amplifier allows the processed audio signal to be heard in a speaker. The parts are altogether carefully connected to yield an acceptable and desired result.

1.4 Scope of the Project

The project is limited to four audio channels. Each channel can be digitally selected. The mixing features of the project are quite manually achieved through the application of simple variable resistors. The incorporated audio amplifier is of low power. The involved integrated circuits (ICs) are the Complementary Metallic Oxide Semi-conductors (CMOS) type for better circuit flexibility and performance.

1.5 Limitation of the Project

Modern audio production often requires a larger audio channel device; therefore, the project is quite limited in application. The absence of modern audio effects like additional treble, mid and bass in the design further increases its limitation. Although the design is relatively digital; its performance in that respect is small. The acquisition of the involved circuit diagram was quite a task. Infact the cornerstone of this project is relevant information for the internet; especially those websites of integrated circuits manufacturers' manuals [see appendixes 1 and 2].

Chapter 2

2.0 Literature Review/Theoretical Background

2.1 Literature Review

Audio devices work with audio frequencies (generally 20 hertz to 20,000 hertz). Early audio devices were based on ***vacuum tubes*** also known as ***"valves"*** [18]. Most modern audio devices are based on solid state devices like transistors, FETs and MOSFETs, but there are still some designers who prefer tube based amplifiers, claiming they have a 'warmer' sound [9]. Key design parameters for audio electronic equipments are frequency response, gain, noise, and distortion. These are interdependent, increasing gain often leads to undesirable increases in noise and distortion. While negative feedback actually reduces the gain, it also reduces noise, oscillation and distortion [4].

The age of audio signal processing started when John Ambrose Fleming, scientific adviser to the Marconi company invented the diode in 1904 based on an observation by Thomas Edison (Edison received U.S. Patent 307031 from this observation) [8]. The unidirectional current and construction of the original diode led to Lee DeForest placing another electrode, a bent wire or screen, between the filament and plate electrode in 1906. DeForest discovered that the current flow from filament to plate depended on the voltage applied to the grid, and that the current drawn by the grid was very low, being composed of the electrons which are intercepted by the grid. As the applied voltage of the grid varied from negative to positive, the current of electrons flowing from the filament to the plate would vary accordingly. Thus the grid was said to electrostatically "control" the plate current. The resulting three-electrode device was therefore an excellent and very sensitive amplifier of voltages. DeForest called his invention the ***audion***, but it is better known as a ***triode***. The tube equivalents of a transistor, triodes were used in early tube audio amplifiers [7]. The non-linear operating characteristic of the triode gave early tube audio amplifiers a distortion at low volume. This is not to be confused with the distortion that tube amplifiers exhibit at high volume levels (known as the tube sound). To remedy the low volume distortion problem, engineers plotted curves of the applied grid voltage and resulting plate currents, and discovered that there was a range of relatively linear operation. In order to use this range, a negative voltage had to be applied to the grid to place the tube in the "middle" of the linear area with no signal applied. This was called the ***idle condition***, and the plate current at this point the ***idle current*** [18].

Today this current would be called the ***quiescent*** or ***standing*** current. The controlling voltage was superimposed onto this fixed voltage, resulting in linear swings of plate current for both positive and negative swings of the input voltage. This concept was called ***grid bias*** [2]. Tubes were ubiquitous in the early generations of electronic devices, such as radios, televisions, audio amplifiers, and early computers such as the Colossus which used 2000 tubes, the ENIAC which used nearly 18,000 tubes, and the IBM 700 series [13]. Unlike transistors, vacuum tubes are inherently immune to the electromagnetic pulse effect of nuclear explosions. This property kept them in use for military applications long after transistors had replaced them elsewhere. Tubes were also considered by many people in the audiophile, professional audio, and musician communities to have superior audio characteristics over transistor electronics. There are many companies who still make specialized audio hardware utilizing tube technology. Tubes' characteristic sound when overloaded is widely used in electric guitar amplification, and has defined the sound of some genres of music, including classic rock and rhythm and blues. Since most guitar amplifiers mount the electronic chassis -

including tubes - inside the same cabinet as the speaker, microphonic effects occur as the tube's elements vibrate with the music and help to create the special vacuum tube guitar amplifier sound. (For high-fidelity use, the vacuum tubes should be isolated from the vibration of the speakers.) Vast array of devices were built during the 1920-1960 period using vacuum-tube techniques. Most such tubes were rendered obsolete by semiconductors. Audio devices such as amplifiers, based on transistors, became practical with the appearance of cheap transistors in the late 1960's [3]. The transistor was developed at Bell Laboratories in 1948. Large scale commercial use didn't come until much later owing to slow development. Transistors used in most early entertainment equipment were the germanium types. When the silicon transistor was developed it took off dramatically. The first advantages of the transistor were relatively low power consumption at low voltage levels which made large scale production of portable entertainment devices feasible. Interestingly the growth of the battery industry has paralleled the growth of the transistor industry. In this context I include integrated circuits which of course are simply a collection of transistors grown on the one silicon substrate.

For compatibility, efficiency and economic audio related electronics require complex circuitry in a limited space. The only way through is the development of integrated circuits. The integrated circuit was first conceived by a radar scientist, Geoffrey W.A. Dummer (born 1909), working for the Royal Radar Establishment of the British Ministry of Defence, and published in Washington, D.C. on May 7, 1952. Dummer unsuccessfully attempted to build such a circuit in 1956 [11]. The first integrated circuits were manufactured independently by two scientists: Jack Kilby of Texas Instruments filed a patent for a "Solid Circuit" made of germanium on February 6, 1959. Kilby received patents US3138743, US3138747, US3261081, and US3434015.

Robert Noyce of Fairchild Semiconductor was awarded a patent for a more complex "unitary circuit" made of Silicon on April 25, 1961 [15]. The break through in integrated circuit technology allows numerous features and importance to audio electronics. Digital Signal Processing is encouraged through the leading technology. Moreover, it is quite obvious that modern electronics are all about integrated circuits.

2.2 Theoretical Background

2.2.1 The typical operation of audio selectors/mixers

Modern audio equipments work with the application of solid state electronics. The ability or grading of such devices is focused on the number of input channels, incorporated digital functions, quality of sound production, compatibility with similar device e.t.c. the figure 2.1 below shows a simple layout of audio selectors/mixer.

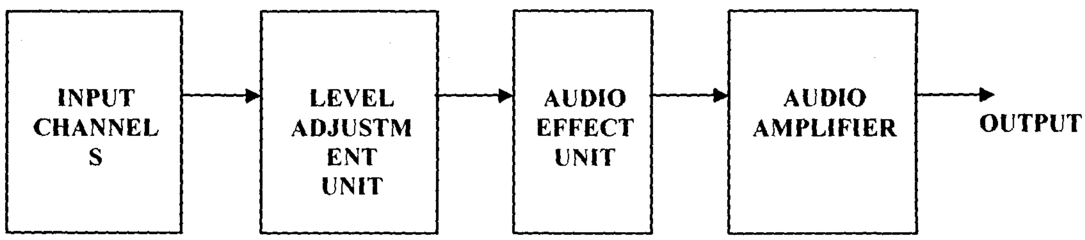


Fig 2.1 A simple layout of audio selectors/mixers

The number of input channels depends on the complexity and purpose of the involved device's design. The number is as low as two and as far in hundreds. The more the number of channels the better is the reacting audio production. This is because each component of the audio production is handled independently. Therefore, bad portion of an audio signal can be easily figured out and amended. Level adjustment unit is designed to independently vary the amplitude of the involved audio channels. The handling of this particular section is determined by choice of the users. The main component of the volume control unit is usually the variable resistor. They are usually ganged together. Modern electronics allows digital alternatives to the early manual operation. This technique minimizes signal distortion. Special effects such as echo, bass, equalizer, pitch, channel selection e.t.c are usually required for good sound production. The project is limited to channel selection. Modern related devices possess numerous special audio effects. Credible sound productions are achievable through the application of computer interfacing and software utilizations, example of such software are SoundForge®, Audioblast, etc [10].

The early blocks usually reduce the strength of input audio signal or channel overall strength of the device. Therefore, an amplifier is usually incorporated to the output stage for significant boosting of the output audio signal. Auxiliary amplifiers are usually used for final power strengthening of the produced sound.

Chapter 3

3.0 Design And Implementation

3.1 Design Analysis

The project includes the following sub circuits:

1. Input terminals
2. Control latches
3. Bilateral switches
4. Audio amplifier
5. Power unit

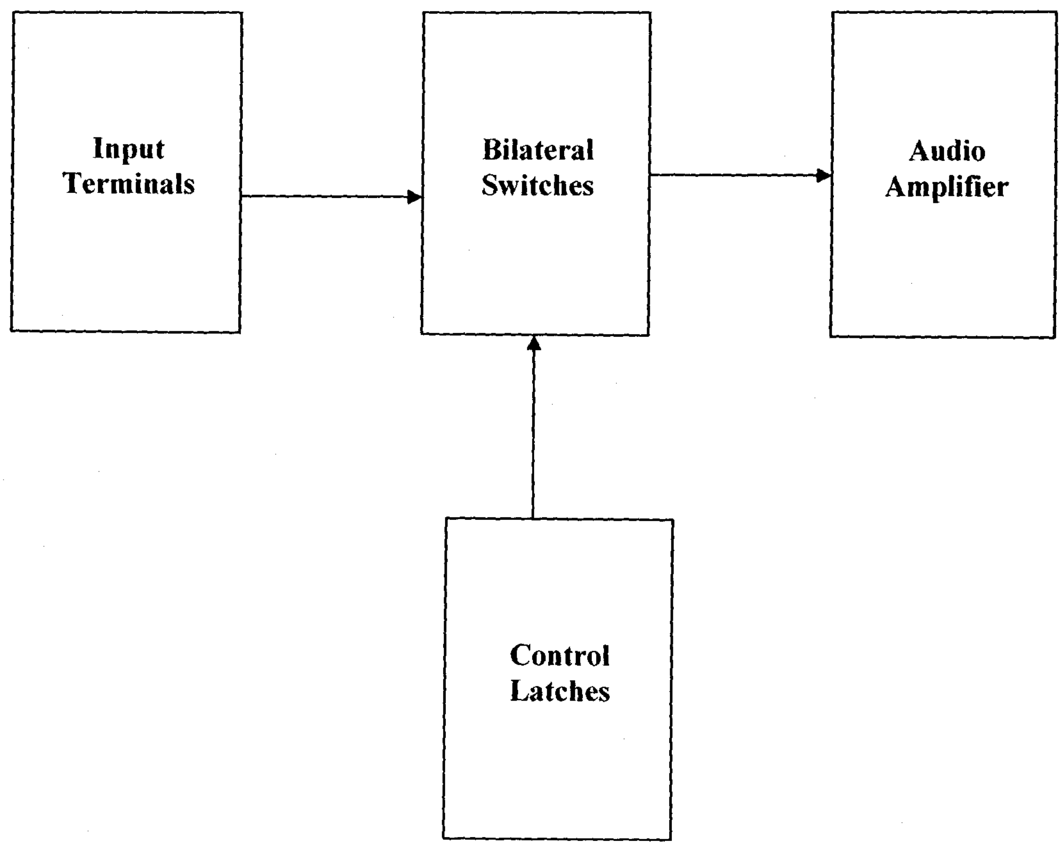


Fig. 3.1 Block diagram of the whole circuit

The power unit is common to all the parts. Therefore it is not very required in the block diagram.

3.1.1 Input Terminals

The input terminals are four in number. They are terminals through which the four audio channels are inputted into the device. Each terminal is simply a two (2) point female socket or plug. One of the points is grounded and the other part is required for the audio signal input.

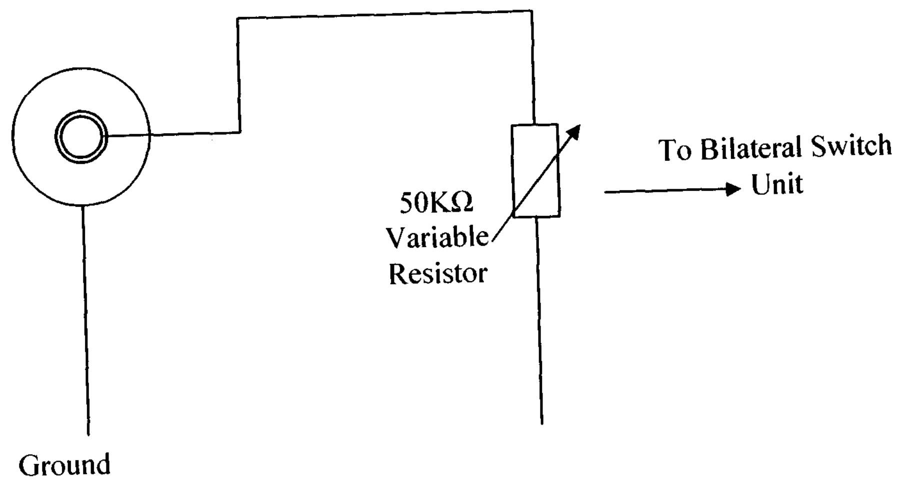


Fig.3.2 A single input terminal with a corresponding variable resistor.

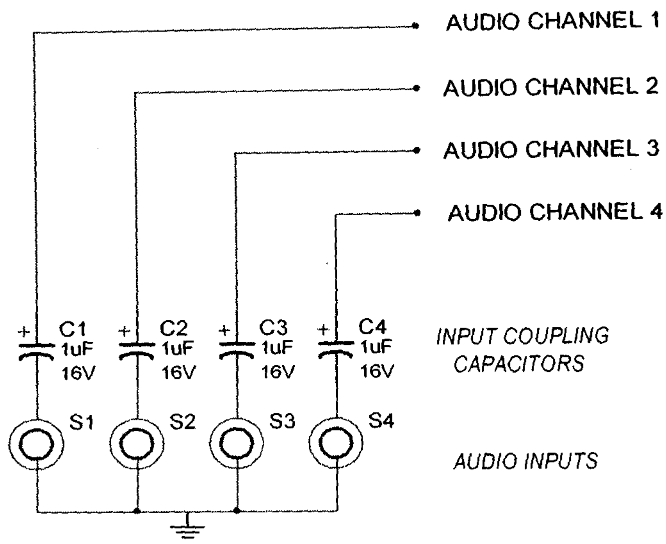


Fig. 3.3 The signal input unit

A 50KΩ variable resistor is associated with each input terminal. The resistor is used for adjusting the audio signal level of a particular audio channel to which it is connected.

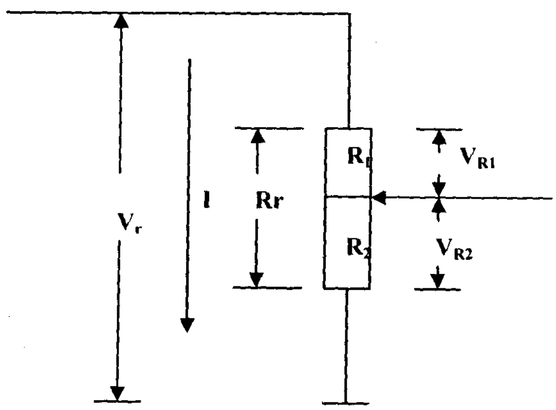


Fig 3.4 The Variable resistor terminal

V_{r2} is required for input into the device:

$$V_{r2} = V_r - V_{r1}$$

$$V_{r2} = (R_r - R_1)I$$

$$V_{r2} = (R_r - R_1)(V_r/R_r)$$

$$V_{r2} = \frac{V_r(R_r - R_1)}{R_r}$$

3.1.2 Control Latches

The control latches are required for switching on and off or controlling the four input channels. In fact, the devices operate the bilateral switches for signal/channel selection. The latches are derived from the 4013B CMOS integrated circuit [5]. The device possesses two independent D-type latches as shown below.

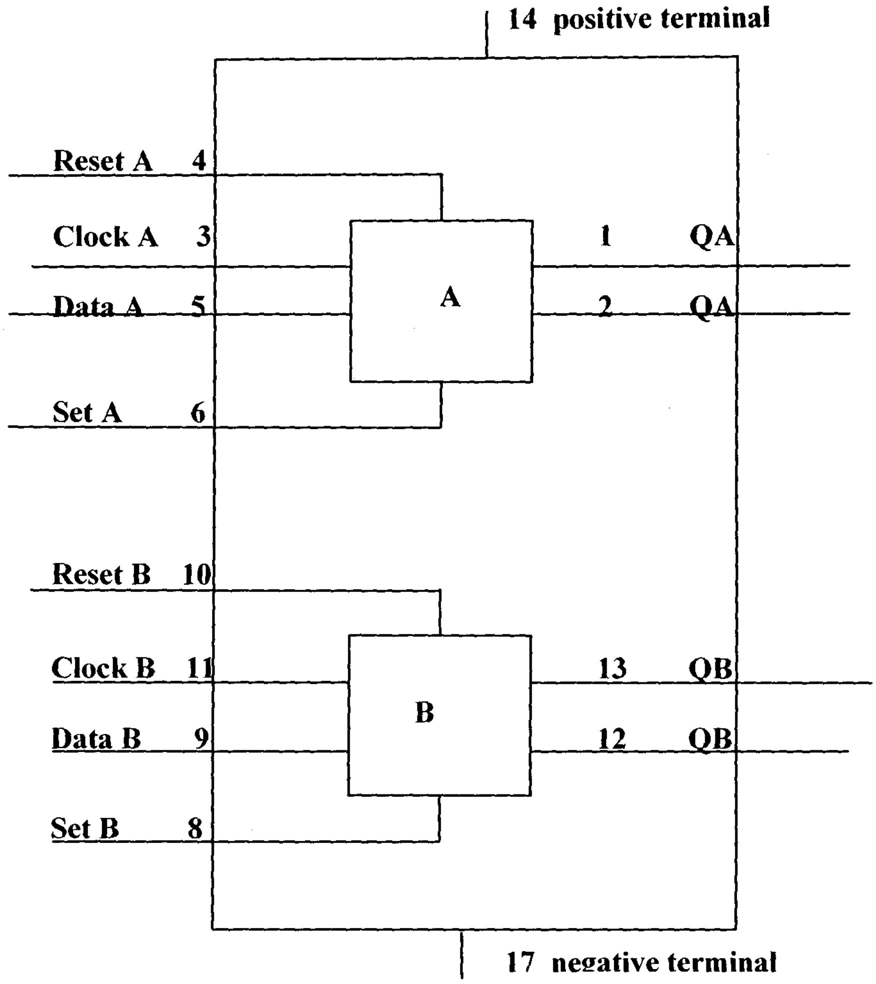


Fig 3.5 The pin configuration of the 4013B IC

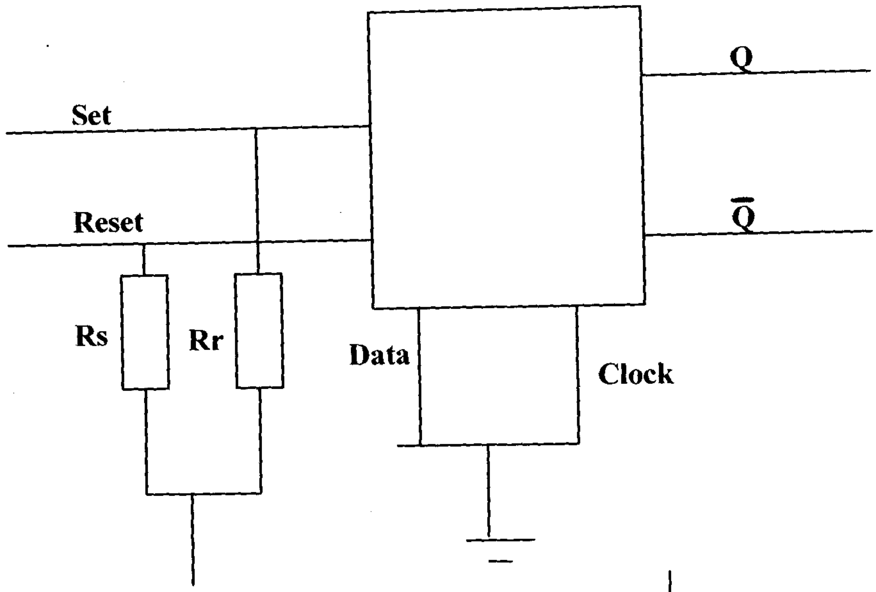


Fig. 3.6 An SR latch.

Rs = Rr = R

$1M\Omega \geq R \geq 1K\Omega$ (It is a CMOS Specification)

Resistances Rs and Rr are required to put the corresponding inputs to initial logical level of 0 (zero). This allows input stability. The related inputs are actively high. Below is a simple SR latch truth table:

Table 3.1 A simple latch truth table

Set	Reset	Q	$\bar{Q}$
0	0	X	$\bar{X}$
1	0	1	0
0	1	0	1
1	1	1	1

X and $\bar{X}$ are Initial logical conditions

Four latches are required for the involved four audio channels; one latch for each channel. Therefore two 4013B integrated circuits are needed for the circuit. The leading device is quite readily available and common for such purposes. The fact that it is a CMOS device allows very low power consumption and a high degree of flexibility which are very important factors in the design and construction of any electronic device or systems.

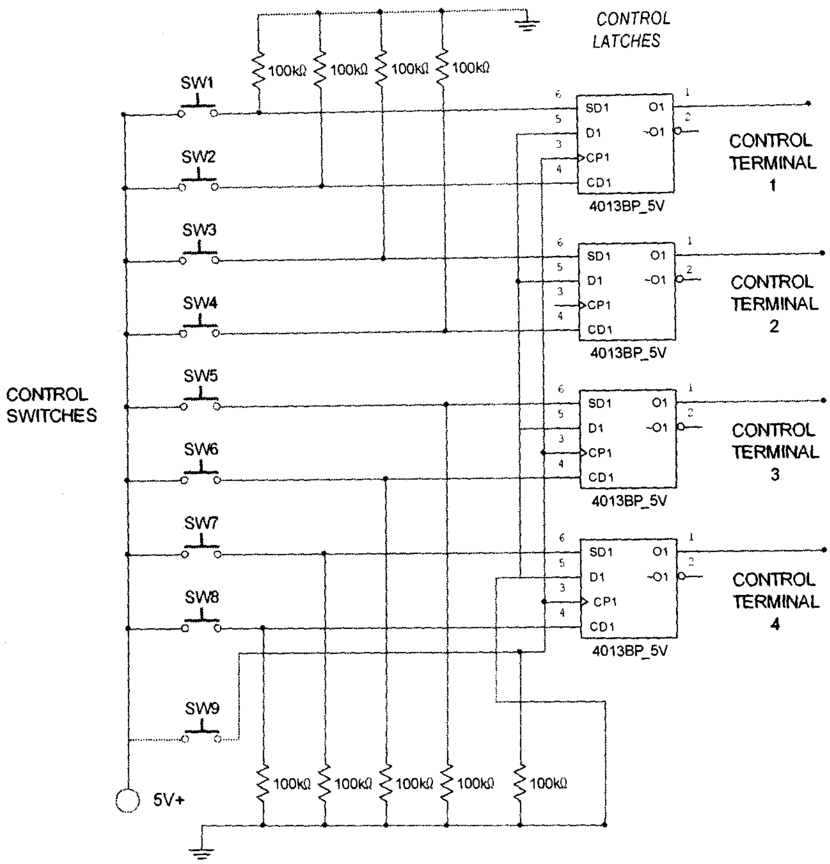


Fig. 3.7 The control latches

The latches are manually controlled through push buttons SW1 to SW8. Two buttons are required for each latch; one for changing the Q output of a particular latch to logical 1 (one) and the other for logical 0 (zero). The Q outputs of the latches are control terminals for the bilateral switches. When pressed, the push buttons are used for sending high logical level signals to corresponding terminals at the latches. The grounded resistors are not indicated in this diagram. The $\overline{Q}$ outputs of the latches are used for light indication purpose. Each of such terminals is connected to a Light Emitting Diode (LED) with a series current limiting resistor.

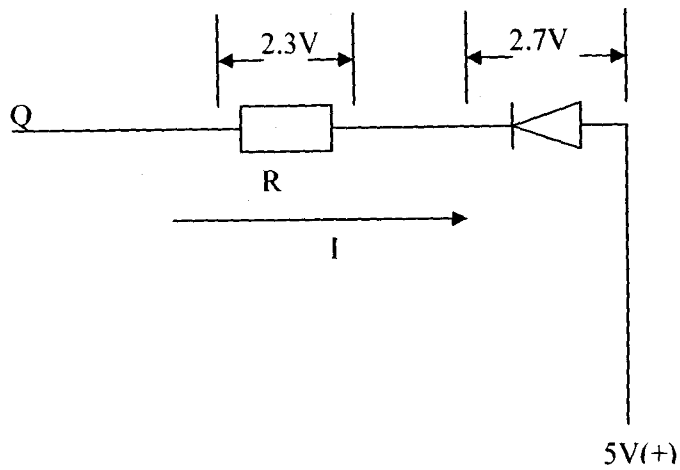


Fig. 3.8 The light indicator circuit

A particular light emitting diode (LED) is put into forward bias when corresponding Q terminal is logical 0 (zero) or low. 2.7V is required across each light emitting diode (LED) and a current of about 10mA.

Therefore,

$$R = \frac{\text{Voltage across the resistor}}{\text{Electric current through the resistor}}$$

$$R = \frac{5 - 2.7}{10 \times 10^{-3}}$$

$$R = \frac{2.3}{10 \times 10^{-3}}$$

$$R = 230\Omega$$

220Ω resistors are used for this purpose here. It possesses similar result with the calculated value. The light indicators only show when a particular channel is on and that indicates that the channel is in use at that time. The table below shows the standard resistor colour codes indicating their corresponding resistance values.

Table 3.2 Resistor colour code

Colour	Number	Multiplier	Tolerance
Black	0	1	
Brown	1	10	
Red	2	100	
Orange	3	1000	
Yellow	4	10000	
Green	5	100000	
Blue	6	1000000	
Violet	7	10000000	
Gray	8	100000000	
White	9	_	
Gold	_	0.1	10%
Silver	_	0.01	_
Body	_	_	20%

3.1.3 Bilateral Switches

The 4066B CMOS integrated circuit forms the bilateral switches. It is a quad bilateral switch intended for the transmission or multiplexing of analogue and or digital signals. It is pin-for-pin compatible with the other common devices like the 4016B, but exhibits a much lower on-state resistance [6]. In addition, the on-state resistance is relatively constant over the full signal input range, regardless of the variations and differences. The 4066B consists of four bilateral switches, each with independent controls. Both the p and n devices in a given switch are based on or off simultaneously by the control signal. As shown in Figure 3.9, the well of the n-channel device on each switch is tied to either the input (when the switch is on), or to Vss (when the switch is off). This configuration eliminates the variation of the switch transistor threshold voltage with input signal and thus, and thus keeps the on-state resistance low over the full operating signal range.

The advantage over single channel switches include peak input signal voltage swings equal to the full supply voltage and more constant on-state impedance over the input signal range. However, for sample and hold applications, the 4016B is better used.

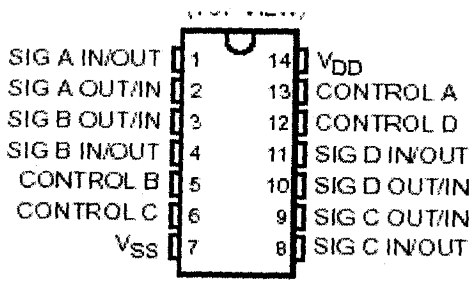


Fig 3.9. Pin assignment of the 4066B

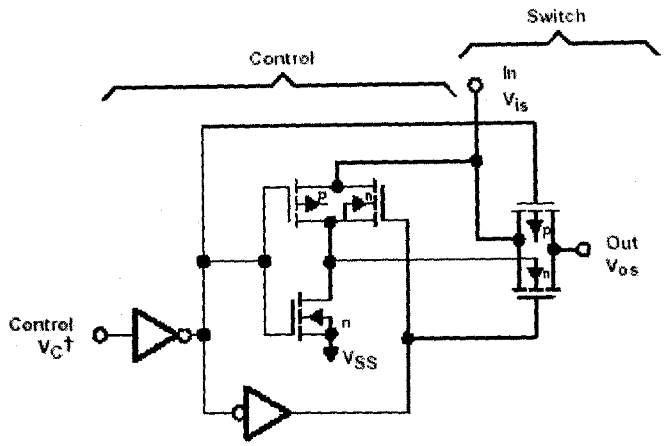


Fig. 3.10, Schematic diagram of one-of-four identical switches and associated control circuitry.

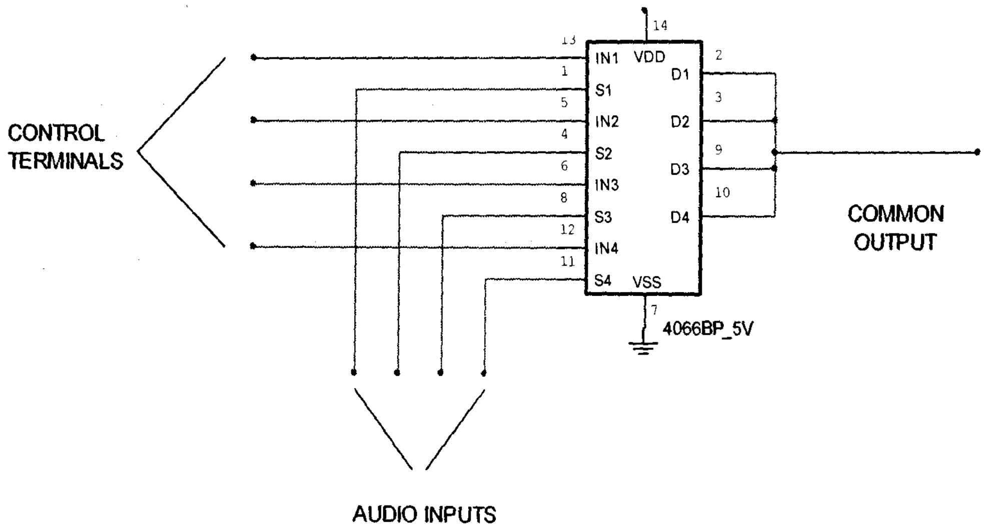


Fig 3.11, The CMOS quad bilateral switching unit

The output of the unit is common and it goes to an audio amplifier (LM386). Any channel whose corresponding control terminal is logical 1 passes signal to the common output. Such action is disallowed when a control terminal is logical 0.

3.1.4 The Audio Amplifier

The audio amplifier is the LM386 integrated circuit. The device is designed for low voltage consumer applications. It is set at internal gain of 20 in order to greatly reduce external components. For additional gain of up to 200, an addition of an external capacitor and resistor between pins 1 and 8 is required.

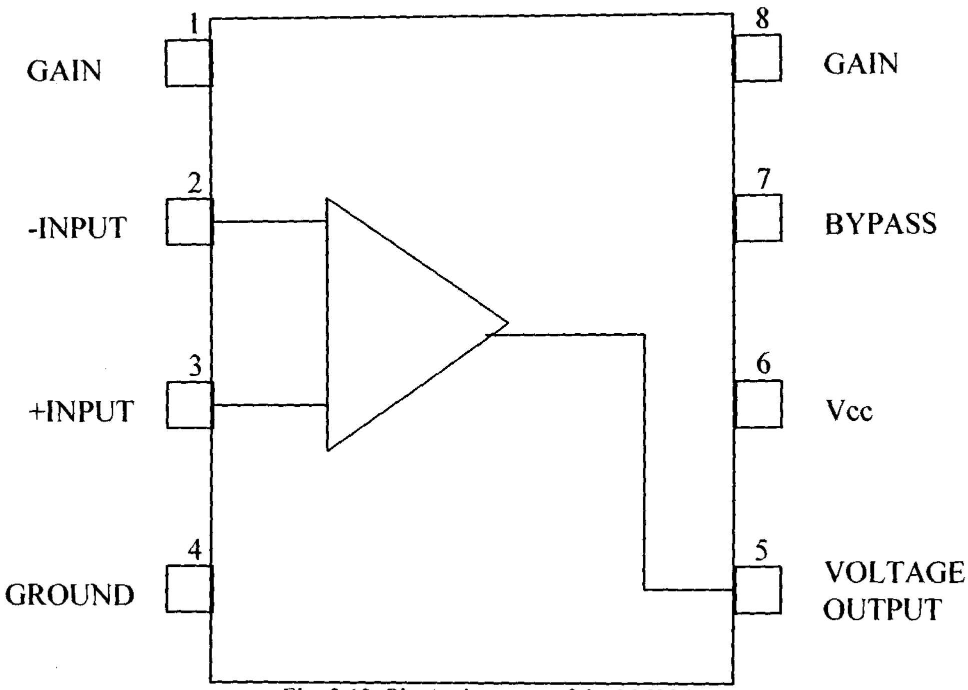


Fig. 3.12, Pin Assignment of the LM386

The audio amplifier is specified by the LM386 integrated circuit's manufacturers' data sheet.

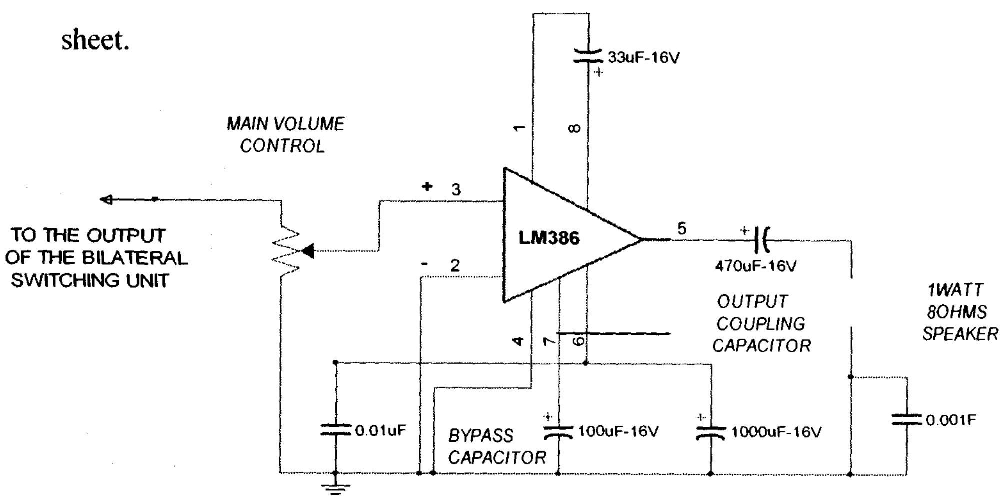


Fig. 3.13 The audio amplifier circuit

This circuit amplifies the result of audio signal from the bilateral switching unit. A 50KΩ variable resistor is used for adjusting the level of the input to the amplifier. The output speaker produces the amplified signal or sound. An auxiliary output terminal is incorporated to the circuit for external amplification or mixing.

3.1.5 The power unit

The power unit is quite the conventional one. It involves a 12Volts (V) output step-down transformer, a bridge rectifier and a 5Volts (V) regulator circuits. The 12V output step-down transformer provides a lower, or rather a workable alternating current supply for the 240Volts A.C. mains. The leading voltage is required to be converted to direct current. That necessitated the incorporation of the bridge rectifier for the purpose of converting the ac supply into a dc supply.

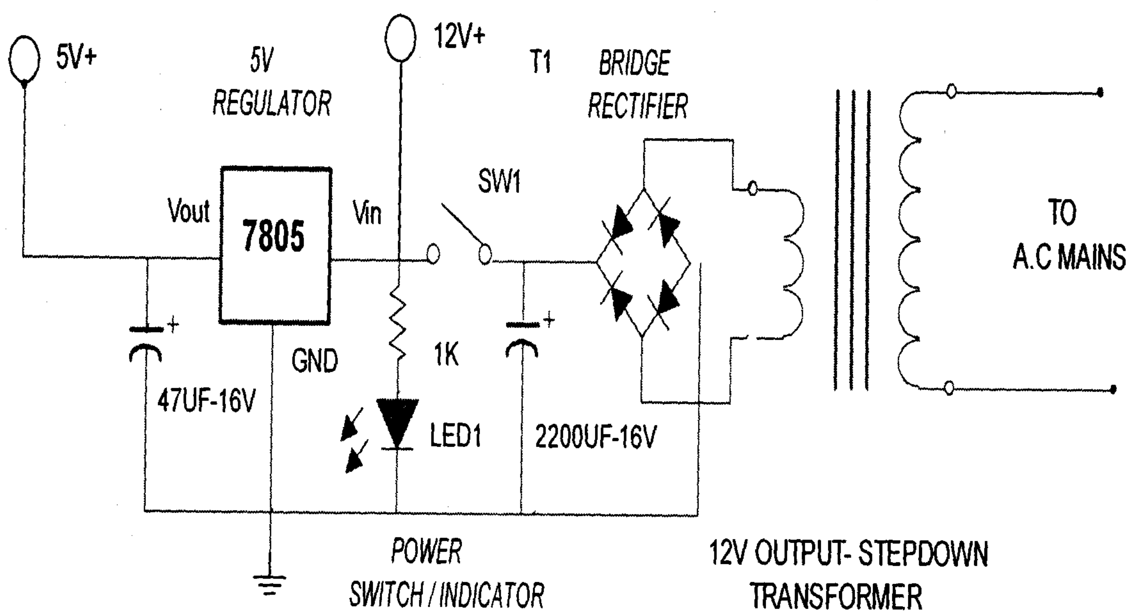


Fig 3.14 Power supply unit

An approximate 12V dc power supply is accomplished after the rectification. The voltage is filtered through a 2200μF, 16V electrolytic capacitor. Such a large capacitive device is required to minimize an undesirable effect called the ***ripple effect*** on the expected dc lower terminals. A power switch is required to open and close the complete circuit to turn the system on or off. This action is clearly shown by a light indicator circuit. The circuit involves a serially connected resistor and light emitting diode (LED). The main work of the connected resistor is to safe guard the LED from being burnt by the "excessive" voltage. If the voltage required across the Light Emitting Diode (LED) is 2.7V, then the serially connected resistor holds the remaining 9.3V. 12V power supply and 10mA are assumed for the circuit.

Therefore, the resistance of the serially connected resistor is given below:

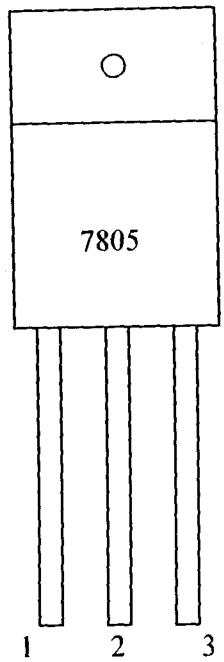
$$R = \frac{\text{voltage across the resistor}}{\text{Current flowing through the resistor}}$$

$$R = \frac{12 - 2.7}{10 \times 10^{-3}}$$

$$R = 930\Omega$$

1000Ω is a more practical resistor value for the specific purpose due to the availability of the resistor.

The rectified voltage is regulated through a 7805 voltage regulator to 5V. The 7805 is a positive voltage regulator with maximum voltage and current ratings of 40V and 1Ampere (A). the device has three terminals as shown below:



1	-	Positive voltage input
2	-	Ground
3	-	Positive voltage output

Fig. 3.15 Pin assignment of the 7805

The device supply most of the involved integrated circuits with the regulated 5V supply except the LM386 (audio amplifier) which requires a reasonably higher electric current for normal operation.

Moreover, the involved transformer is rated 12V and 500mA. Therefore the circuit must operate under the available current rating.

3.1.6 Light Emitting Diodes (LED)

As the name indicates it is a forward biased P-N junction which emits visible light when energized. Electrons are in the higher conduction band on the N side whereas holes are in the lower valence band on the P side. During recombination, some of this energy difference is given up in the form of heat and light (i.e. photons). If the semi conductor material is translucent, light is emitted and the junction becomes a light source [1].

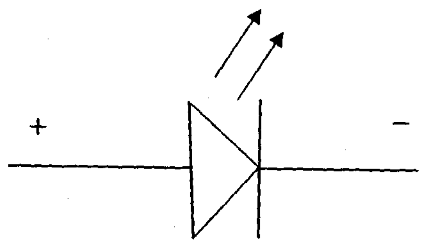


Fig. 3.16 Light Emitting Diode (LED)

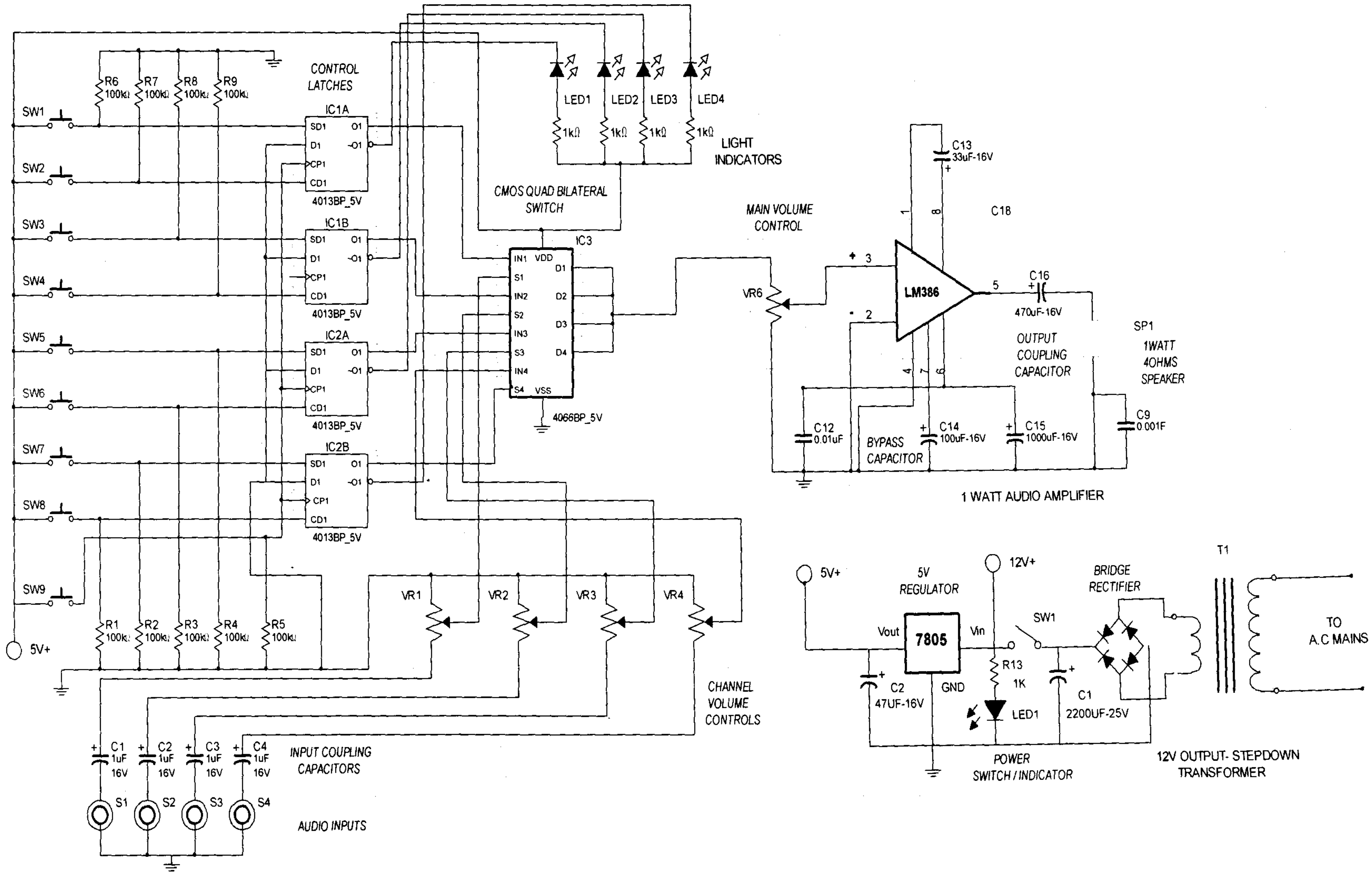


Fig. 3.17. The complete circuit diagram

Chapter 4

4.0 Construction, Testing and Results

4.1 Construction

The early circuit design was the backbone of this construction. The circuit was first constructed on a bread board to ascertain its workability before subsequent transfer to a more permanent vero board. The already produced circuit diagram was a handy guide in the process of construction. The major operation during the construction was soldering. Most of the involved components were soldered except the integrated circuits which were fixed on their corresponding IC sockets. The IC sockets were of course first soldered to the board. The construction was done in bits, unit after unit to prevent confusing the parts and wrong connections. The soldering iron used for the soldering work here is the standard 40W type. This is because the heat is minimal and will not burn of these electronic components.

4.1.1 The Casing

The secondary part of the construction involved the casing or packaging of the complete circuit. The involved materials include a plain black plastic and a converted CD ROM metallic casing which serves as the base. It has dimensions as follows: height is 40mm, width is 145mm and the length is 200mm. Several ducts were made on the casing for the involved attachments such as the variable resistors (for volume control), channel plug-in terminals, channel indicators and switches.

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OCTOBER 2006

Fig 4.1 Showing the plastic top with switches, volume control, channel inputs, power switch and auxiliary output.

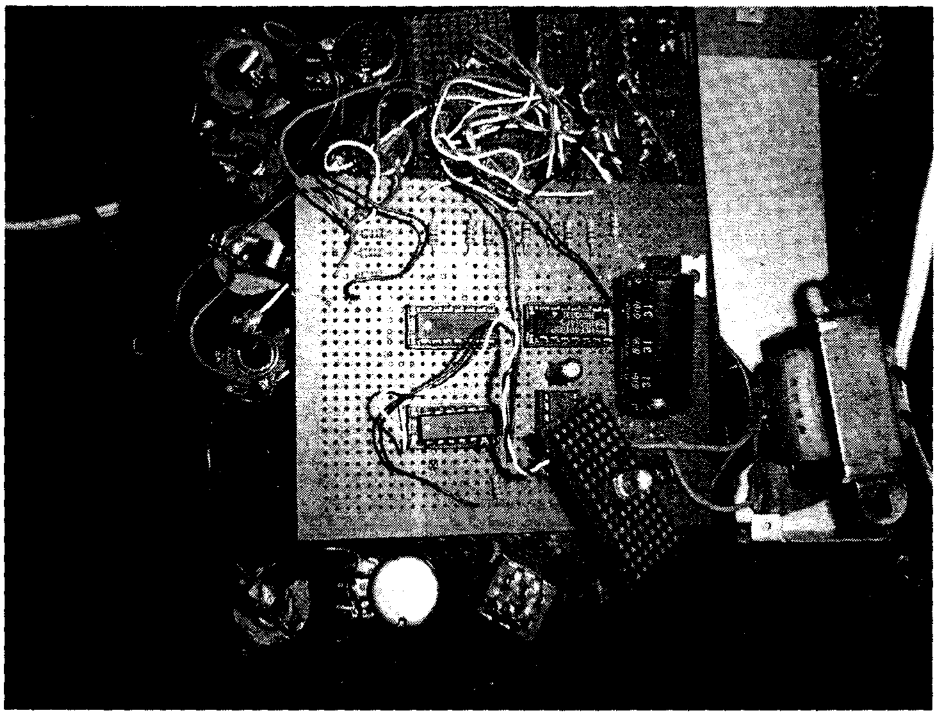

Fig. 4.2 Showing some of the internal parts of the design.

4.2 Testing And Result

The test mainly involves checking out the switching features of the device and getting an output from the incorporated speaker and or the auxiliary output terminal. Four different audio sources such as a tape player and an MP3 player were used during the test. The four audio signals were connected to the channel lines of the device and each line selected per time. Pairing of the channels was also done to achieve the mixing of at least two of the channels at the same time. The signal was heard from the incorporated speaker. When the auxiliary output was used (i.e. connected to an external amplifier and speaker), the signal was also heard. It is noteworthy to add that some degree of noise accompanies the signal output. This is due to inadequate earthen of the design.

Chapter 5

5.0 Conclusion, Recommendations and References

5.1 Conclusion

The aim of this project is to achieve the mixing of two or more audio signals and the selection of channels to be mixed or heard using CMOS integrated circuits among various other electronic components and applications; obtaining a high quality audio signal as an output. By this project, this has been achieved. This device has provided a cost effective, simple and a less voluminous audio device, with an overall less power consumption and minimal noise and distortion.

It finds its application in audio recording studios, churches, FM/AM radio stations, or any social gathering as an audio mixer and in international conferences as a selector.

5.2 Problems Encountered

Some problems were encountered in the course of carrying out the construction of this project; they include:

1. There was a regular experience of power outage which in no small way delayed this work.
2. Some of the components were not readily available and some were not in good conditions as at when they were bought, causing some challenges in the work.

5.3 Recommendations

For the onward improvement on this project, some attention should be on the following recommendations:

- The number of input channels could be expanded for better applications
- More digital effects could be incorporated into the design.
- Microprocessors or microcontrollers could be used for the switching and other features.
- Information display panel could be incorporated into the design for better control.

5.1 References

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CD4013B Types

CMOS Dual 'D'-Type Flip-Flop

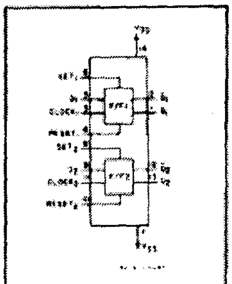
High-Voltage Types (20-Volt Rating)

■ CD4013B consists of two identical, independent data-type flip-flops. Each flip-flop has independent data, set, reset, and clock inputs and Q and $\overline{Q}$ outputs. These devices can be used for shift register applications, and, by connecting $\overline{Q}$ output to the data input, for counter and toggle applications. The logic level present at the D input is transferred to the Q output during the positive-going transition of the clock pulse. Setting or resetting is independent of the clock and is accomplished by a high level on the set or reset line, respectively.

The CD4013B types are supplied in 14-lead hermetic dual-in-line ceramic packages (F3A suffix), 14-lead dual-in-line plastic packages (E suffix), 14-lead small-outline packages (M, MT, M96, and NSR suffixes), and 14-lead thin shrink small-outline packages (PW and PWR suffixes).

Features:
- Set-Reset capability
- Static flip-flop operation — retains state indefinitely with clock level either "high" or "low"
- Medium-speed operation — 16 MHz (typ.) clock toggle rate at 10V
- Standardized symmetrical output characteristics
- 100% tested for quiescent current at 20 V
- Maximum input current of 1 μA at 18 V over full package temperature range; 100 nA at 18 V and 25°C
- Noise margin (over full package temperature range): 1 V at V_{DD}=5 V; 2 V at V_{DD}=10 V; 2.5 V at V_{DD}=15 V
- 5-V, 10-V, and 15-V parametric ratings
- Meets all requirements of JEDEC Tentative Standard No. 13B, "Standard Specifications for Description of 'B' Series CMOS Devices"

Applications:
- Registers, counters, control circuits



CD4013B FUNCTIONAL DIAGRAM

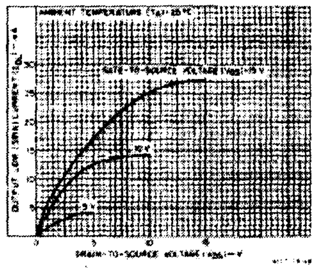


Fig. 1 — Typical output low (sink) current characteristics.

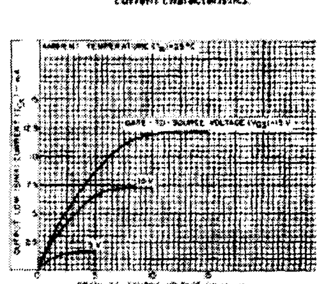


Fig. 2 — Minimum output low (sink) current characteristics.

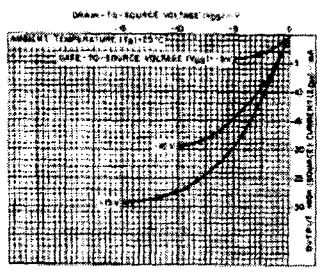


Fig. 3 — Typical output high (source) current characteristics.

RECOMMENDED OPERATING CONDITIONS

At T_A = 25°C, Except as Noted. For maximum reliability, nominal operating conditions should be selected so that operation is always within the following ranges:

CHARACTERISTIC	V_{DD} (V)	LIMITS MIN.	LIMITS MAX.	UNITS
Supply-Voltage Range (For T_A = Full Package Temperature Range)	–	3	18	V
Data Setup Time t_S	5	40	–	ns
	10	20	–	
	15	15	–	
Clock Pulse Width t_W	5	140	–	ns
	10	60	–	
	15	40	–	
Clock Input Frequency f_{CL}	5	dc	3.5	MHz
	10		8	
	15		12	
Clock Rise or Fall Time t_rCL,* t_fCL	5	–	500	μs
	10	–	30	
	15	–	6	
Set or Reset Pulse Width t_W	5	180	–	ns
	10	80	–	
	15	50	–	

*If more than one unit is cascaded in a parallel clocked operation, t_rCL should be made less than or equal to the sum of the fixed propagation delay time at 15 pF and the transition time of the output driving stage for the estimated capacitive load.

Appendix 1, the 4013B Data Sheet

STATIC ELECTRICAL CHARACTERISTICS

CHARACTERISTIC	CONDITIONS V_O (V)	V_{IN} (V)	V_{DD} (V)	LIMITS AT INDICATED TEMPERATURES (°C) −55	−40	+85	+125	+25 Min.	+25 Typ.	+25 Max.	UNITS
Quiescent Device Current, I_{DD} Max.	–	0,5	5	1	1	30	30	–	0.02	1	μA
	–	0,10	10	2	2	60	60	–	0.02	2	μA
	–	0,15	15	4	4	120	120	–	0.02	4	μA
	–	0,20	20	20	20	600	600	–	0.04	20	μA
Output Low (Sink) Current, I_{OL} Min.	0.4	0,5	5	0.64	0.61	0.42	0.36	0.51	1	–	mA
	0.5	0,10	10	1.6	1.5	1.1	0.9	1.3	2.6	–	mA
	1.5	0,15	15	4.2	4	2.8	2.4	3.4	6.8	–	mA
Output High (Source) Current, I_{OH} Min.	4.6	0,5	5	−0.64	−0.61	−0.42	−0.36	−0.51	−1	–	mA
	2.5	0,5	5	−2	−1.8	−1.3	−1.15	−1.6	−3.2	–	mA
	9.5	0,10	10	−1.6	−1.5	−1.1	−0.9	−1.3	−2.6	–	mA
	13.5	0,15	15	−4.2	−4	−2.8	−2.4	−3.4	−6.8	–	mA
Output Voltage: Low Level, V_{OL} Max.	–	0,5	5	0.05				–	0	0.05	V
	–	0,10	10	0.05				–	0	0.05	V
	–	0,15	15	0.05				–	0	0.05	V
Output Voltage: High-Level, V_{OH} Min.	–	0,5	5	4.95				4.95	5	–	V
	–	0,10	10	9.95				9.95	10	–	V
	–	0,15	15	14.95				14.95	15	–	V
Input Low Voltage, V_{IL} Max.	0.5,4.5	–	5	1.5				–	–	1.5	V
	1,9	–	10	3				–	–	3	V
	1.5,13.5	–	15	4				–	–	4	V
Input High Voltage, V_{IH} Min.	0.5,4.5	–	5	3.5				3.5	–	–	V
	1,9	–	10	7				7	–	–	V
	1.5,13.5	–	15	11				11	–	–	V
Input Current, I_{IN} Max.	–	0,18	18	±0.1	±0.1	±1	±1	–	$\pm10^{-5}$	±0.1	μA

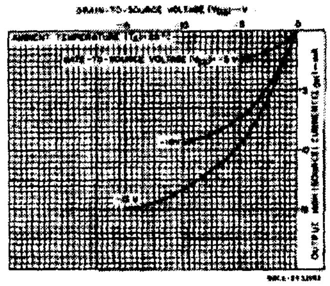


Fig. 4 – Minimum output high (source) current characteristics.

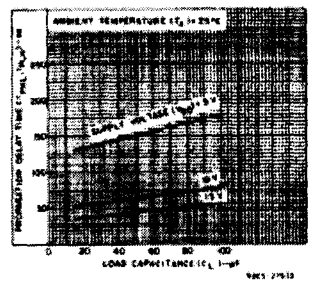


Fig. 5 – Typical propagation delay time vs. load capacitance (CLOCK or SET to Q,CLOCK or RESET to $\overline{Q}$).

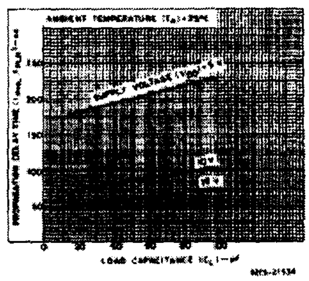


Fig. 6 – Typical propagation delay time vs. load capacitance (SET to $\overline{Q}$ or RESET to Q.

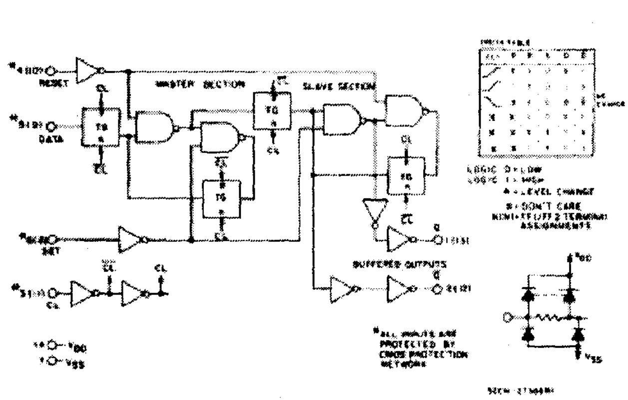


Fig. 7 – Logic diagram and truth table for CD4013B (one of two identical flip-flops).

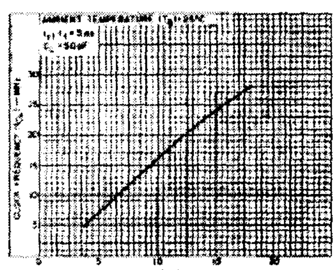
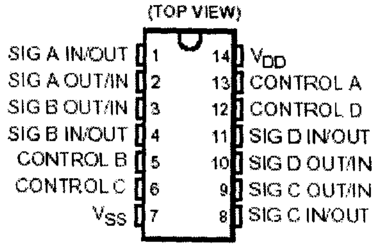


Fig. 8 – Typical maximum clock frequency vs. supply voltage.

Appendix 1 (contd)

- **15-V Digital or ±7.5-V Peak-to-Peak Switching**
- **125-Ω Typical On-State Resistance for 15-V Operation**
- **Switch On-State Resistance Matched to Within 5 Ω Over 15-V Signal-Input Range**
- **On-State Resistance Flat Over Full Peak-to-Peak Signal Range**
- **High On/Off Output-Voltage Ratio: 80 dB Typical at f_{is} = 10 kHz, R_L = 1 kΩ**
- **High Degree of Linearity: <0.5% Distortion Typical at f_{is} = 1 kHz, V_{is} = 5 V p-p, $V_{DD} - V_{SS} \geq 10$ V, R_L = 10 kΩ**
- **Extremely Low Off-State Switch Leakage, Resulting in Very Low Offset Current and High Effective Off-State Resistance: 10 pA Typical at $V_{DD} - V_{SS}$ = 10 V, T_A = 25°C**
- **Extremely High Control Input Impedance (Control Circuit Isolated From Signal Circuit): 10^{12} Ω Typical**
- **Low Crosstalk Between Switches: –50 dB Typical at f_{is} = 8 MHz, R_L = 1 kΩ**
- **Matched Control-Input to Signal-Output Capacitance: Reduces Output Signal Transients**
- **Frequency Response, Switch On = 40 MHz Typical**
- **100% Tested for Quiescent Current at 20 V**
- **5-V, 10-V, and 15-V Parametric Ratings**
- **Meets All Requirements of JEDEC Tentative Standard No. 13-B, *Standard Specifications for Description of "B" Series CMOS Devices***
- **Applications:**
  - **Analog Signal Switching/Multiplexing: Signal Gating, Modulator, Squelch Control, Demodulator, Chopper, Commutating Switch**
  - **Digital Signal Switching/Multiplexing**
  - **Transmission-Gate Logic Implementation**
  - **Analog-to-Digital and Digital-to-Analog Conversion**
  - **Digital Control of Frequency, Impedance, Phase, and Analog-Signal Gain**

E, F, M, NS, OR PW PACKAGE
(TOP VIEW)



description/ordering information

The CD4066B is a quad bilateral switch intended for the transmission or multiplexing of analog or digital signals. It is pin-for-pin compatible with the CD4016B, but exhibits a much lower on-state resistance. In addition, the on-state resistance is relatively constant over the full signal-input range.

The CD4066B consists of four bilateral switches, each with independent controls. Both the p and the n devices in a given switch are biased on or off simultaneously by the control signal. As shown in Figure 1, the well of the n-channel device on each switch is tied to either the input (when the switch is on) or to V_{SS} (when the switch is off). This configuration eliminates the variation of the switch-transistor threshold voltage with input signal and, thus, keeps the on-state resistance low over the full operating-signal range.

The advantages over single-channel switches include peak input-signal voltage swings equal to the full supply voltage and more constant on-state impedance over the input-signal range. However, for sample-and-hold applications, the CD4016B is recommended.

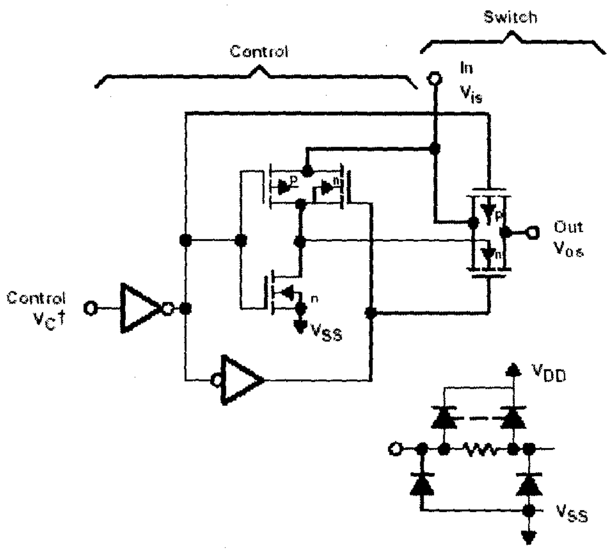
Appendix 2, the 4066B Data Sheet

description/ordering information (continued)

ORDERING INFORMATION

T_A	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
−55°C to 125°C	CDIP – F	Tube of 25	CD4066BF3A	CD4066BF3A
	PDIP – E	Tube of 25	CD4066BE	CD4066BE
	SOIC – M	Tube of 50	CD4066BM	CD4066BM
		Reel of 2500	CD4066BM96	
		Reel of 250	CD4066BMT	
	SOP – NS	Reel of 2000	CD4066BNSR	CD4066B
	TSSOP – PW	Tube of 90	CD4066BPW	CM066B
		Reel of 2000	CD4066BPWR	

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.



† All control inputs are protected by the CMOS protection network.

NOTES: A. All p substrates are connected to V_{DD}.

B. Normal operation control-line biasing: switch on (logic 1), $V_C = V_{DD}$; switch off (logic 0), $V_C = V_{SS}$

C. Signal-level range: $V_{SS} \leq V_{is} \leq V_{DD}$

92CS-29113

Appendix 2 (contd)