Loughborough University

Department of Electronic & Electrical Engineering

Design & Make Project

ELC026

Standalone CD-ROM Audio Controller

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1. Project Description

"A standalone unit to implement the audio functions of an ATAPI CD-ROM Drive."

2.Research

A large portion of the project work involved research into how the problem could be solved. This chapter describes the process involved in designing the device from the initial stages.

2.1 Interface Considerations

The first stage of research into this project was to find a suitable way of interfacing with the CD-ROM drive. Without an interface, it would obviously be impossible to implement any functions to the CD-ROM drive. As almost every CD-ROM drive is ATAPI compliant, the decision was made early on in the development to work with this standard. Practically, ATAPI is a mixture of SCSI and IDE (ATA). The IDE interface is used for transmission of ATA and ATAPI commands. Hence ATA Packet Interface (ATAPI).

Knowing that the physical interface is IDE, the next stage was to find a controller to enable the ATAPI commands to be sent to the CD-ROM drive. Searching through catalogues revealed no IDE controllers. The reason for this is that IDE is very close to that of a PC's ISA bus. Finally the conclusion was made that a separate IDE interface IC was not required. The decision was soon made that direct communication to the IDE connector could be achieved by use of a micro-controller.

2.2 ATAPI

As ATAPI is a variation of ATA, it was necessary to research both standards in order to understand how the ATAPI CD-ROM drive can be communicated with. The two standards that were researched for this project were X3T10 (ATA-2) and SFF8020 (ATAPI). Both these documents were vital in the development of this project and are included on the disk with this report. Understanding of these standards was very difficult both because of the wording and the way that they can be interpreted.

ATAPI basically enables SCSI commands to be sent along with ATA commands. It was created almost specifically so that CD-ROM drives can be used on a standard PC with a cheap IDE port. All of the commands needed to control the audio functions of a CD-ROM are included in the ATAPI instruction set. An ATA command is to be issued telling the device that an ATAPI packet command is to be sent. When the device accepts the ATA command it is then ready to receive the ATAPI command and then execute the operation.

The two documents X3T10 and SFF8020 are included on the disk with this report.

2.3 Circuit Design

In designing the circuit for this project the IDE interface was researched. The IDE interface consists of a 16-bit data bus with address lines and control bits. It was decided that an 87C51

micro-controller would be suitable for communicating directly with the interface. Also, external buttons for Play, Stop, Pause, Forward and Reverse would need to be added. Careful consideration of the amount of ports required was made. Almost every I/O line on the 87C51 would be used.

Audio signals can be output from the rear of the CD-ROM drive or from the headphone connector included with most CD-ROM devices. Therefore no extra audio circuitry is required.

3. Project Design

3.1 Circuit Diagram

The circuit consists of an 87C51 micro-controller with an IDE 40-Way connector, which is connected to the CD-ROM drive. Also, a power connector is included so the CD-ROM drive can be powered from the main PCB. Power to the board is 12 VDC, which is regulated down to 5V for the boards' logic. De-coupling capacitors are included. The 87C51 clock runs at 12MHz. Figure 3.1.1 shows the main circuit diagram.

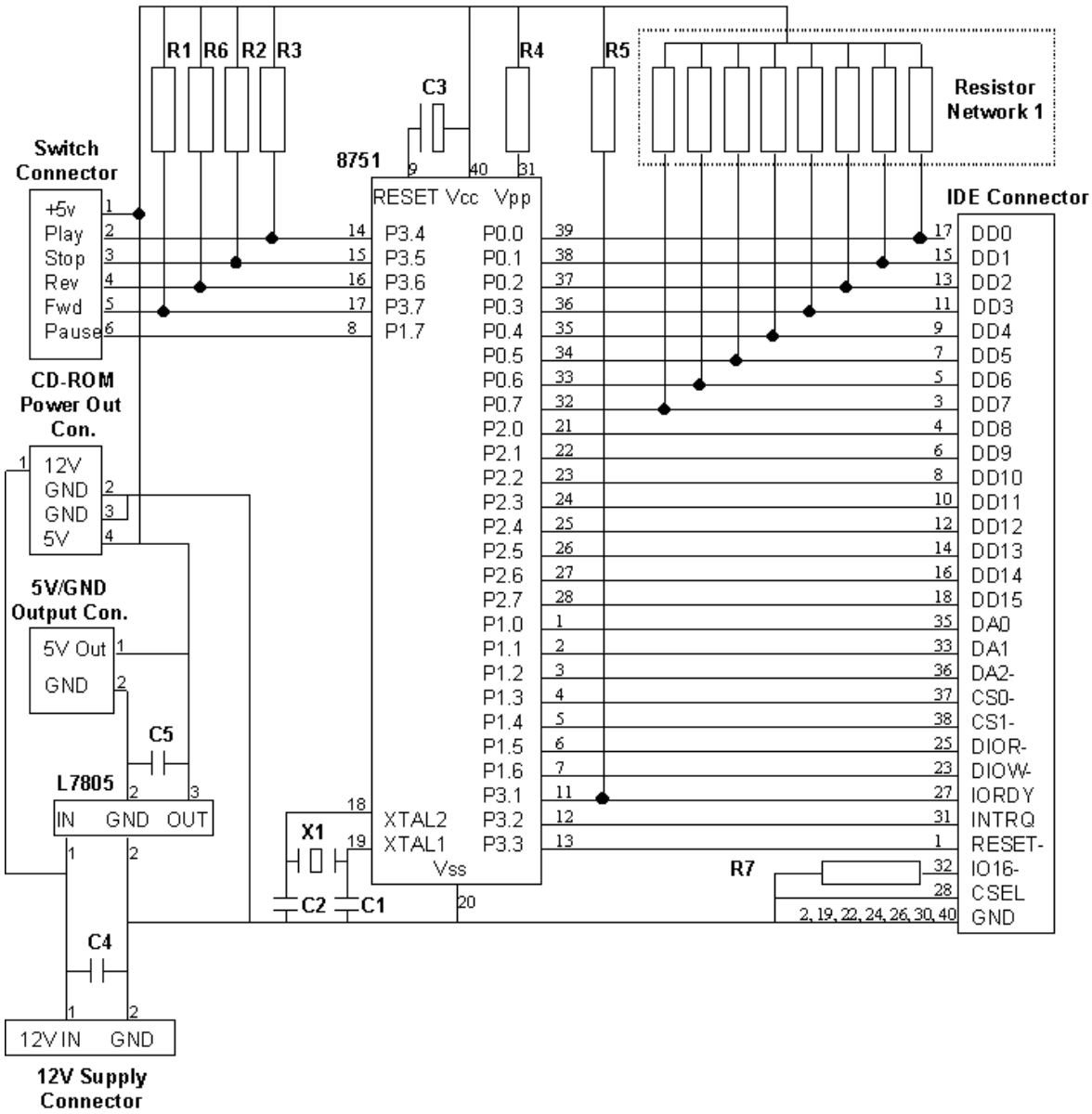

Figure 3.1.1

The component list is shown below in figure 3.1.2;

Name	Value	Description
R1	10k	Resistor
R2	10k	Resistor
R3	10k	Resistor
R4	100k	Resistor
R5	1k	Resistor
R6	10k	Resistor
R7	1k	Resistor
C1	30pF	Capacitor
C2	30pF	Capacitor
C3	10uF	Electrolytic Capacitor
C4	0.1uF	De-coupling Capacitor
C5	0.1uF	De-coupling Capacitor
X1	12MHz	Timing Crystal
RN 1	8x10k	SIL Resistor pack
L7805	5V Out	5V Regulator
87C51FA		Micro-Controller

Figure 3.1.2

Figure 3.1.3 shows the *IDE CONNECTOR* Pin functions. Note that not all the pins are utilized in this project.

Pin	Signal	Name	Source
1	RESET-	RESET	I
2	Ground	Ground	I/O
3	DD7	DATA BUS BIT 7	I/O
4	DD8	DATA BUS BIT 8	I/O
5	DD6	DATA BUS BIT 6	I/O
6	DD9	DATA BUS BIT 9	I/O
7	DD5	DATA BUS BIT 5	I/O
8	DD10	DATA BUS BIT 10	I/O
9	DD4	DATA BUS BIT 4	I/O
10	DD11	DATA BUS BIT 11	I/O
11	DD3	DATA BUS BIT 3	I/O
12	DD12	DATA BUS BIT 12	I/O
13	DD2	DATA BUS BIT 2	I/O
14	DD13	DATA BUS BIT 13	I/O
15	DD1	DATA BUS BIT 1	I/O
16	DD14	DATA BUS BIT 14	I/O
17	DD0	DATA BUS BIT 0	I/O
18	DD15	DATA BUS BIT 15	I/O
19	Ground	Ground	
20	N.C.	(Coding Pin)	
21	DMARQ	DMA REQUEST	O
22	Ground	Ground	
23	DIOW-	I/O WRITE	I
24	Ground	Ground	
25	DIOR-	I/O Read	I
26	Ground	Ground	
27	IORDY	I/O Channel Ready	
28	SPSYNC:CSEL	SPINDLE SYNC or CABLE SELECT	
29	DMACK-	DMA ACKNOWLEDGE	I
30	Ground	Ground	
31	INTRQ	INTERRUPT REQUEST	O
32	IOCS16-	16 BIT I/O	O
33	DA1	ADDRESS BIT 1	I
34	PDIAG	PASSED DIAGNOSTICS	O
35	DA0	ADDRESS BIT 0	I
36	DA2	ADDRESS BIT 2	I
37	CS0-	CHIP SELECT 0	I
38	CS1-	CHIP SELECT 1	I
39	DASP-	DRIVE ACTIVE	O
40	Ground	Ground	
Note 1: Signals followed by a "-" indicate Active Low. Note 2: Source "0" is an *Output* from Device (CD-ROM), Source "1" is an *Input* to Device.			

Figure 3.1.3

Figure 3.1.4 shows the *CD-ROM Power Out* connector diagram. A standard IDE Power lead is connected to this connector.

Pin	Description
1	CD-ROM +15V
2	CD-ROM GND
3	CD-ROM GND
4	CD ROM +5V

Figure 3.1.4

Figure 3.1.5 shows the *SWITCH CONNECTOR* pin configuration. All switched are Normally Open contact. Pressing a switch causes a port go logic 1.

Pin	Description
1	Common Switch +5V
2	Play
3	Stop
4	Rev
5	Fwd
6	Pause

Figure 3.1.5

Figure 3.1.6 shows the 12V Supply Connector, which is connected to the Power Circuitry.

Pin	Description
1	12V In
2	GND

Figure 3.1.6

Figure 3.1.7 shows the 5V/GND Output Connector, which was intended for future use.

Pin	Description
1	5V Out
2	GND

Figure 3.1.7

The circuit connects the ports of the 87C51 to the relevant IDE pins, which are all TTL/CMOS compatible. Inputs to the 87C51 from the switches include 10K pull-down resistors. The front panel switches are supplied with 5V. When a switch is pressed, the current will flow to the 87C51, hence producing a logic 1 at the given pin.

Power to the circuit comes from the Power Circuitry described later. The 12V input is regulated by the L7805 to give a 5V supply to the micro-controller. Power to the CD-ROM drive is obtained from the connector on the board which provides 12V, 5A and GND.

3.2 Main PCB Layout

The PCB Layout is shown in figure 3.2.1. This is the top-side view of board, the resistor network on the underside is also indicated. Connector pin numbers are also shown. The L7805 regulator is mounted on the rear of the case, for better heat dissipation. R7 was added prior to PCB production and is soldered to the underside of the board (not shown).

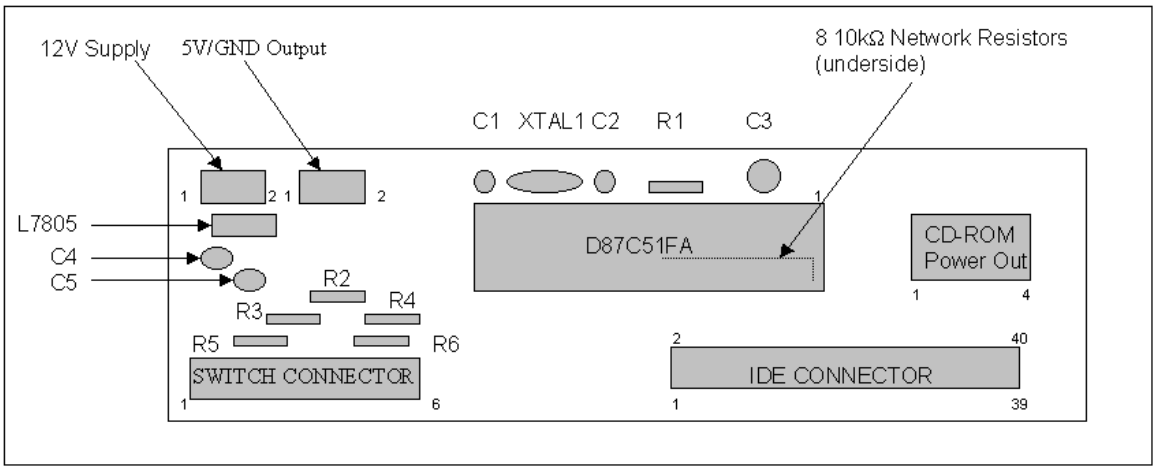

Figure 3.2.1

3.3 Power Circuitry

As the device is intended for home use, it was decided that it should be mains powered. For this reason a mains transformer giving a 12V output is used. The diagram below shows the transformer with its rectifying and smoothing circuitry.

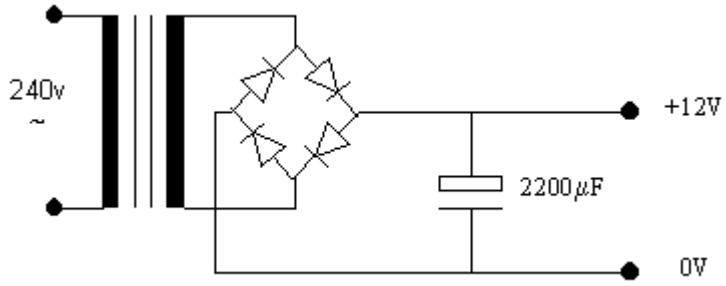

Figure 3.3.1

The simple circuit was produced separate to the main PCB and is wired on standard copper strip board. A single unit full wave bridge rectifier is used. The rectifier gives a dc voltage output and the capacitor smoothes the output. The 12V Supply from this circuit is connected to the Power In connector of the main PCB.

3.4 Internal Layout of Device

The CD-ROM Drive is shown with the main PCB underneath and the transformer circuitry towards the rear of the case. The front panel is cut out for the CD-ROM drive and the 5 audio buttons. The rear panel contains the mains connector which is Earthed to both the metal panels and the CD-ROM drive. The regulator is attached to the rear panel with heat-conductive insulation to isolate the ground signal from Earth. The phono connectors are shown on the side of the plastic casing. The CD-ROM drive is held in place with four metal "L" brackets.

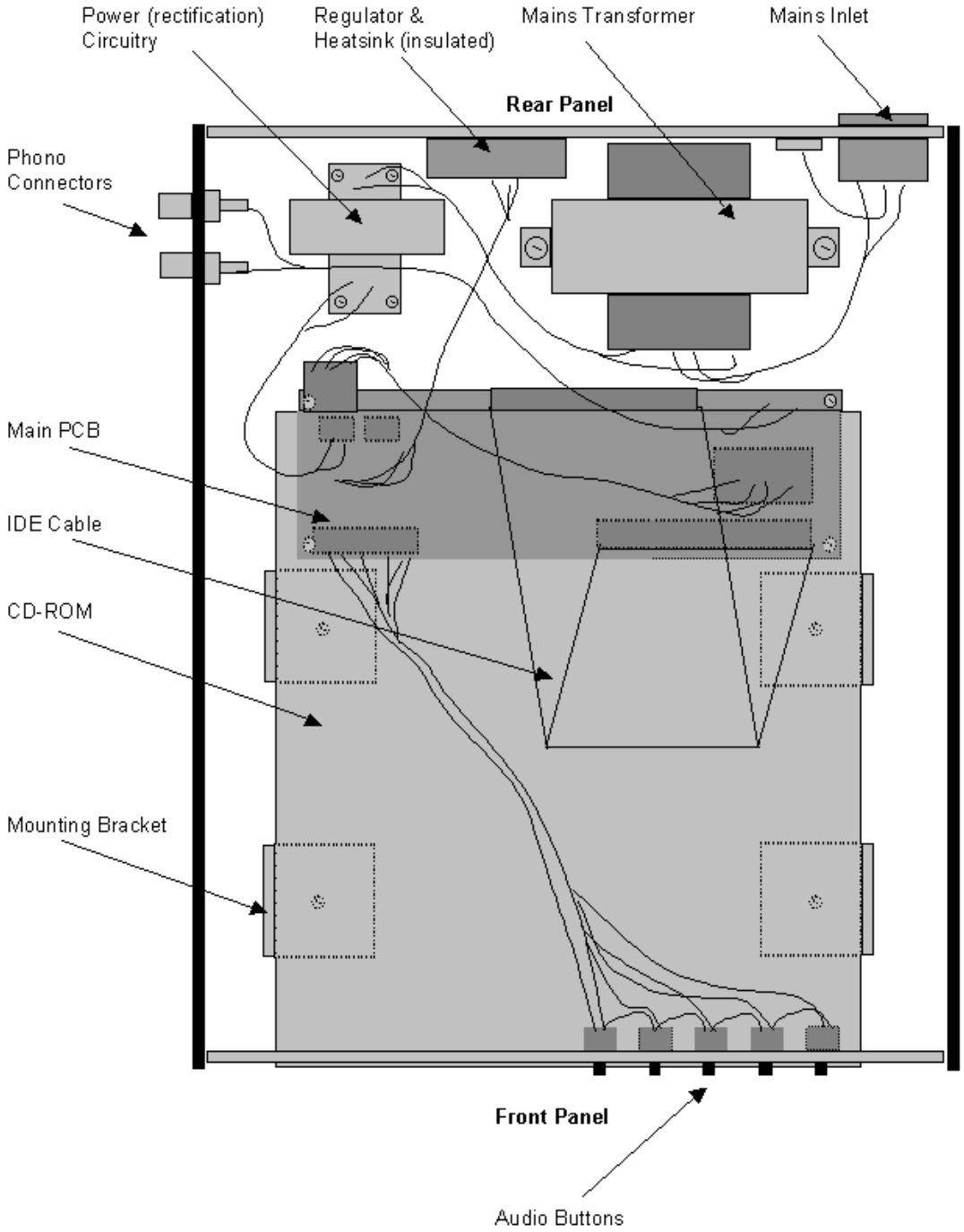

Figure 3.4.1

3.5 Assembler program

The 87C51 program controls the unit. The program sets up the CD-ROM for audio CD access and sends ATAPI commands to the drive upon user request from the panel buttons. The ATAPI drive has a set of registers which must be loaded every time a command is sent to the device. To read or write to the registers, the CS0, CS1, DA2, DA1 and DA0 signals must be set to the relevant address. The list of registers is shown in figure 3.5.1. With the address set, the DIOR- or DIOW signal must be strobed for a read or write, respectively.

Command register block						
Addresses					***Name and function***	
CS0	**CS1**	**DA2**	**DA1**	**DA0**	**Read access**	**Write access**
1	0	0	0	0	Data register	
1	0	0	0	1	ATAPI error register	ATAPI feature register
1	0	0	1	0	ATAPI cause of int.	Not used
1	0	0	1	1	Reserved	
1	0	1	0	0	ATAPI byte count register (bits 0-7)	
1	0	1	0	1	ATAPI byte count register (bits 8-15)	
1	0	1	1	0	Drive select register	
1	0	1	1	1	ATAPI status register	Command register
Control register block						
Addresses					***Name and function***	
CS0	**CS1**	**DA2**	**DA1**	**DA0**	**Read access**	**Write access**
0	1	0	0	0	Not used	Not used
0	1	0	0	1	Not used	Not used
0	1	0	1	0	Not used	Not used
0	1	0	1	1	Not used	Not used
0	1	1	0	0	Not used	Not used
0	1	1	0	1	Not used	Not used
0	1	1	1	0	Alternative ATAPI Status register	Control register
0	1	1	1	1	Reserved	Not used

Figure 3.5.1

For a complete list of the register definitions, refer to the ATAPI standard. The registers are ALL 8-bits wide, using the data bus Bits 0-7. Figure 3.5.2 shows the status register definition.

Bit	7	6	5	4	3	2	1	0
	BSY	DRDY	DF	DSC	DRQ	CORR	IDX	ERR

Figure 3.5.2

- **BSY (Busy):** If BSY is set, no other bits in the status register are valid. BSY is always set when the controller itself is accessing the command register block. During this time the host may not access any of the registers in the command register block.

- **DRDY (Drive ready):** Indicates that the drive is ready to accept a command. When the drive is first switched on, DRDY remains clear until the drive is ready for operation.

- **DF (Drive Fault):** Indicates an error on the drive

- **DSC (Drive seek complete):** Indicates that the heads are positioned.

- **DRQ (Data request):** This bit is set if a correctable read error has occurred.

- **IDX (Index):** This bit is set once per rotation of the medium.

- **ERR (Error):** Indicates an error has occurred in the process of executing the previous command. The error register contains further information.

Every other register operates in a similar way, hence it is fairly simple to communicate with the ATAPI registers.

The first part of the code simple sets up all the ports and resets the CD-ROM drive. When sending an ATAPI command, an ATAPI packet command is first issued. The status register is first read to check is the device is ready. The code loops, waiting for a button to be pressed. When a button is pressed the program will go into another loop for that button.

If the play button is pressed, the code will execute a Packet command followed by the ATAPI packet to read the TOC (Table of Contents). This stores the track locations into memory for the FWD and REV functions. The Packet command is again issued and then the Play packet sent.

When no buttons are read in, the sub-channel is read. This is another ATAPI command. The sub-channel gives the audio status and returns the track number which is currently playing. Again, this information is needed for the FWD and REV functions.

The Stop and Pause functions are similar to the Play function although the TOC is not read in and the functions for Stop and Pause are different packets. For the Pause packet command, the Audio status is read. If the device is paused, a resume bit in the packet will be set. This allows the pause button to be used toggle pause on or off.

The low level code simply sets up the various addresses for the registers and strobes the DIOR- and DIOW- pins for a read or write operation.

4. Costing Summary

The following table shows the cost of parts included in this project. Note that the cost of the CD-ROM drive is not included, as the project is intended to *control* a CD-ROM drive.

Part	Description	Source	Order Code	Qty	Approx. Cost (ex VAT)
D87C51FA	Microcontroller chip	Stores		1	£6.00
L7805	5V Regulator	Stores		1	£0.50
Block Connector	4 Way Terminal Block	Stores		1	£0.20
Block Connector	2 Way Terminal Block	Stores		2	£0.30
Block Connector	6 Way Terminal Block	Stores		1	£0.25
X1	12MHz Timing crystal	Stores		1	£1.00
C1	30pF Capacitor	Stores		1	£0.10
C2	30pF Capacitor	Stores		1	£0.10
C3	10uF Electrolytic Capacitor	Stores		1	£0.15
C4	0.1uF Capacitor	Stores		1	£0.05
C5	0.1uF Capacitor	Stores		1	£0.05
R1	10k	Stores		1	£0.02
R2	10k	Stores		1	£0.02
R3	10k	Stores		1	£0.02
R4	100k	Stores		1	£0.02
R5	1k	Stores		1	£0.02
R6	10k	Stores		1	£0.02
R7	1k	Stores		1	£0.02
Resistor Network	8x10k In Line Resistor	Stores		1	£0.06
Phono connector	Phono Connector (Red)	Farnell	149-269	1	£0.66
Phono connector	Phono Connector (Black)	Farnell	147-012	1	£0.66
Micro-switch	Standalone 6.4mm (Black)	Farnell	385-833	5	£4.31
Mains Socket	IEC Switched Inlet	Farnell	151-746	1	£2.32
Full Wave Rectifier	Full Wave Rectifier	Farnell	663-478	1	£1.57
Transformer	Mains Transformer 0-12V	Farnell	141-487	1	£7.51
Terminal Shroud	For above transformer	Farnell	177-223	1	£0.38
PCB	PCB Production	In House		1	£9.50
Instrument Case	“1598 Series”	Farnell	772-728	1	£14.31
			TOTAL		£50.12

With a total cost of only £50.12, the project is over budget by £10. The main reason for this was the cost of the casing at almost £15. Finding a box large enough to house the circuitry, the transformer and the CD-ROM limited the choice considerably.

5. User Manual

5.1 Description of Unit

The unit is a stand-alone CD-ROM audio player. It can play standard audio CD's only. The functions that can be performed are;

- Play
- Stop
- Next Track
- Previous Track
- Pause

The unit includes a Left and Right phono connector at the rear of the case for connection to an Auxiliary input or a hi-fi or suitable amplifier.

5.2 Operating Instructions

Operation of the unit is quite simple. Firstly, make sure that the phono connectors at the rear of the unit are connected to an output device. Alternatively, connect a pair of headphones to the headphone jack on the CD-ROM drive (if available). Be sure to turn up the volume control now (if present) next to the headphone jack.

Figure 5.2.1 shows the front panel of the unit.

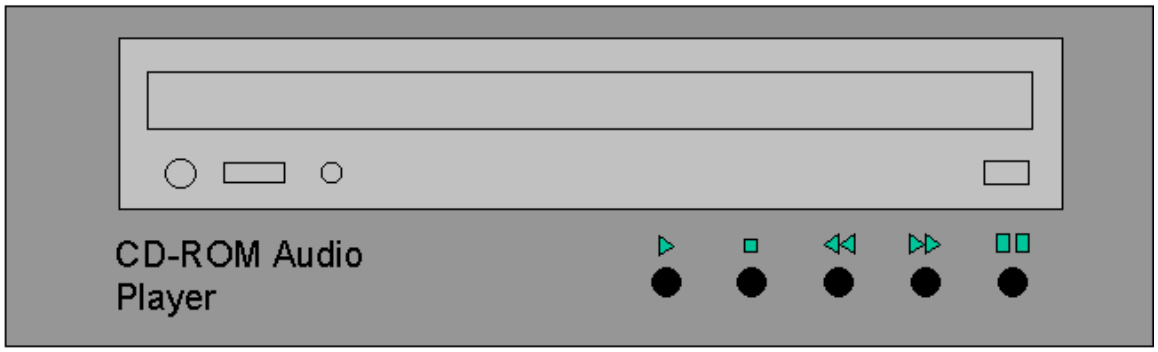

Figure 5.2.1

The 5 audio buttons can be seen below the CD-ROM drive.

<u>To play a CD</u>

- Press the CD-ROM Eject button
- Insert an Audio CD
- Press the Play Button

To stop a track playing

- Press the stop button (second from left)

The CD will stop playing. If the Play button is pressed again, the Track 1 will be played.

To pause a track

- Press the pause button once to pause audio (Last button from left).
- Press the pause button when in a paused state to resume play.

Skipping forward or back a track

- Press the Fwd or Rev button (third and fourth from left)

Audio will continue from the start of the next, or previous track

5.3 Troubleshooting

Problem	Usual Cause	Solution
CD will not play.	No CD Present.	Press CD-ROM Eject button, insert audio CD.
CD will not play.	Unit not powered up.	Check power lead, check power.
No audio playing.	Non-audio CD preset	Replace with audio CD
No sound from Phono Connectors.	Phono connector not connected.	Connect up audio leads to phono connectors and ensure external amplifier is properly configured.
No sound from CD-ROM headphone connector.	Volume not turned up.	Turn up CD-ROM volume knob (if present).
Music sounds undesirable	Bad taste in music	Change CD!

5.4 Specifications

Functions:		
Play Button		
Stop Button		
Advance Track (Fwd) Button		
Previous Track (Rev) Button		
Pause Button		
Audio Specifications:		
Stereo Phono Output	-	1V RMS (each channel)
Electrical Specifications:		
Supply Voltage	-	240Va.c.
Maximum Current Rating	-	2A
Normal Operating Current	-	800mA
Physical Dimensions:		
Width	-	178mm
Height	-	80mm
Length	-	280mm

5. Conclusion and Evaluation

At the start of this project I knew nothing about the IDE or ATAPI devices. My knowledge of the two is now very good. I have also learnt that there are many more things to consider when designing a product, especially for the commercial market. Safety is a very important issue and one which I have had to consider when designing the power circuitry. Producing an ergonomic design is also important. I wanted the unit to be user friendly and simple to use. I feel that I have achieved my objectives.

Once I understood the many pages of standards and interpreted their meanings, the project came together quite well. I am very pleased with the final result. I have a working device which looks good and achieves the original objective.