" THE DEVELOPMENT OF A FAXMODEM CARD FOR A PERSONAL COMPUTER "

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REGIONAL DEVELOPMENT CENTRE

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BARRACK STREET

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DECLARATION

I declare that the contents of this thesis represents my own work and the opinions contained here are my own. It has not been submitted before for any examination at this or any other institute.

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SIGNATURE

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ABSTRACT

This thesis describes the development of a **FAXMODEM** card for a Personal Computer (PC). The faxmodem card incorporates intelligence and sufficient memory to store twenty pages of fax information.

When using the developed software with this faxmodem card, it converts a personal computer into a complete communications tool. It allows facsimili messages to be sent and received in the background. The modem used with any available communications software will enable the user to communicate with any computer or bulletin board.

OPSOMMING

Die tesis beskryf die ontwikkeling van 'n '**FAKSMODEM**' kaart vir gebruik in 'n persoonlike rekenaar.Die kaart omskep 'n rekenaar om in 'n belangrike kommunikasie hulp middel.

Fakse kan afgestuur en ontvang word terwyl die rekenaar met 'n ander taak besig is. Die faksmodem kaart wat ontwikkeld is, het intelligensie en beskik oor genoeg geheue om twintig bladsye faks informasie te stoor. Die ontwerp is van so 'n aard dat dit met enige kommmunikasie sagte ware gebruik kan word om met enige rekenaar of bulletien bord te kommunikeer.

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ACKNOWLEDGEMENTS

On completion of this thesis, I would like to extend my thanks to the following individuals for their assistance and support.

1.	Mr.P.H. Kleinhans (Associate Director) School of Elec.Eng. Cape Technikon	Primarily for being the project leader. For suggesting and commissioning the project concept and under whose guidance this research has been conducted. Further more, to the Cape Technikon for funding the project .
2.	Mr A.S. Herbert (Senior Engineer) Telkom.	for the provision of the facilities at the R.D.C.
3.	Mr K. Kay (Manager Office Equipment) Sharp Electronics.	for endless discussions related to the principle operation of facsimile machines.

I would like to extend my thanks to my numerous colleagues at the Regional Development Centre, Telkom, Cape Town for their mutual support and with whom many helpful discussions were held.

NOVEMBER 1993

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CHAPTER 1

INTRODUCTION

1.1 The PC as a communication terminal

Can the PC be used as a communication terminal of the future?

How is this possible ?

The computer used as a communications device has had a large impact on society. The use of a PC to transfer large amounts of data quickly and ethically has simplified the process of data transferal.

With the rapidly increasing popularity of dial up on-line services offered by Telkom, more users are relying on the PC to access information. As this type of application becomes standard, modems increasingly become an integral part of the PC.

Since facsimile systems share a lot of technology with personal computers, fax cards have emerged to allow PC users to send and receive faxes. These cards are able communicate with other fax cards or ordinary fax machines.

CHAPTER 2

OBJECTIVE

This thesis describes an investigation and design of a faxmodem card for a personal computer, that works fully in the background.

A number of faxmodem cards were tested and in some cases it were found that these cards either lock up the computer or drain it's resources while faxing, disadvantaging the user. Mr P. H. Kleinhans from the School of Electrical Engineering at the Cape Technikon commissioned this project with the following major objectives:

1. **To design a faxmodem card that works fully in the background.**
2. **The faxmodem card should form an integral part of the Personal Computer.**

Most of the relevant information for the design was obtained from technical literaure, provided by various Technical Institutions, as well as the Regional Development Centre, Telkom, Cape Town.

Telephonic and written correspondence with various institutions involved with repair of facsimile machines and data modems provided relevant data and application notes on operation of facsimile machines and data modems.

The objectives of this report are therefore :-

i) **To provide background information on data communications.**

ii) **To provide a detailed description and analysis of the proposed modem incorporated on the faxmodem card.**

iii) **To provide the background information on facsimile machines.**

iv) **Introduce the architecture of a facsimile machine and highlight critical requirements on hardware/firmware.**

v) **To provide a detailed description and analysis of the proposed fax incorporated on the fax modem card.**

Chapter 3

DATA COMMUNICATIONS TODAY

Today computers of all sizes, including personal computers (PC), are able to communicate with each other and with remote terminals. While a myriad of computer and terminal configurations are possible, an examination of various systems, three basic configurations are apparent:

i) small computer or terminal to a large host computer;

ii) large computers to large computers;

iii) small computers to small computers in special local area networks.

The following section examines the small computer or terminal to a large host computer combination.

Personal computers can be used as intelligent terminals in a data communications network, to communicate with a large computer.

Other types of terminals can also be used in this manner. One application where the personal computer or terminal is often used is to access the numerous data bases that are now available on large computers. These data bases include such information as the latest news reports, stock market performance data /share prices and new shopping services.

The basic components of a data communications system allowing access to a large computer and it's data base is illustrated in **Figure 1.**

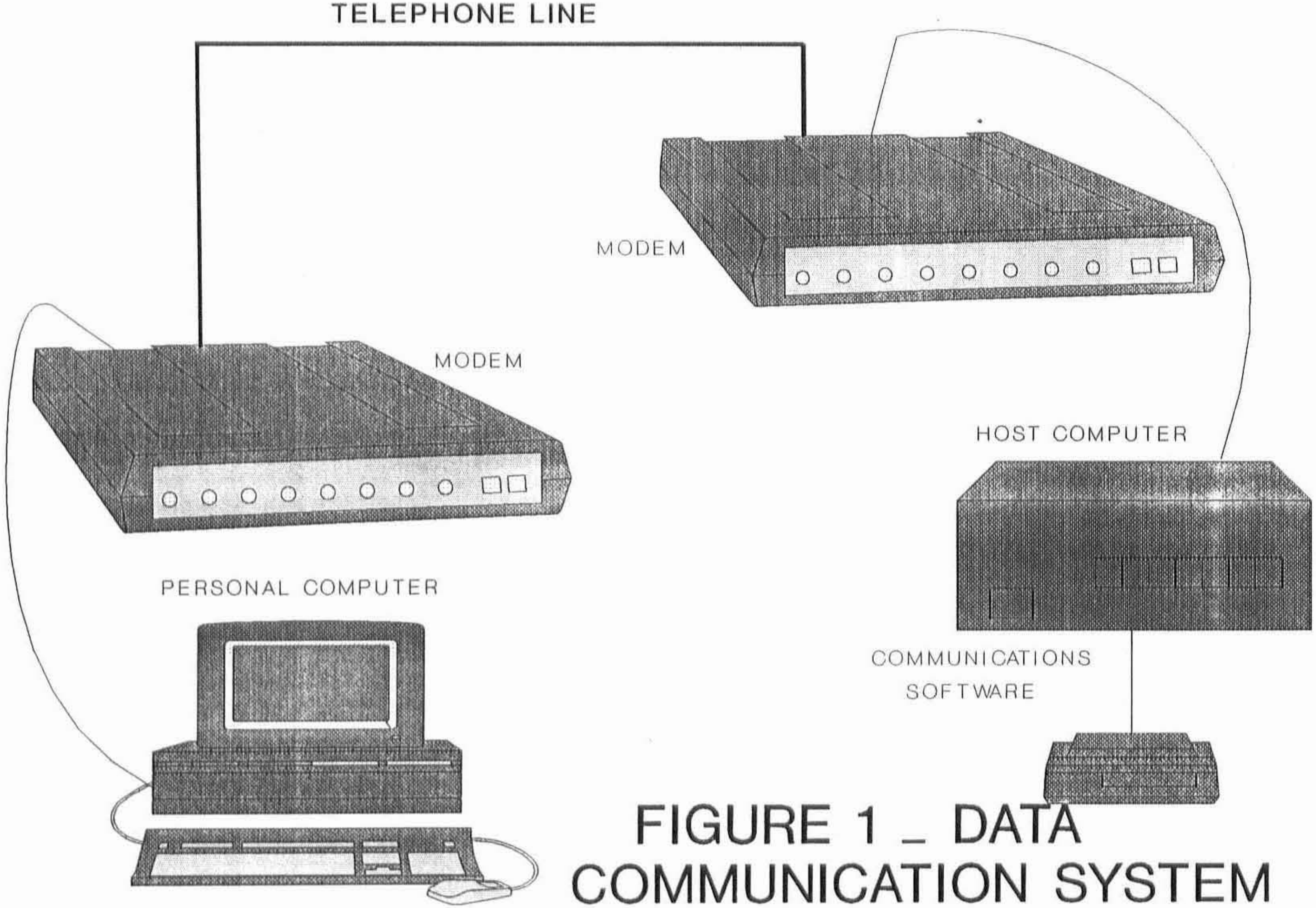


FIGURE 1 _ DATA COMMUNICATION SYSTEM

The components include:

i) A personal computer or computer terminal located at a site remote from the large host computer with which it communicates.

ii) A *modem which converts digital data (data in the form of bits)* generated by the personal computer or computer terminal, to analog signals (frequency) which can be sent over communication channels (telephone lines) .

iii) The communication channel over which the data is sent. Standard telephone lines are often used, but other communication channels such as a microwave and satellite are available.

iv) A modem at the other end of the communication channel to convert the analog data back to a digital form.

v) The fifth component of the data communications system allowing a personal computer to communicate with a large computer is the large host computer itself.

When the user of a personal computer wishes to obtain data from one of the large computer (such as obtaining an airline schedule and making a reservation), the user enters several commands which establish the link with the large computer. Each time the user enters a command or data to be transmitted, it is electronically sent to the modem as a series of bits. The modem may be housed within the personal computer or may be externally connected to the computer. The modem converts the data from digital form to analog form. The data, in analog form is sent from the modem through the communication line.

When the data arrives at it's destination, it must be demodulated by the modem, i.e. convert the data from analog form back to digital form. The data is then sent to the host computer where it can be processed. When data is sent from the large host computer to the personal computer or terminal, the same steps occur in the reverse order.

CHAPTER 4

PERSONAL COMPUTER HARDWARE AND SOFTWARE

A personal computer or intelligent terminal used for data communication applications require certain hardware and software, including:

i) Software designed to allow data communications.

ii) A communications adapter with a serial interface.

Each item is explained in the following sections.

4.1 Communications Software

The standard software available with personal computers allows the user to process data, retrieve, store, and execute programs and perform a variety of other tasks. When a personal computer is to be used to communicate with a large host computer, however, software must perform additional functions, including: establishing contact with the host computer, directing that data be transmitted across communication lines, handling errors which occur while the data is being transmitted, accepting data from the host computer, and other functions. Therefore the user must acquire a software package to perform these communications functions.

There are different types of communication software packages available. The simplest merely allow the user to establish contact with remote computers and enter and receive data. More sophisticated communications software allows large amounts of data to be transmitted from a data base on the host computer to the personal computer for storage on auxiliary storage (called **downloading**); allows data to be transferred from files on the personal computer to data bases on the host computer **(uploading)**.

Before obtaining a communications software package, users should carefully review their communications requirements, so that the appropriate software can be chosen to meet the project needs.

4.2 Serial Interface

Some personal computers are now manufactured with all the hardware required to allow the computer to communicate with a large host computer. Therefore before a personal computer can be used for data communications, additional hardware must often be added. This hardware consist of a board called a **'COMMUNICATIONS ADAPTER'**. The communications adapter also performs other functions, including such tasks as adding and deleting required bits, interfacing with software to control the speed of transmission, error handling, and similar tasks.

Data is moved in parallel form internally within the computer. In order to transfer data down a communication channel, the bits must be transmitted one bit after the other (called **serial transmission**).

CHAPTER 5

MODEMS FOR THE PERSONAL COMPUTER

The second component in the data communications system which allows a personal computer to communicate with a large host computer is a **modem.** The term modem is an abbreviation for modulator/demodulator. The purpose of the modem is to change digital data, consisting of bits, into an analog signal that can be transmitted over telephone lines; and on the receiving end, change the analog signal into digital data that can be stored in main computer memory of the host computer.

To allow the serial stream of bits to be communicated to other components a **serial interface,** or **port** is needed. Data is transmitted in and out of the computer through the serial interface. The serial interface is discussed in section **6.3 (Modem Bus Interface)**.

5.1 Modem types

A variety of modems are available for personal computers, including:

i) EXTERNAL , DIRECT CONNECT MODEMS

ii) ACOUSTIC COUPLERS

iii) INTERNAL MODEMS

5.1.1 External modems

External, direct connect modems are attached to a personal computer by a cable. These modems are contained in a relatively small housing which can be placed adjacent to the computer. A cord from the modem plugs directly into a standard telephone jack to allow communication over telephone lines. They require separate power supplies, enclosure and an RS-232 interface in both the modem and in the PC.

5.1.2 An acoustic coupler

An acoustic coupler is a modem that is connected to a personal computer or terminal by a cable. A standard telephone headset is placed into rubber cups on the acoustic coupler. The acoustic coupler converts the digital signals generated by the terminal or personal computer into a series of audible tones which are picked up by the mouth piece in the headset in the same manner as if it were speaking into a telephone. The analog signals are then transmitted over the communication channel. An acoustic coupler provides portability because it can be used with any telephone headset in any setting. It is generally less reliable than an internal modem or external modem, because even small outside sounds can be picked up by the acoustic coupler and be transmitted.

5.1.3 An internal modem

An internal modem requires no external supply or connections except for the telephone line. It is space saving.

CHAPTER 6

DESIGNING A MODEM AS AN INTEGRAL PART OF A PC

Modems are evolving from stand-alone, to PC plug-in, to optional module, to standard feature on the PC.

6.1 PC bus add-in card.

These modems plug into the PC bus typically using thirty (30) pins to implement an 8 bit I/O mapped UART 'com port' interface on a half-card. The Bus interface chips, address decoders, card edge connectors and a UART are required to implement the interface.

PC bus add-in modem cards save the additional cost of an enclosure, power supply and RS-232 connectors.

6.2 A typical modem design.

Figure 2 shows a minimum modem design using INTEL 89024 modem chip set. The modem chip set consists of 89026 microcontroller and the 89027 analog front end (AFE). The microcontroller is programmed to provide DSP-based modulation, demodulation and user-interface (AT COMMAND SET) functions.

The AFE provides the complex filtering required to split the phone line bandwidth into send and receive channels , tone generation and analog AGC (automatic gain control) receiver functions.

To implement a fully functional 2400 bps (bits per second) modem, a data access arrangement (DAA) is the only requirement. The DAA interfaces the modem to the phone line and isolates it from hazardous voltages on the phone line .

6.3 MODEM PC BUS INTERFACE

The modem interfaces to the PC BUS via the 8250 UART and the 22V10 GENERIC ARRAY LOGIC (GAL). The 22V10 GAL provides address decoding and port selection logic. (see **Figure 3**). The 8250 provides an interface, allowing the modem to work with commercial applications software such as PC BEL, SMART TERM, SMART COM, and PC TERM. The port selection logic will automatically redirect interrupts from the UART to the appropriate system interrupt.

A serial interface is needed to allow the serial stream of bits to be communicated. The serial interface consists of the 8250 UART. The serial interface, acts as a pathway through which the computer transfers serial data to and from modems.

The communication/serial interface also performs other functions, including tasks such as adding and deleting required control bits, interfacing with the software to control the speed of transmission, error checking and similar tasks. (**GENERIC ARRAY LOGIC Appendix A.**)

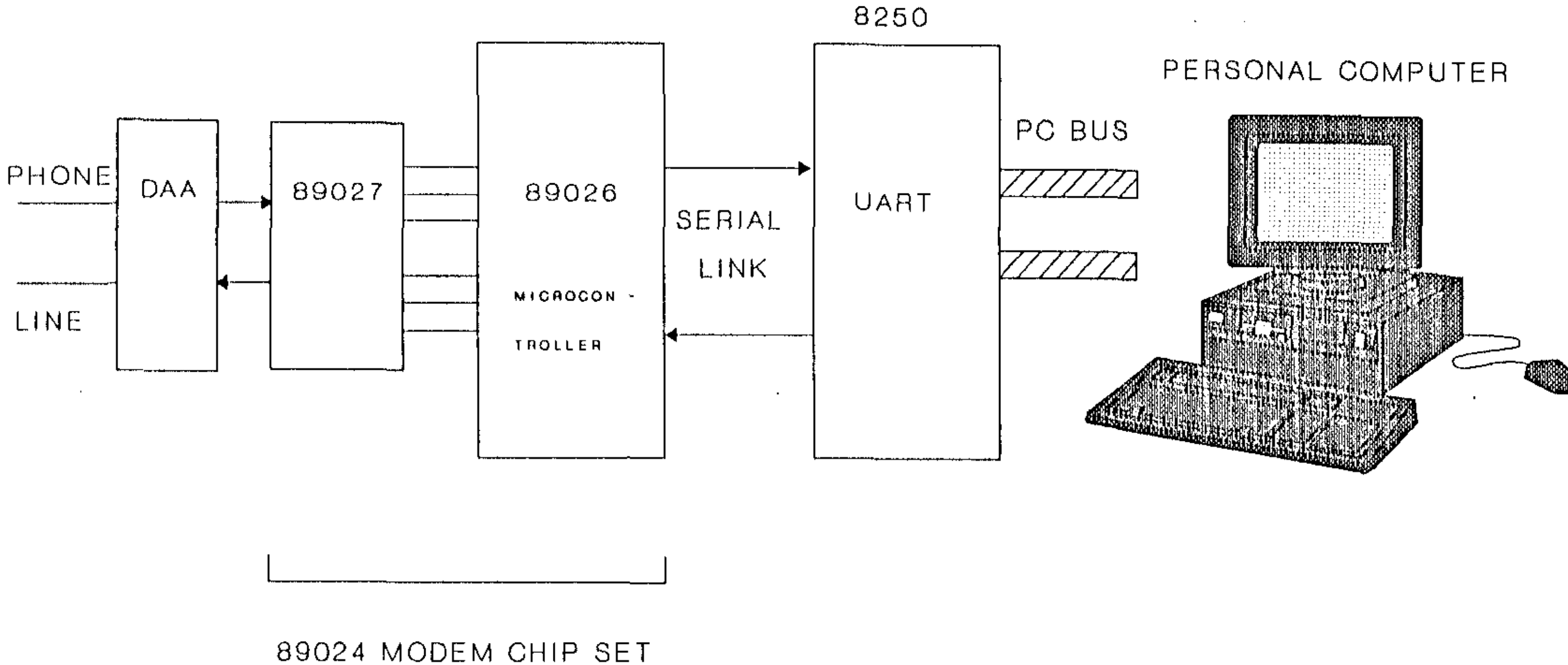


FIGURE 2 _ MODEM ADD-IN CARD

6.4 Communications device address

The UART register of the 8250 is addressed through the I/O address space. The modem can be configured for either of the two I/O address spaces for serial asynchronous communication devices.

These locations are designated COM1 and COM2. The 89024 may occupy one of the two addresses, however only one device at a time may be assigned to each designation. The location is selected by installing a jumper (JP1) on the faxmodem card. Table 1 defines the COM port selections.

TABLE 1: COM PORT SELECTION

Jumper JP1	COM Port	Interrupt	I/O Address
Installed	COM1	INT 4	03F8h-03FFh
Removed	COM2	INT3	02F8h-02FFh

Some IBM PC Compatible computers have an on-board asynchronous serial port which occupies one of the COM port address spaces and cannot be disabled. The 89024 must not be set to occupy a COM address which is already occupied by any other asynchronous serial port.

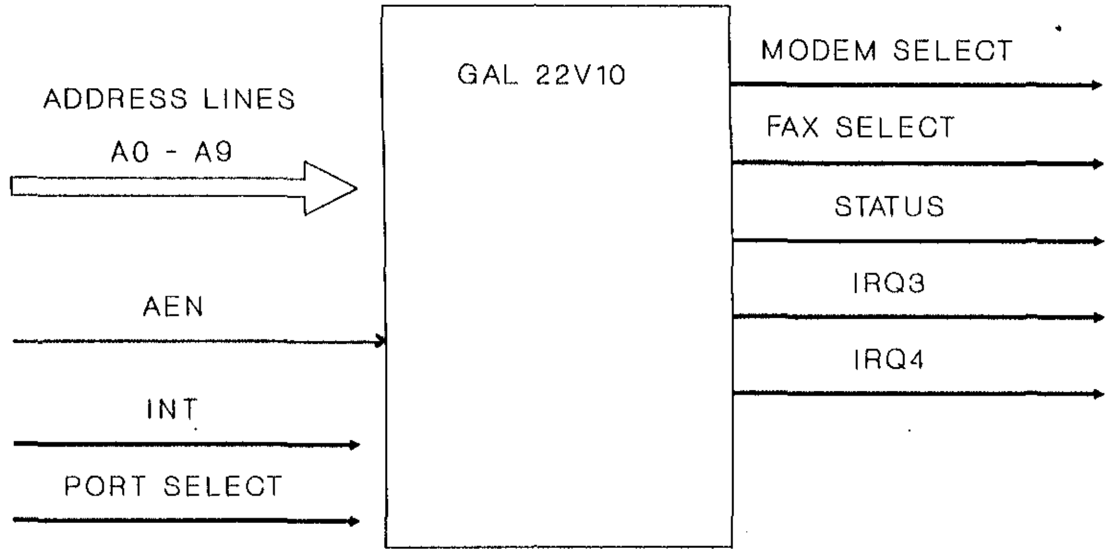


FIGURE 3 _ GAL ADDRESS DECODING

6.5 89024 EXTERNAL NVRAM INTERFACE

One of the key functions of the HAYES SM 2400 provided by INTEL 89024 intelligent modem is an interface for an external serial **NVRAM 'X244'** device to store modem configurations parameters.

These parameters can be stored in an external serial NVRAM device, through a simple interface with the 89026 micro controller. **Figure 4** illustrates this simple interface.

Several of the AT commands that invoke a transaction with the external NVRAM are listed below.

AT commands : ATZ

ATDS

Expanded NVRAM (9346) support which allows storage and retrieval of four phone numbers and two user's profiles. Commands supported are &n, DS, & Wn and & Zn.

Connection of the external NVRAM to the 89026 microcontroller is optional. Upon power up, the 89026 will determine whether an external NVRAM is attached. A newly installed NVRAM may be initialized by executing an AT & W command.

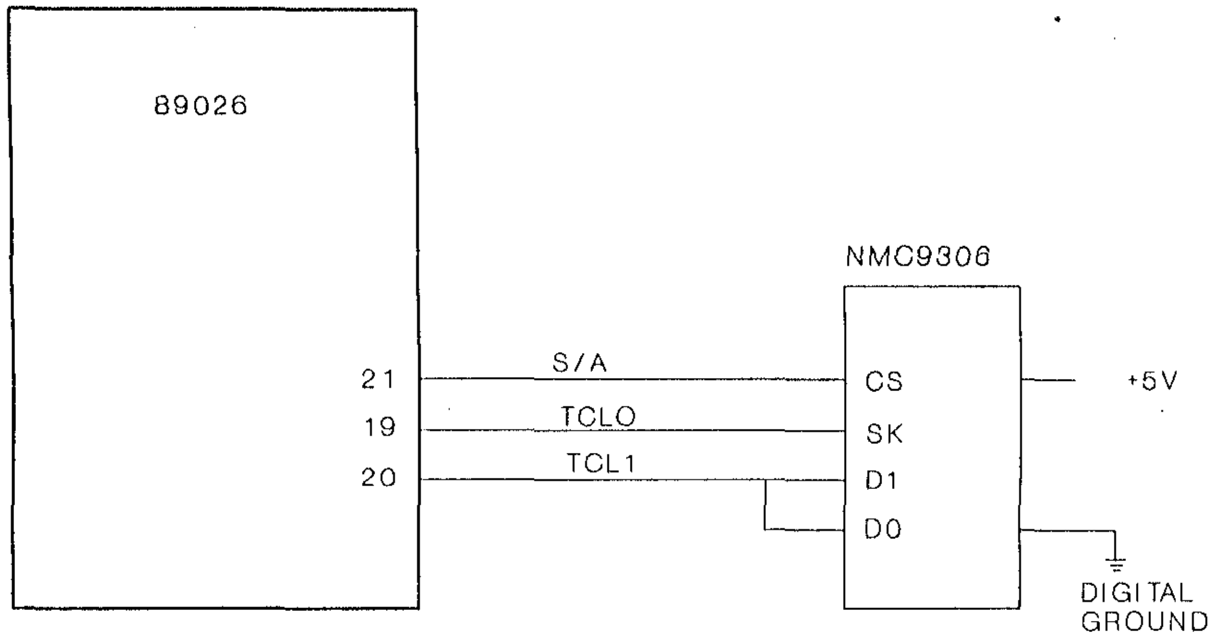


FIGURE 4 _ NVRAM INTERFACE

6.6 89024 MODEM CHIP SET

The Intel 89024 chip set is a highly integrated, high performance, intelligent modem, providing a complete system in two chips. The Intel 89024 chip set is made up of the 89026 application specific processor chip and the 89027 analog front end chip. (See **Figure 5**). The 89024 chip set performs a comprehensive set of 2400 bps, full duplex modem functions. The solution is based on 16-bit microcontroller technology and is highly flexible, thereby addressing a broad range of market segment requirements. The minimum chip count is a very cost effective design solution. **Figure 6** depicts the system block diagram.

The 89024 system is designed to support the following modem specifications:

1. CCITT V.22 BIS 2400 bps sync and async
   1200 bps sync and async

2. CCITT V.22 A & B 1200 bps sync and async
   600 bps sync and async

3. BELL 212A 1200 bps sync and async

4. CCITT V.21/BELL 103 0 to 300 bps anisynchronous

The modem is software configurable, using a standard serial terminal interface and has a set of default features, which may work in most applications without changes.

The Serial digital interface of the chip set is at TTL (transistor, transistor logic) levels. A 8250 UART has been used as a digital interface and will permit direct transfer of data to and from a microcomputer bus.

The Intel 89024 command set conforms to the Hayes Smart Modem command set. Most PC software written for the Hayes Smart modem can be used with the 89024 chip set.

As an **intelligent data communication** device, the 89024 system analizes and executes commands sent to it as ASCII characters. The modem will return word or digit messages as ASCII characters.

The modem can automatically call and answer remote modems. All the software and hardware required for the auto-dialing and auto-answering (in both DTMF and pulse type networks) are built into the chip set. The chip set also provides an auxiliary signal to drive a monitor speaker. The 89024 is capable of detecting and identifying the call-setup-signals of most telephone networks. Call progress messages are sent during automatic call setup. These progress tones can be monitored at the speaker output **'SP1'**.

6.7 Modem DAA INTERFACE

A DAA (Data access arrangement) is required for interfacing a modem to the telephone network. **Figure** 7 depicts the schematic for the data access arrangement. The 89024 chip set contains all

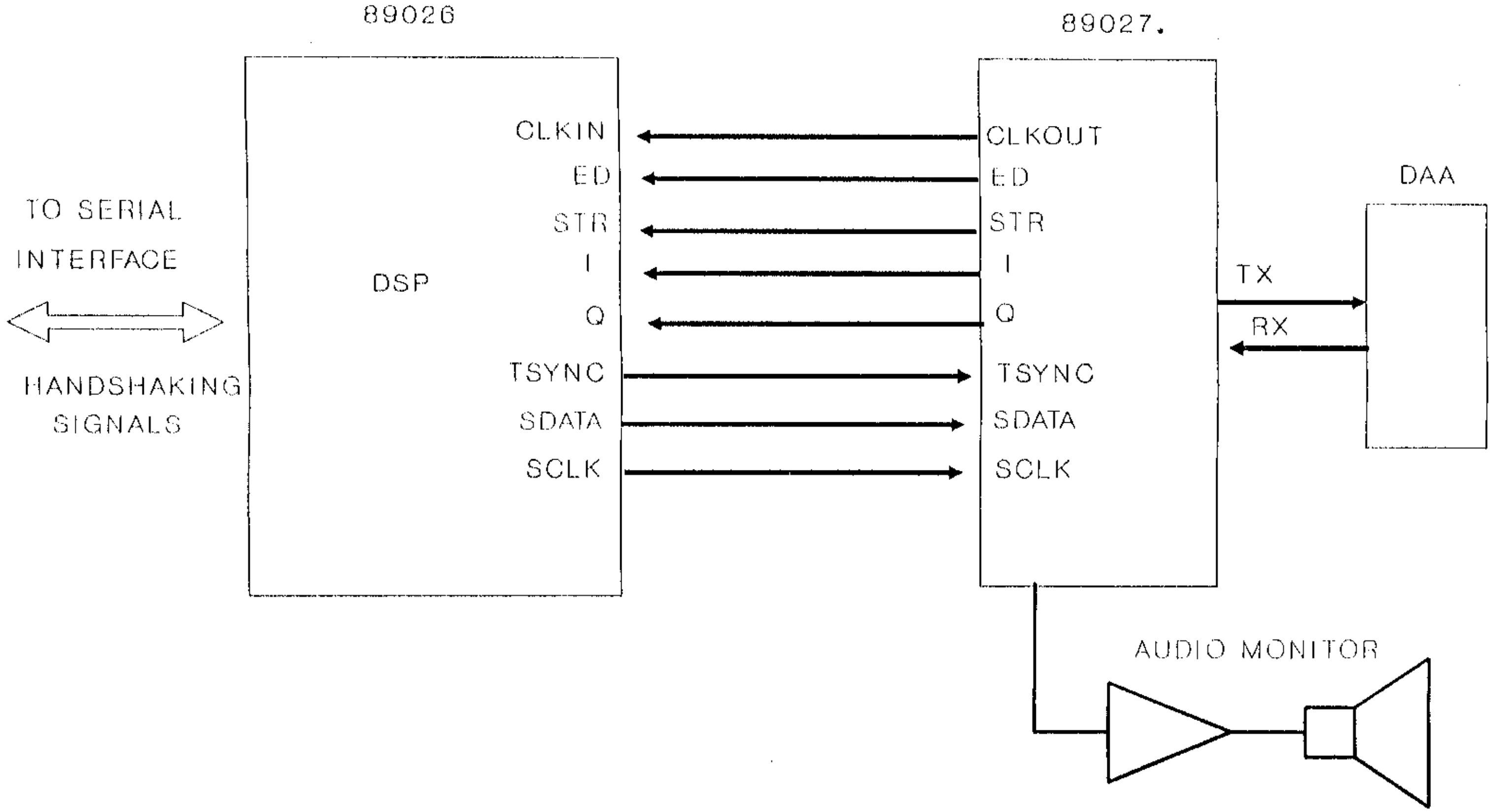


FIGURE 5 _ 89024 MODEM CHIP SET

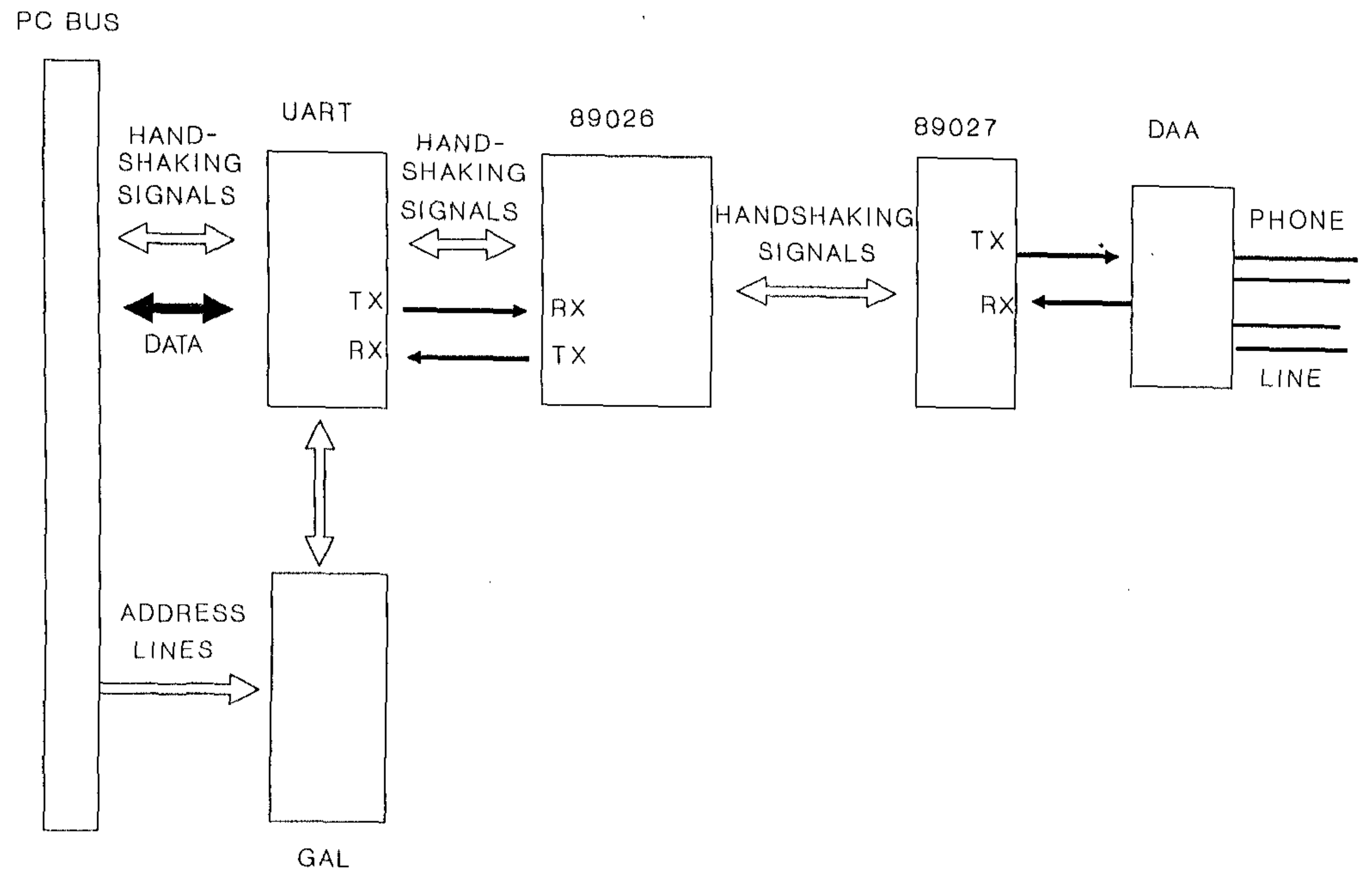


FIGURE 6 _ MODEM SYSTEM BLOCK

functions required for establishment, progress and determination of data calls, through the Public Switched Telephone Network (PSTN), or through a privately owned line. It has a built in **DTMF** dialler, and alternately provides an off-hook (OH) signal, to be used for **PULSE** dialing using an external relay (in DAA). The choice between DTMF or pulse dialing can be explicitly specified by command ; eg ATDT or ATDP can be automatically selected by the modem (if additional custom code is written).

The modem chip set has it's own two to four wire converter and provides a billing time delay of two seconds. By enabling the 'HYB' pin on the 89027 (analog front end) an internal four to two wire hybrid is used and an external one is not required.

The DAA uses a transformer to isolate the modem from the line. The transformer has a turn ratio of 1:1 and can handle a dc line current up to 50 ma or 80 ma on the line side. A 600 ohm resistor **(R10 see MODEM.SCH CIRCUIT diagram APPENDIX D)** defines the impedance seen by the telephone line. A pair of back to back zener diodes prevents surges from damaging the analog front end (89027). The telephone line is connected to the line transformer through resistors 'R22 and R23'. The gas electrodes suppress lightning surges.

6.8 Modem levels

The modem output level is set by 'TX0-TX3' pins to be -8dbm. Assuming a 1db DAA insertion loss, transmitted signal at TIP and RING will be -9dbm which satisfies TELKOM maximum power requirements. Any DAA must meet TELKOM requirements and be registered accordingly.

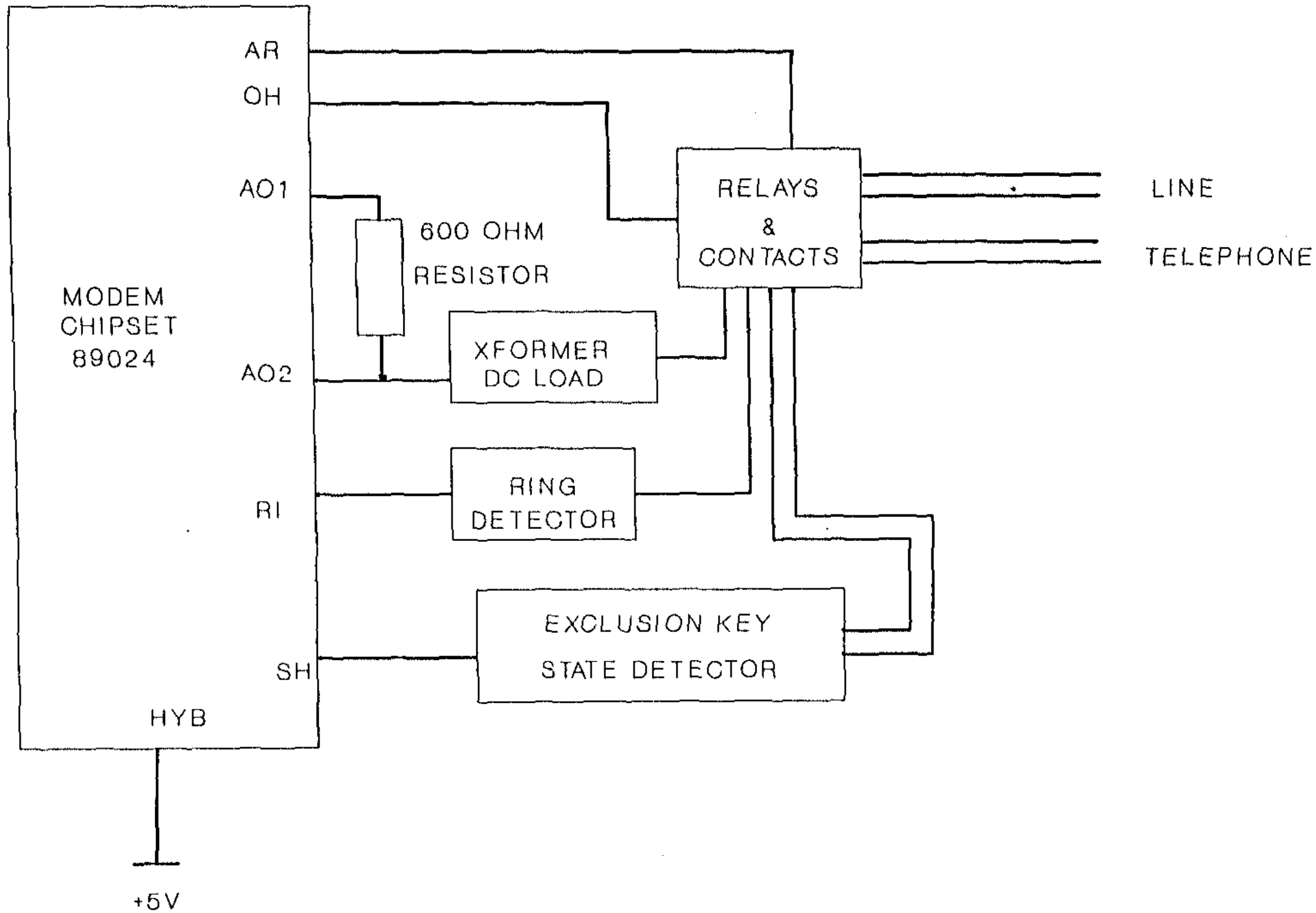


FIGURE 7 _ DAA ARRANGEMENT

This interface isolates the modem from the telephone line while providing line coupling, ring detection and on/ off hook control.

TABLE 2 defines transmit levels.

TABLE 2 : TRANSMIT LEVELS

TRANSMIT OUTPUT LEVEL		
TX 3, 2, 1, 0	TYP	Units
0 0 0 0	+5	dbm
0 0 0 1	+4	dBm
1 1 1 0	-9	dBm
1 1 1 1	-10	dBm

6.9 Ring Detect

The ring detect circuit is comprised of an opto-coupler (4N25), a 0.68mf, 250-volt capacitor to block the DC loop current, an 2.2k ohm current limiting resistor, and two 9.1 volt zener diodes to define the minimum ring voltage. The resistor/capacitor network is selected to define the ringing detector impedance between the modem and the incoming ring voltage. This is the ringer equivalence number **(REN)** as defined by TELKOM, **'part 4.3.1 specification: 3B24/001'**. At the output of the opto-isolator, two resistors and a capacitor smooth the ring frequency envelope to detect the cadence of the ring voltage.

When an incoming call occurs, the DAA signals the 89026 microcontroller by placing a 20 HZ square wave signal on 'RI' pin. This signal is filtered by C22 and R13. As illustrated in **Figure 8**, the following signals of the modem chip set perform the analog interface. The **'AR'** (Auxiliary Relay Control) signal allows the modem to be used with standard telephones without exclusion keys and full use of the auto-dialing and auto-answer features. When the modem is idle, the telephone line will be under the control of the telephone set. The modem will capture the line using 'AR' control, only when it is originating or answering a call or when commanded to do so from the terminal.

All parts of the circuit can be seen in **APPENDIX D** .

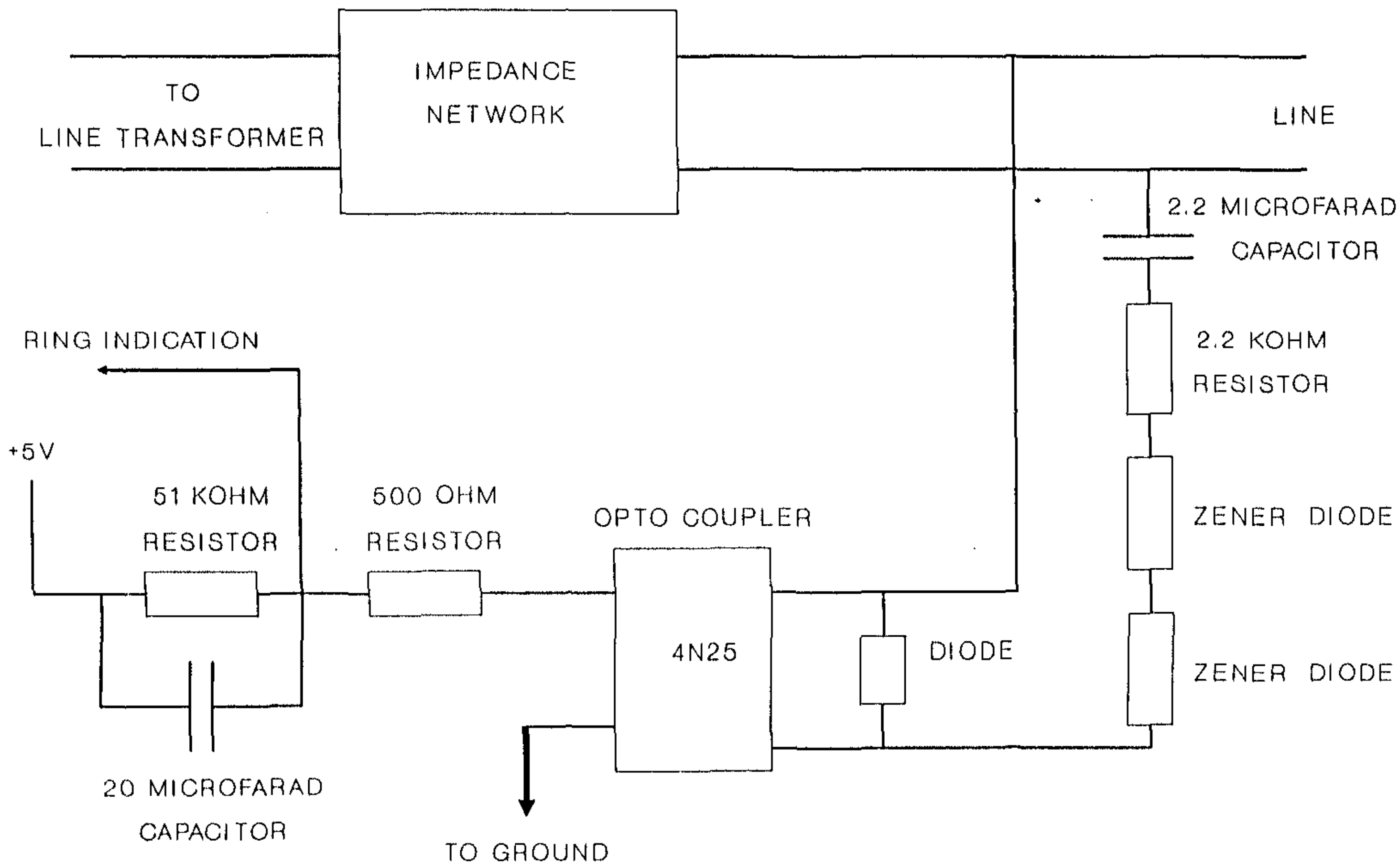


FIGURE 8 _ RING DETECTION

CHAPTER 7

MODEM SOFTWARE

Many modems used with microcomputers are 'smart' modems. This means that they have some on-board intelligence. A 'smart' modem includes an on-board microprocessor, which can set up the modem and supervise it's operation. When the smart modem is in the 'on-line' state, it is connected to the telephone line and is ready to send or receive data. In 'command' state, the modem is ready to accept commands from the operator. The operator would use the 'command' mode to reconfigure the modem, changing the operating speed, for example.

Hayes Microcomputer Products was an early leader in the modem business, and most 'smart' modems are advertised as 'Hayes' compatible. 'Hayes modems' use a standard command set. The Hayes command set is sometimes called the 'AT' command set, since the commands begin with the prefix 'AT'.

It is possible to supervise a modem using these commands, by typing them on the computer keyboard by hand. The 89024 chipset has a serial command set compatible with Hayes Smartmodem 2400.

7.1 SOFTWARE CONFIGURATION COMMANDS

This section lists the 89024 commands and registers that may be used while configuring the modem. Commands instruct the modem to perform an action, the value in the associated registers determine how the commands are performed, and the result codes returned by the modem tell the user about the execution of the commands.

The commands may be entered in a string, with or without spaces in between. Any spaces within or between commands will be ignored by the modem. During the entry of any command, the 'backspace' key (CNTRL H) can be used to correct any error. Upper case or lower case characters can be used in the commands. Commands described in the following paragraphs refer to asynchronous terminals using ASCII codes.

7.1.1 COMMAND SET

The command set is tabulated in **Table 3 and Table 4.**

TABLE 3: COMMAND SET

AT	Attention code.
A	Go off-hook in answer mode
A/	Repeat previous command string
Bn	BELL/CCITT Protocol Compatibility
Ds	The dialing commands (0-9 ABCD * # PRTS , ; @)
En	Echo command (En)
Hn	Switch-Hook Control If &J1 option is selected,H1 will also switch the auxiliary relay
In	Request Product Code and Checksum
Ln	Speaker Volume
Mn	Monitor On/Off
O	On-line
Qn	Result Codes
Sn=x	Write S Register
Sn?	Read S Register

TABLE 4: COMMAND SET

Vn	Enable Short-form Result Codes
Xn	Enable Extended Result Code
Yn	Enable Long Space Disconnect
Z	Fetch Configuration Profile
+++	The Default Escape Code

& COMMAND SET

The & command set is tabulated in **Table 5.**

TABLE 5: & COMMAND SET

&C	DCD Options
&D	DTR Options
&F	Fetch Factory Configuration Profile
&G	Guard tone
&J	Telephone Jack Selection
&L	Leased / dial - up Line Selection
&M	Async/Sync Mode Selection
&P	Make/break Pulse Ratio
&R	RTS/CTS Options
&S	DSR Options
&T	Test Commands
&W	Write Configuration to Non Volatile Memory
&X	Sync Clock Source
&Z	Store Telephone Number

7.2 CONFIGURATION REGISTERS

The modem stores all the configuration information in a set of registers. Some registers are dedicated to special command and function, and others are bit-mapped, with different commands sharing the register space to store the command status.

See Appendix B

CHAPTER 8

FACSIMILE MACHINES

8.1 FAX Background

Over the last few years, the facsimile or fax machine has quietly revolutionized the way a modern business operates. Sending text, line art and even simple photographs across the city or the globe is now as simple as making a telephone call.

A modern fax machine is really three separate devices in one box i.e a scanner, a modem and a thermal dot-matrix printer.

Figure 9 depicts a block schematic of a fax machine.

Figure 10 depicts a block schematic of the software architecture of a fax machine.

8.2 Classification of facsimile apparatus for document transmission over the public networks

i) For document facsimile transmission by international communications carried on public networks there is a need for providing sufficient operating speeds to meet users' requirements.

ii) Users' requirements may be served at the present time by classifying the following four basic categories of document facsimile apparatus.

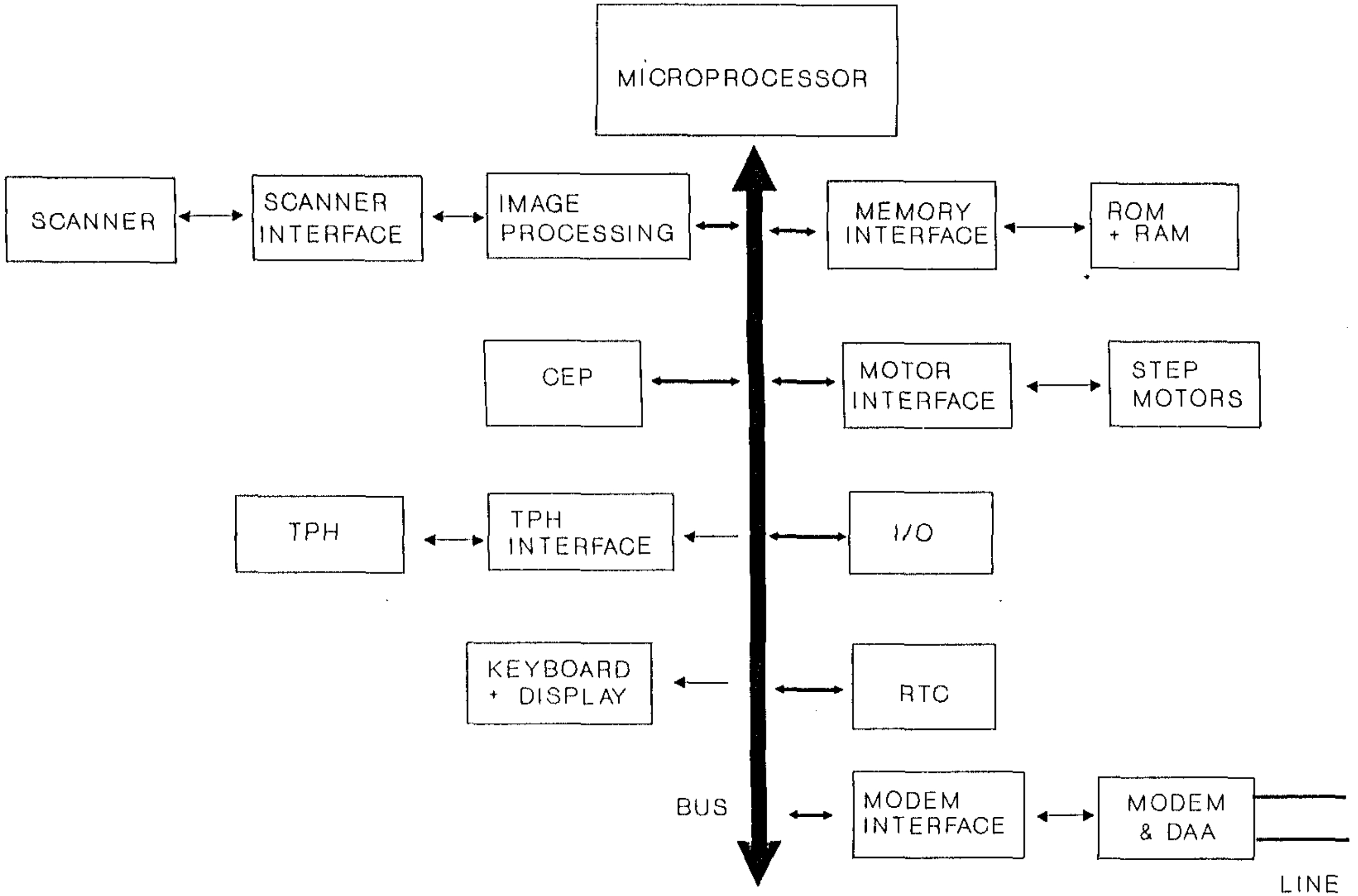


FIGURE 9 _ BLOCK DIAGRAM OF FAXMACHINE

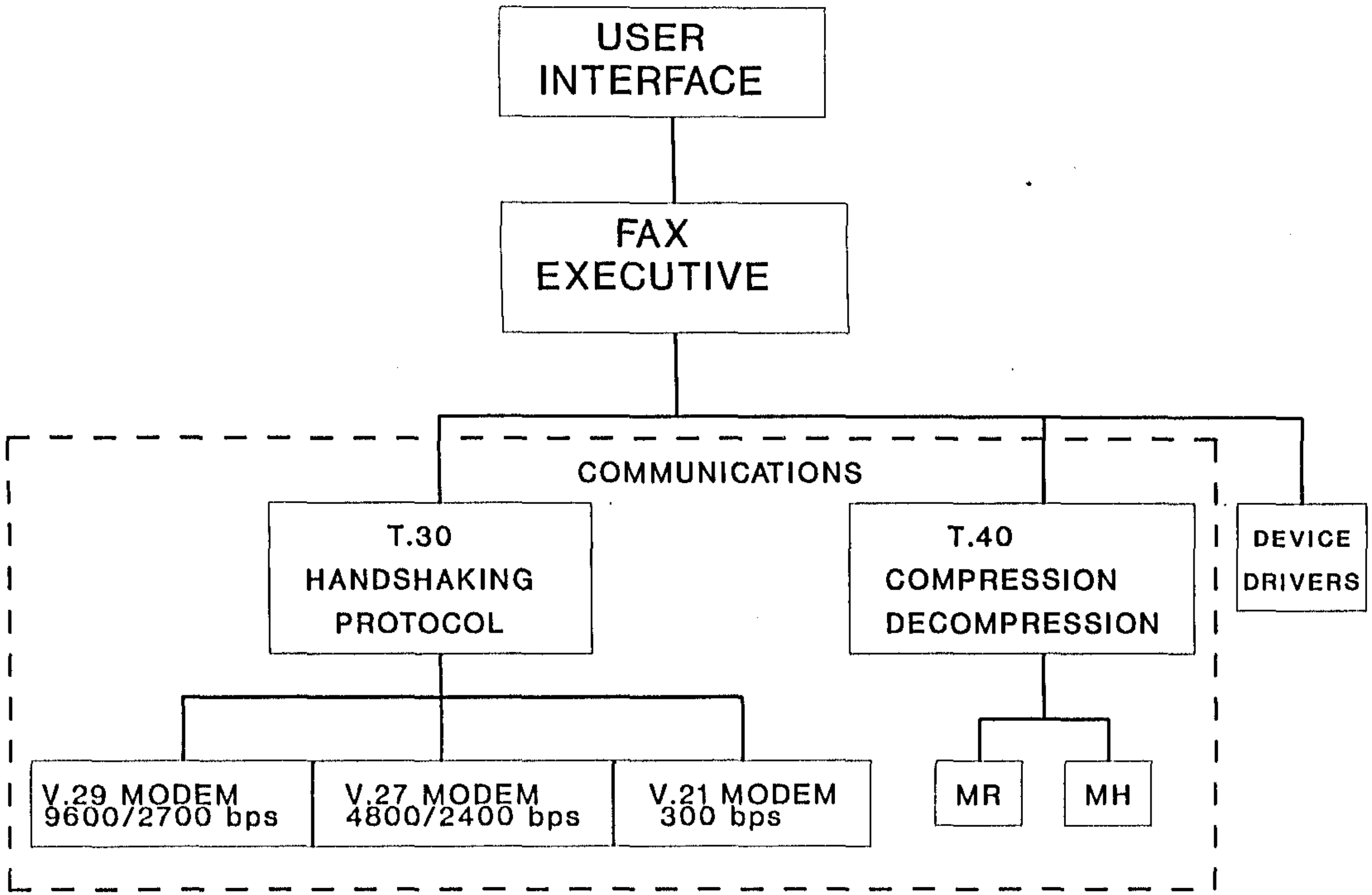


FIGURE 10 _ SOFTWARE ARCHITECTURE

8.2.1 Apparatus for use over the public telephone network

8.2.1.1 Group 1

Apparatus which use double sideband modulation without any special measures to compress the bandwith of the transmitted signal and which is suitable for the transmission of documents of ISO A4 size at nominally 4 lines per mm in about six minutes via a telephone-type circuit.

Apparatus in this group may be designed to operate at a lower definition suitable for the transmission of documents of ISO A4 size in a time between three and six minutes.

8.2.1.2 Group 2

Apparatus which exploit bandwith compression techniques in order to achieve a transmission time of about three minutes for the transmission of an ISO A4 size document at nominally 4 lines per mm via a telephone-type circuit. Bandwith compression in this context includes encoding and/ or vestigal sideband working but excludes processing of the document signal to reduce redundancy.

8.2.1.3 Group 3

Apparatus which incorporate means for reducing the redundant information in the document signal prior to the modulation process and which can achieve a transmission time of one minute for a typical typescript document of ISO A4 size via telephone-type circuit. The apparatus may incorporate bandwith compression of the line signal.

8.2.1.4 GROUP 4

Apparatus which incorporate means for reducing the redundant information in the document signal prior to transmission mainly via public data networks (PDNs). The apparatus will utilize procedures applicable to the PDN and will assure an essential error-free reception of the document. The apparatus may also be used on the public telephone network where an appropriate modulation process will be utilized.

The users will choose among this apparatus, in accordance with their needs and the facilities afforded by the connection and the network.

Procedures for groups 1, 2, and 3 document facsimile transmission in the public switched telephone network should be in accordance with recommendation T.30. (Refer to International Telecommunication Union CCITT Vol viii FACSIMILE vii.3).

Procedures for group 4 document facsimile transmission should be in accordance with recommendation T.62, T.70 and T.73

8.3 STANDARDS

The CCITT has standards defining both the actual modulation schemes used over telephone line, and also the broader aspects of how the two fax machines establish the connection and then transfer the data in an intelligible form.

CCITT V.29 is a synchronous standard which runs the line at 2400 baud, half duplex, using QAM (quadrature amplitude modulation). Depending upon the quality of the line, the number of bits sent during each signalling period is either two, three or four, giving data rates of 4800, 7200 or 9600 bps respectively.

The V.27 ter standard is the other standard modulation scheme for faxes. Again, it is asynchronous standard, but runs at 1600 baud falling back to 1200 baud when required, and using PSK (phase-shift keying) rather than QAM. At 1600 baud, tribit encoding is used, giving a data rate of 4800 bps, while at the 1200 baud speed, dibits are sent for a data rate of 2400 bps.

The bit error rate **(BER)** achieved on a given line falls as the number of bits transfered at a time is reduced, and the fax machines automatically determine the optimum speed to use while maintaining an acceptable BER. Also the V.29 4800 bps rate performs better over a given line than does V.27 ter at the same rate, so the former is preferable if both ends are V.29 -equipped.

Essentially what two modem fax machines do, in establishing a call, is test the BER initially using the V.29 standard at 9600 bps. If this is given a suitably low BER, they continue operating at this data rate, but otherwise they begin dropping to lower rates until an acceptable BER is achieved.

If none of the three V.29 rates achieves this, they will drop down to V.27 ter 2400 bps rate.

8.3.1 Standardization of Group 2 Facsimile Apparatus for Document Transmission

The CCITT,

considering

i) that Recommendation T.2 refers to Group 1 type apparatus for ISO A4 document transmission in approximately six minutes;

ii) that there is a demand for Group 2 apparatus which enables an ISO A4 document to be transmitted in approximately three minutes;

iii) that the Group 2 apparatus reproduces document quality similar to Group 1 apparatus;

iv) that such a service may be requested either alternatively with telephone conversation, or when either or both stations are not attended; in both cases, the facsimile operation will follow Recommendation T.30;

v) interconnection between two machines of different designs, both confirming to Recommendation T.3 may give a lower guaranteed reproducible area in certain cases;

unanimously declares the view

that Group 2 facsimile apparatus for use on the general switch telephone network and international leased circuits shall, in future, be designed and operated in accordance with this Recommendation.

8.3.2 Standardization of Group 3 facsimile Apparatus for Document Transmission

The CCITT,

considering

i) that Recommendation T.2 refers to Group 1 type apparatus for ISO A4 document transmission over a telephone-type circuit in approximately six minutes;

ii) that Recommendation T.3 refers to Group 2 type apparatus for ISO A4 document transmission over a telephone-type circuit in approximately three minutes;

iii) that there is a demand for Group 3 apparatus which enables an ISO A4 document to be transmitted over a telephone-type circuit in approximately one minute;

iv) that for a large number of applications black and white reproduction is sufficient;

v) that such a service may be requested either alternatively with telephone conversation, or when either or both stations are not attended; in both cases, the facsimile operation will follow Recommendation T,30;

unanimously declares the view

that Group 3 facsimile apparatus for use on the general switched telephone network and international leased circuits should be designed and operated according to the standards stipulated in the CCITT VOLUME VII - FACSILE VII.3 .

8.4 Facsimile Protocol

During facsimile communication, not only is data representing the scanned document transmitted and received, but additional information such as telephone numbers, paper width, baud rate, sub-scan line density and a whole host of other data is sent in what is known as **PROTOCOL**.

Further the quality of the telephone line is tested before and monitored during image transmission and if found to be inadequate, then the transmission speed is slowed down. In this manner, the state of the line and the other facsimile is confirmed before sending and receiving of documents commences. This exchange of information follows a set of guidelines laid down by the CCITT to ensure compatibilty between machines.

Figure 11 shows the transmission (TX) and reception (RX) procedure when a single page document is sent in G3 mode. This can be broken down into the following steps :-

8.4.1 Modem block

For G3 mode, transmit/received date is supplied to the SIO. Carrier transmission is controlled by the send request signal (RTS) through the serial input/output (SIO).

For G2 mode, the carrier transmission is controlled by the interface memory through data bus and transmit/receive data is supplied to the line memory.

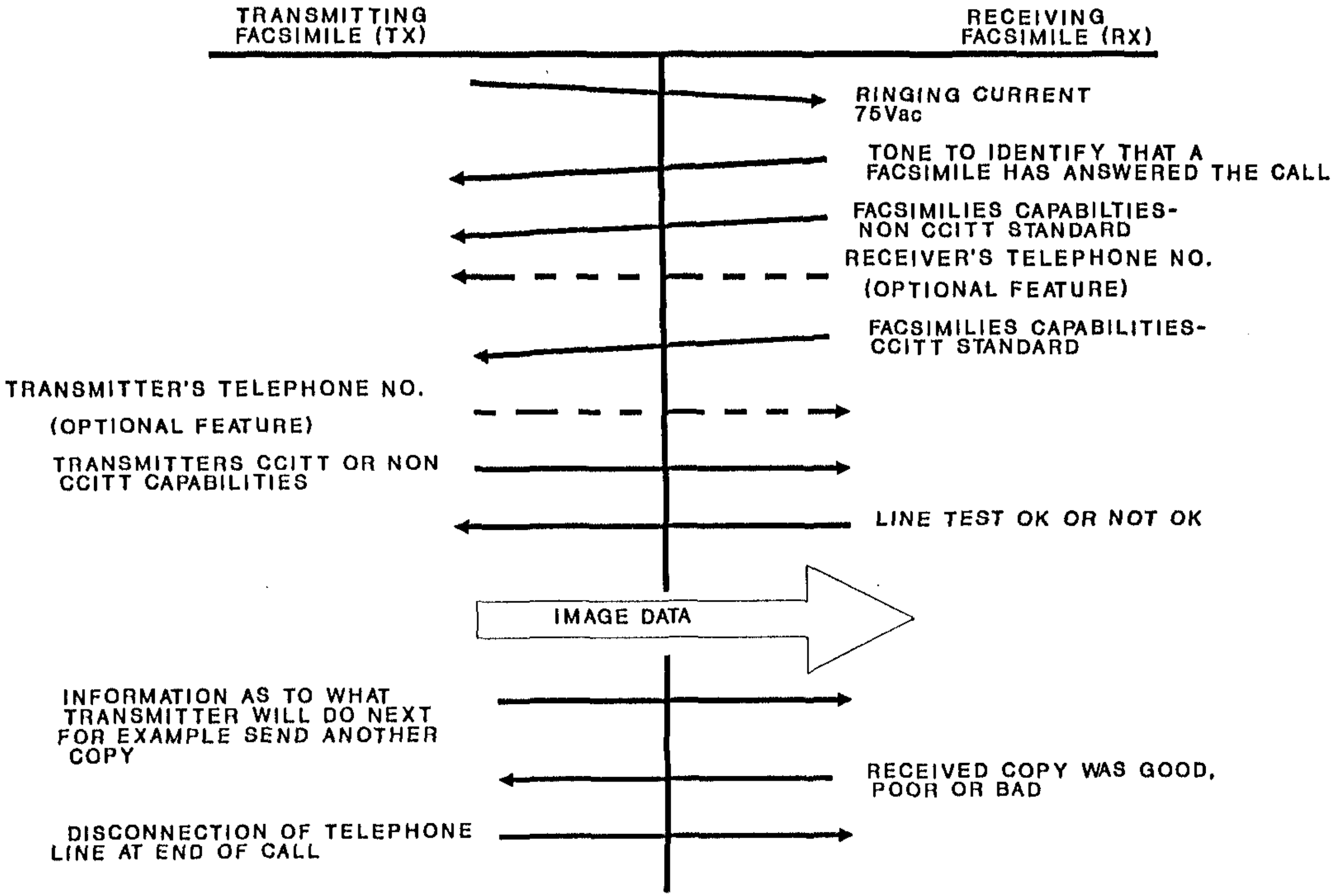


FIGURE 11 _ CCITT G3 TRANSMISSION PROTOCOL-GENERAL

TABLE 6: Communication modes

COMMUNICATION MODE	SPEED	CARRIER FREQUENCY
G3	9600 bps	1700 Hz
G3	7200 bps	1700 Hz
G3	4800 bps	1800 Hz
G3	2400 bps	1800 Hz
G3	300 bps	1650 / 1850 Hz
G2		2100 Hz

8.4.2 CED tone 2100 Hz transmit

The CPU writes to the command register of the modem board the command that indicates the use of the modem in G2 transmission time.

Next, the CPU sets in the parameter register of the modem board via data bus, the data that corresponds to 2100 Hz frequency.

The CPU in the modem board interprets and executes the command and parameter. The G2 modem is chosen and goes into the transmit mode. A 2100 Hz CED signal is sent from the TXout line.

8.4.3 DIS (NSF) Signal transmit

The main CPU sets the 300 bps modem operating command to the modem board via the data bus. The CPU in the modem board decodes the command registered and selects the 300 bps modem to go into the transmission mode.

The 300 Hz transmission timing clock is sent to the SIO from the modem.

The CPU writes in the SIO command register to send a send request signal (RTS) to the modem to send the data.

Clear to send (CTS) signal sent to the SIO to inform it that the modem is ready for transmission.

The transmission data stored in the SIO transmission buffer is converted from parallel to serial form within the SIO, to be sent bit by bit through TXDA (transmit data output line) line in synchronization with the transmit timing clock (300 Hz).

The transmission data sent from the SIO are modulated in the 300 bps modulation circuit of the modem and sent through the TXout line.

8.4.4 DIS (NSF) Receive

Before receiving the procedure signal (such as 9 nsf, dis, etc.) the CPU must choose the 300 bps modem and the receive mode command must be sent via the data bus using the out command.

The CPU in the modem board decodes the data stored in the command register and the 300 bps modem is chosen.

The (nsf) signal sent from the facsimile is entered to the line interface and sent out through the RX line.

The RXin signal sent from the line interface to the modem board is received by the 300 bps demodulator of the modem board and the carrier detect circuit at the same time. The receive timing clock of 300 Hz is then sent to the SIO.

The SIO shifts, bit by bit, the data received onto the RXDA line into the SIO receive register.

8.5 Bits, Bauds and BPS

Fax machines make use of modems (modulator/demodulator) to transfer digital information over analog telephone lines, in the same way as computer modems do. The information is in binary form, and the speed at which the data is transferred between the two points is known as the bit rate, measured in bits per second (bps).

The signalling rate is that associated with the speed of operation of the communication channel itself, and is not directly related to the amount of information being transferred. Signalling rates are measured in baud, and the maximum signalling rate over a given channel (either radio or hardwired) is limited by the bandwith (BW) of the channel.

BPSK does not encode data. It does however required less bandwith than FSK type schemes.FSK requires two frequencies that are orthogonal to each other and this implies large bandwith. By using MPSK schemes, phase encoding is used, therefore minimizing bandwith.

BPSK uses 2 phase 0^0 and 180^0 $\therefore$ a '1 ' gives one phase and

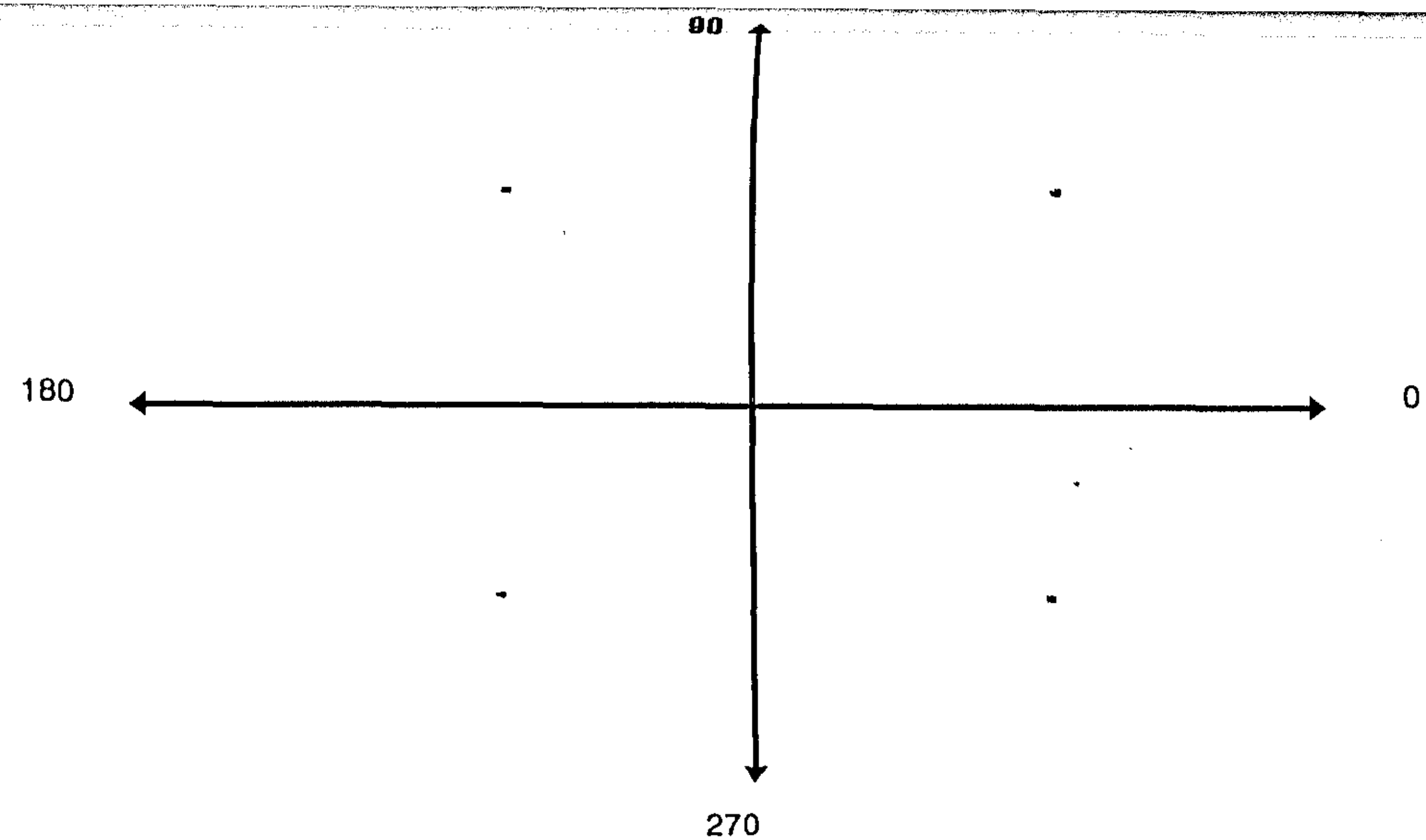
'0 'gives another phase.

QPSK requires half the bandwith of PSK, since the symbol rate is half that of PSK.

B α symbol rate. QPSK signal space is shown in **Figure 12**.

QAM is an amplitude modulation scheme similar to phase shift keying schemes. The concept of Quadrature comes from the fact that these schemes require in phase 3 quadrature carrier eg. QPSK modulator. It's signal space is shown in **Figure 13** (16-QAM).

These requirements for fax machines differ somewhat from those required by most computer applications, as information only needs to be transmitted in one direction at a time. This means that the entire bandwith of the line can be used to transmit data in one direction, and so higher baud rates are possible. So with a given number of bits being transferred at once, a correspondingly higher data rate is obtained.



DIBIT VALUES (1200)	BIT VALUES (600 BPS)	PHASE CHANGES
00	0	+90
01	-	0
11	1	+270
10	-	+180

FIGURE 12 QPSK REPRESENTATION

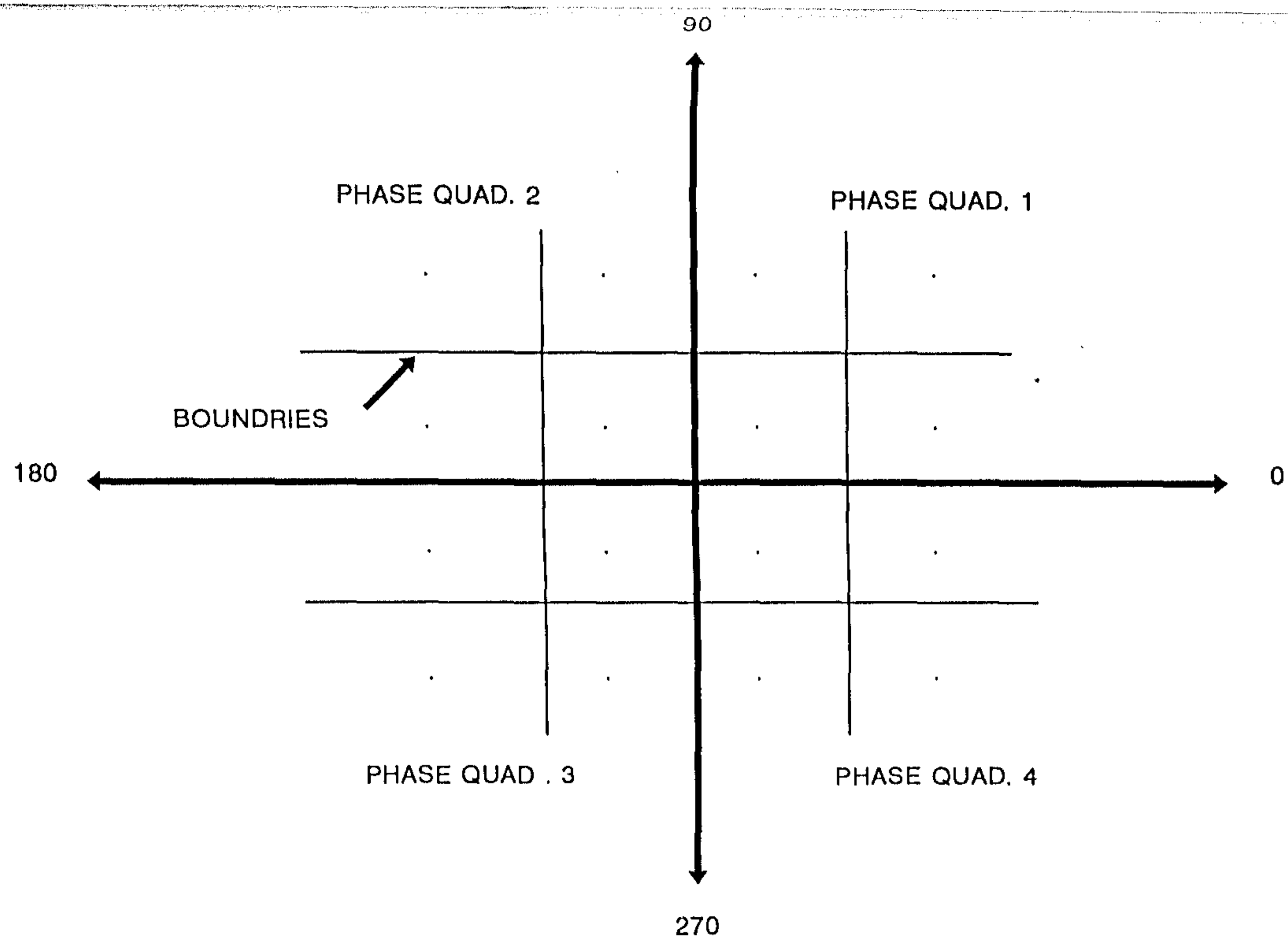


FIGURE 13 _ 16-QAM MODULATION

One component required in modems using PSK and QAM is a scrambler. This device encodes (or scrambles) the transmitted data so that a long strings of zeros or ones in the data stream do not cause loss of synchronisation at the receiving end.This is because PSK and QAM both depend on the receiver catching the phase changes in the carrier, in order to regenerate a clock signal at the receiving end. An extended period without phase changes will eventually cause the receiver to loose sync with the transmitter, causing loss of data.

The operation of the scrambler basically ensures that, regardless of the content of the data stream, phase changes occur at a high enough rate to maintain sync between the two ends. One result of this is that each bit of the scrambled signal is derived from more than one bit of the actual data stream, and at the other end the descrambler re-generates each bit of the original data stream from several bits of the incoming data. This means that an error in the transmission of one group of bits will affect several groups of bits at the receiving end, so that a single error tends to corrupt more than one bit of the received image.

8.6 Synchronous Data Transmission.

In synchronous data transmission, special characters synchronize the transmitting and receiving elements of the link. This permits transmissions to occur without the overhead of start and stop bits as in asynchronous communication.

Synchronous protocols fall into two main categories:

i) Character- or byte-oriented protocols that specify a definite character length.

ii) Bit-oriented protocols that do not specify character boundaries.

Bisynchronous (BSC), short for binary synchronous communication, is one of the most common character-oriented protocols. Bisynchronous uses a set of special characters to define the structure of the data transmission frame. At the start of each block of data are PAD and SYN characters which signal the start of a frame and allow the receiving station to synchronize with the transmitting station clock. A variety of different bisynchronous transmission frames can be created using the available character control set. **Table 7** shows the list of characters and a typical bisynchronous frame :

TABLE 7: BISYNC DATA STRUCTURE

P	P	S	S	H	D	S	T	D	IT	B	D	S	T	D	E	B	P
2	A	Y	O	E	L	T	R	L	B	C	L	T	R	L	T	C	A
2	D	N	H	A	E	X	A	T		C	E	X	A	E	B	C	D
A				D			N						N				
2				I			S						S				
2				N									P				
D				G									A				
													R				
													E				
													N				
													T				

TABLE 8: BISYNC CONTROL CHARACTERS

Bisync Character	Hex Value	Character Description
SYN	32	Synchronous idle
PAD	55	Start of frame pad
PAD	FF	End of frame pas
DLE	10	Data line escape
ENQ	2D	Enquiry
SOH	01	Start of heading
STX	02	Start of text
ITB	1F	End of intermediate block
ETB	26	End of transmission(block)
ETX	03	End of text

SDLC, short for synchronous data link control, typifies the second type of synchronous protocol, the bit-oriented protocol. Instead of using a control character set as does bisynchronous, SDLC uses a variety of bit patterns to flag the beginning and end of a frame. Other bit patterns are used for the address, control and packet header fields which route the frame through a network to its destination. Table 9 shows a typical SDLC transmission frame:

TABLE 9: SDLC TRANSMISSION FRAME

DATA START FLAG	ADDRESS FIELD	CONTROL FIELD	INFORMATION FIELD	CYCLIC REDUND. CHECK	CYCLIC REDUND. CHECK	DATA END FLAG

CHAPTER 9

FAX CARDS

Since facsimile systems share a lot of technology with a personal computer, a fax card has emerged to allow PC users to send and receive fax information. A fax card is significantly cheaper than a fax machine, because the scanner and printer are not included. It is assumed that the computer has a printer to allow incoming faxes to be printed out if desired, or they may simply be displayed on the screen. Text and graphics can be generated using ordinary word processors and drawing packages and then transmitted as a fax.

The proposed fax card contains a V.29/ V.27 ter modem and all the required support circuitry to allow the computer to drive the modem, and make it appear as an ordinary facsimile machine as far as the line is concerned.

Using a chip, R96EFX, from ROCKWELL, microprocessor, memory chips, buffers and other supporting chips a fax card can be constructed which can be plugged into an expansion slot of an IBM PC, XT, AT or compatible, and provide the ability to send and receive facsimili messages using the personal computer.

CHAPTER 10

HARDWARE SOLUTION

10.1 Achievement by the hardware

An interface must be designed to connect the PC to the communication medium (fax card). This interface should not degrade the working of the PC. It means that the data and control signals to be sent between the microprocessor, on the card, and the PC must be sent at a data rate that does not inconvenience the operator .

10.2 Options examined for the design of the circuit

Two options were examined to transfer the data and control signals between the microprocessor on the card and the PC, viz.

i) Read/ write data byte by byte with assembly language or any high level language such as 'BASIC', 'TURBO PASCAL', from/ to an I/O port ;

ii) Use DMA of the PC.

To make a choice between the two possibilities, a few calculations must be made.

The length of a typical message is not longer than one A4 page. If the extreme case ought to be chosen, i.e. a full page of characters and with single spaces. A file containing such data types will be 3700 bytes in size. Assume that the extreme length size of bytes used for control signals to transfer data is approximately 1000 bytes long. The quantity of data (including control signals) to be transfered for such a file is approximately 5k bytes.

The data rate, whereby data is transfered by means of DMA from the PC can be compared with the data rate that can be achieved with 'BASIC' or 'ASSEMBLY LANGUAGE'. The DMA function of the PC is specially designed to aid in high-speed data transfer. Using the DMA facility, it is possible to transfer data at a maximum rate of 476 kilobytes per second. At this rate, approximately one half of the system-bus bandwith is used. This will slow the execution of any program to one-half speed when the maximum DMA data rate is in operation. The DMA facility is specially designed such that the microprocessor cannot be locked out. **TABLE 10** shows the results.

Eg.

i) Assume a file size of 3619 bytes were transfered from the PC to the proposed faxmodem card.

ii) Assume the quantity of the control signals to transfer the fore mentioned file is approximately 1000 bytes long.

iii) The file size (including control signals) is approximately 5k bytes.

The results for the two different options for the above example, is shown in **Table 10.**

Note : a 12MHz AT computer was used.

TABLE 10: DATA RATES OF DIFFERENT OPTIONS

DATA RATE (BYTES/SEC)	LANGUAGE	TIME TO TRANSFER FILE
210	BASIC	24.381 s
86950	ASSEMBLY LANGUAGE	0.059s
47600	DMA	0.011s

The figures used in this section for the quantity of data and control signals to be sent has been greatly exaggerated. It can be seen that if the assembler language is being used, a block of 5k bytes can be transfered in 0.06 seconds between the two processors. The data rate given in the table is approximately the same as what it will take the card with a 80C188 microprocessor. This is the data rate between the PC and the proposed card over the interface.

The data to be sent to or from the microprocessor on the card is normally stored in one of the sub-directories on one of the hard disk drivers. The data to be sent to the card must first be read from the disk drivers and the data received from the card written to the hard disk.

To determine how long it will take to read a file byte by byte, a small test program of approximately 5k byte long was written to measure the time. From the small test program it was determined that it takes approximately 550 ms to read data from the hard drive and approx. 800 ms to write data to a file. This measurements was performed on a 12 MHz AT computer and assumed that all the necessary instructions to transfer the file to the card were included in the file. The transfer time can be shortened if a faster computer and hard drive are used.

From the measurements it can be seen that most of the time is consumed by the reading and writing of data to and from the disk drive. The longest total time it will take to transfer a block of approximately 5k bytes to or from the card is thus 800 ms + 6 ms = 806 ms.

It will be acceptable for most operators to wait for ≤ 0.8 seconds while data is been transfered. It must be remembered that the size of the file and the control signals has been greatly exaggerated.

If the DMA option is considered, the 1 DMA channel still available on the PC, will have to be utilised. This will slow down the operating time of the PC.

10.3 Suitable Solution for the Hardware

From the results of the previous section, it was decided to use the first option i.e. to transfer data through a bi-directional port between the two processors.

Figure 14 depicts a block proposition of the hardware problem.

Intelligence was placed on the card, by including a processor, because the card must not degrade

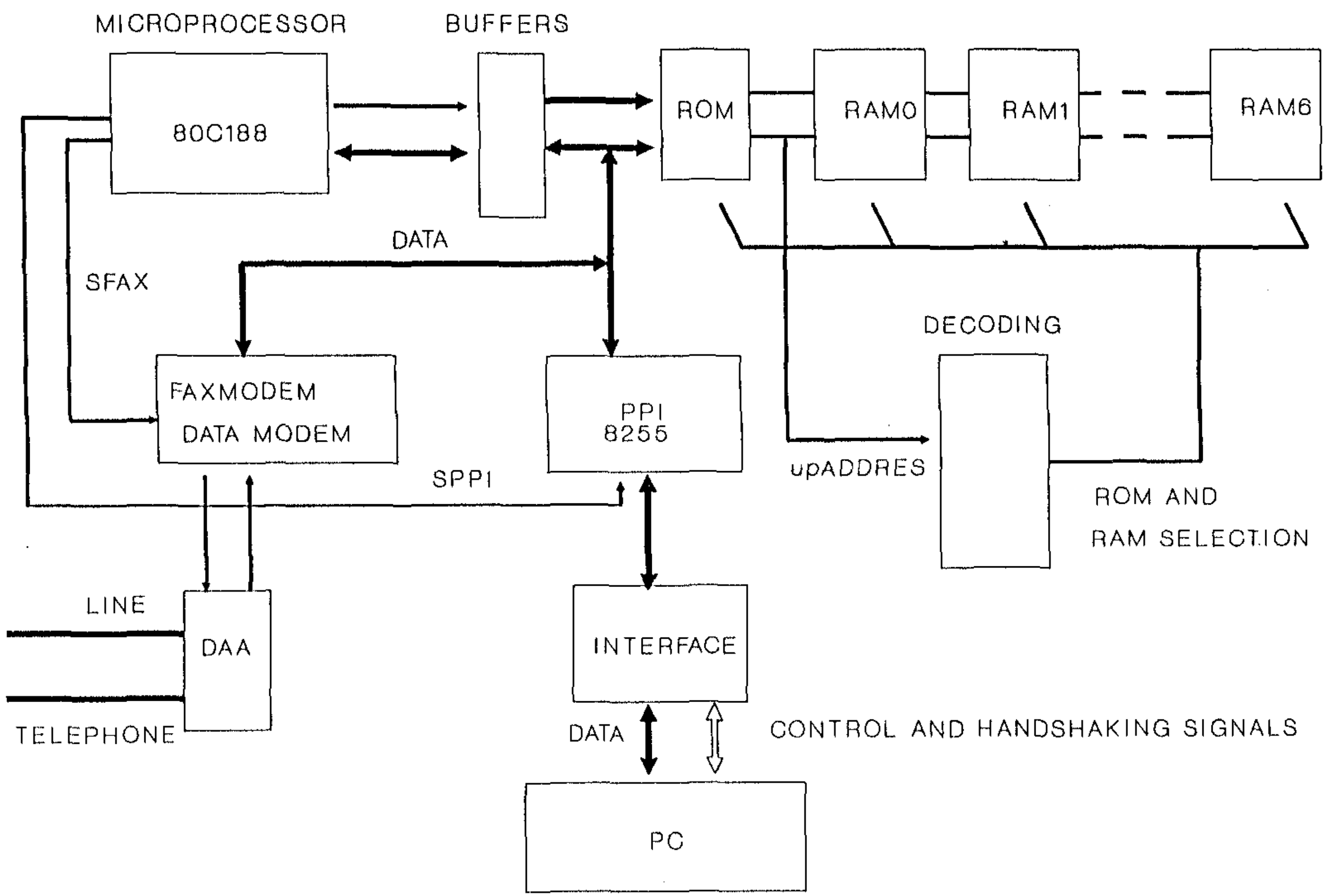


FIGURE 14 _ HARDWARE PROBLEM

the normal operation of the personal computer. Conversion programs (converting files to fax format) that normally run on the PC can be executed on the card.

As seen from the block diagram **(Figure 14)** we have two main parts i.e. the PC on the one side and the microprocessor on the other side.

The PC is connected to the microprocessor on the fax card via two ports i.e. 300h and 301h, as suggested with the first option. The one port (300h), is a bi-directional port through which data can be transfered between the two processors. The other port (301h) can be used for handshaking. The Programmable peripheral interface (PPI) can be seen as the interface between the microprocessor and the personal commuter. The handshaking signals are generated by the PPI.

Since a number of memory chips and decoding logic are connected to the microprocessor, it is necessary to buffer address-, data- and control signals of the microprocessor. It is also necessary to use a latch since the data bus is time multiplexed with the lower order eight address lines.

Provision is made for 128kB EPROM at the end of the memory where the program for the microprocessor is stored. Provision is also made for 7 blocks of RAM 128kB each. This gives a total of 896kB static memory. Smaller blocks of memory could have been used but then the memory space is not continuous. The microprocessor must test in the beginning to see where memory has been decoded in the memory space.

Part of the circuit is used to activate one of the PC's hardware interrupts. The interrupt generated by the PPI, is to let the PC know when data is to be read from the card or as a confirmation of data written to the microprocessor on the card has been placed in the latch of the PPI.

The same interrupt sent to the PC is also sent to the microprocessor. The microprocessor can then determine whether a byte must be read from the PC or a byte already sent has been read by the PC. These are all the main parts that constitutes the card.

10.4 Advantage of the proposed circuit

The card has an on-board microprocessor, so that it operate in the background, without disrupting the normal use of the computer.

The microprocessor (80C188), on the card provides 7 peripheral select lines that can be used to select the appropriate communication medium. A minimum number of components are required since the decoding of the interrupt is already generated on the card. The only components that are needed are the chips to connect the interface with the different media.

The interface is fast enough not to inconvenient the operator to wait too long for the PC to transfer the data between the disk drives and memory.

The interface does not make use of the only available DMA channel on the PC.

Another advantage is that the PC is not degraded. The PC's microprocessor time is saved and the

PC can execute other tasks.

CHAPTER 11

DESIGN OF CIRCUIT

The adapter fax card for the IBM PC or compatible is based on a dedicated VLSI (very large scale integration) chip, R96EFX. It offers the full range of speeds up to 9600bps, auto dial, auto answer and on-board line isolator.

The following fax chips, INTEL 89C124, the Rockwell Monofax R96EFX and the Yamaha YM7109, were considered for the design. It was decided to use the Rockwell Monofax R96EFX chip for the fax application. The reason for the choice is that data and technical specifications of the Rockwell R96EFX was readily available and the microprocessor bus interface supports modem connection to a wider variety of other microprocessors, such as the 8085 or 6500 bus compatible microprocessor.

The ROCKWELL Monofax R96EFX is a 'fax machine' in a chip. Containing a modem operating under the CCITT V.27 ter and V.29 standards, giving speeds from 2400 to 9600bps, it provides all the facilities required of a modem in a Group 3 fax machine. The V.29 standard offers speeds of 9600 and 7200 bps, while V.27 ter option handles the lower speeds of 4800 and 2400 bps.

Auto-dialling is achieved through a built-in DTMF tone generator for tone dialling, while the alternative pulse dialling is achieved by pulsing the line looping relay.

The R96EFX, in common with most modem chips, uses digital signal processing (DSP) to generate the transmitted signals, and to decode the received ones. This has the advantage that there are no critical adjustments to be made in setting up the modem- the entire modem is locked to a single 24.00014 MHz crystal.

11.1 Main Control Block

The main control block consists of a **MICROPROCESSOR, EPROM** and **RAM** which are employed to control all operations.

All the parts of the circuit can be seen in the schematics **APPENDIX D.**

11.1.1 Microprocessor and Buffers

The following microprocessors were considered in the design i.e. 8031, 8088, 8086, 80C188 and 80186.

The 8031 is a general inexpensive microcontroller. If the 8031 microcontroller is to be used, the conversion program (that normally runs on the PC) to be executed by the fax card, have to be rewritten using the 8031 instruction set. This process will be time consuming.

The disadvantage of the 8088 is that it cannot run at the clock speed of the 80C188 and 80186 microprocessors. Max clock speed is 8MHz.

The 80C188 is almost the same as the 8086 and the 80186. The 80C188 is an 8-bit processor, it's architecture is based on the 80C186 internal structure. The 80C188 handles the external bus the same way the 80C186 does, with distinction of handling only 8 bits at a time.

It was decided to use the 80C188 microprocessor. The reason for the choice is that the instruction set of the 80C188 is virtually the same as the microprocessor used in the PC (8088, 8086, 80186 and 80286). Programs that normally run on the PC can now be used in the EPROM or ROM of the microprocessor on the card. Single instructions, not in the instruction set of the 80C188, but are used in the program, can be simulated using defined procedures.

Another reason for choosing the 80C188 microprocessor for the design is because of the 8-bit data bus. A data bus of 8 bits wide is sufficient to connect all the associated. The data rate maintained by the 80C188 microprocessor is acceptable as seen from the calculations done earlier. All the calculations done was for a 8088 as microprocessor in a PC.

11.1.1.1 80C188 Microprocessor and Buffers

Figure 15 depicts the circuit of the microprocessor and the buffers.

The microprocessor is operated with a clock of 10 MHz derived from the external crystal 20 MHz crystal.

The microprocessor controls the fax modem (R96EFX) mode , protocol signal, transmit/receive

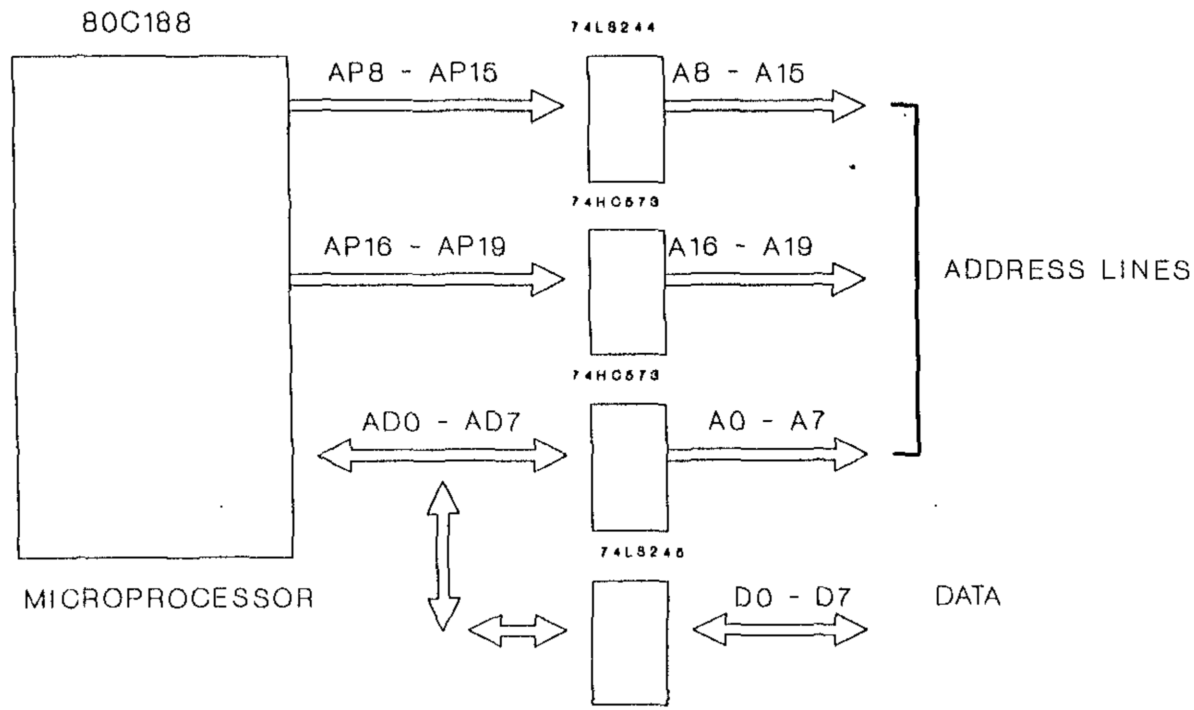


FIGURE 15 _ MICROPROCESSOR AND BUFFERS

of fax, recognition of received signal etc, via the data bus. The protocol signal path for both transmit and receive is processed in terms of a byte between the microprocessor and the R96EFX via the bus. HDLC and CRC checks are software supported. The microprocessor controls the fax modem by accessing the memory in the modem. The microprocessor also selects between data/fax modem by enable/disable the analog switch (U33). Refer to '**line.sch** 'circuit **Appendix D.**

11.1.2 Memory organization of microprocessor

Two types of memory are used with the microprocessor i.e RAM and EPROM.

It was decided to make provision for the new 128kb memory chips (RAM) that is available. If these chips are used the number of chips required to provide the required memory is reduced. Provision is made for seven of these memory chips. This gives a total of 896kB memory (SRAM) on the card.

The size of a typical file converted into the **FAX-format** is approximately 32kB. The quantity of memory provided on the card makes it possible for a document of up to twenty pages to be stored on the card and converted to the correct fax format to be faxed or allowing twenty pages of fax information to be received by the card.

Provision is made for 128kB EPROM to store the source code of the 80C88 microprocessor.

The memory map of the microprocessor (fax card) is shown in **Table 11** .

TABLE 11: Microprocessor's Memory space

EPROM 0	FFFFF H E0000 H
RAM 6	DFFFF H C0000 H
RAM 5	BFFFF H A0000 H
RAM 4	9FFFF H 80000 H
RAM 3	7FFFF H 60000 H
RAM 2	5FFFF H 40000 H
RAM 1	3FFFF H 20000 H
RAM 0	1FFFF H 00000 H

11.1.2.1 Mapping of Microprocessor's Memory and I/O space

The 80C188 can address 1MB of memory space. It was decided to divide the memory space in 8 blocks of 128kB each . This simplifies the address decoding . The most significant three address lines (A17, A18 , A19) are connected to a three-to-eight decoder (74ls138). The outputs of the three-to-eight decoder selects the seven blocks of 128kB static random access memory chips (SRAM0 to SRAM6) .

The UCS line of the microprocessor selects the EPROM.

The ports used by the fax card are shown in **TABLE 12**.

TABLE 12: PORTS USED BY FAX CARD

Available address locations	Hex address	Use
8	02F8H - 02FFH	Second serial port (Data modem)
2	0300H - 0301H	Fax - card
118	0302H -0377H	Not used
8	0378H -037FH	Printer port
8	03F8H - 3FFH	Primary serial port (Data modem)

The I/O space of the microprocessor consists of 64k 8-bit or 32k 16-bit ports. The 80C188 can generate chip selects for up to seven peripheral devices. These chip-selects are active for seven contiguous blocks of 128 bytes above a programmable base address. The base address may be located either in memory or I/O space .

Seven cs lines called PCS0-6 are generated by the 80C188. The base address is user programmable, however it can only be in multiples of 1k bytes i.e the last significant ten bits of the starting address are always zero. Only two of these lines are used i.e PCS0 and PCS1, to select the PPI and R96EFX respectively. PCS2 to PCS6 can be used to select other communications media/peripherals connected to the fax card.

Figure 16 shows the address decoding circuit of the SRAM, EPROM and the I/O space components. The interface of the EPROM and RAM can be seen in **Figure 16** .

11.1.3 Mapping of the ports in the PC's memory space.

Two ports are required in the design between the microprocessor on the card and the PC. The two consecutive port addresses in the I/O space of the PC i.e ports 300h and 301h are used.

Figure 17 depicts the address decoding of the two PC ports.

11.1.4 Fax Bus Interface

11.1.4.1 PROGRAMMABLE PERIPHERAL INTERFACE (PPI) mode of operation

Figure 18 illustrates how the PPI is connected to the rest of the circuit .

The PPI is used in MODE 2. This functional configuration provides a means of communicating with a peripheral device, on a single 8 bit bus, for both transmitting and receiving (bidirectional I/O). Handshaking signals are provided to maintain proper bus flow discipline. Interrupt generation and enable/disable function are also available.

The bi-directional port can be directly connected to the PC's data bus without any buffering

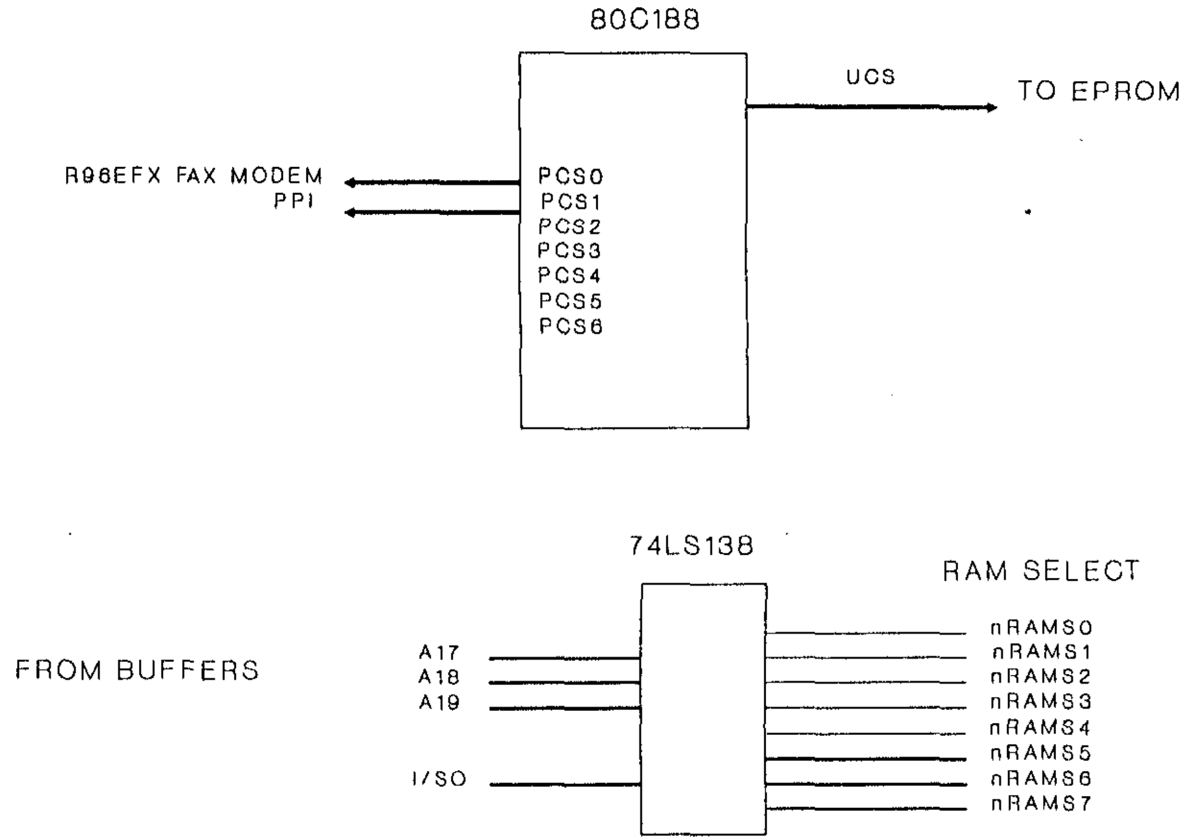


FIGURE 16 _ DECODING SRAM,EPROM AND I/O SPACE

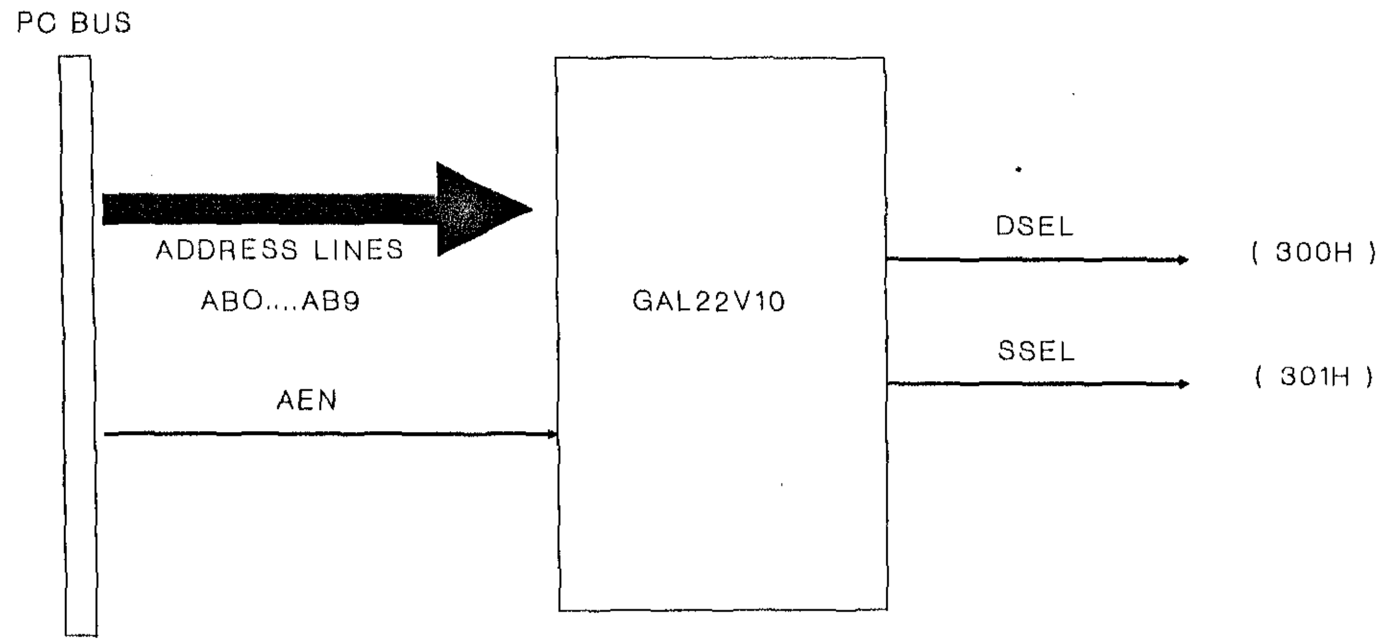


FIGURE 17 _ DECODING PC'S PORTS

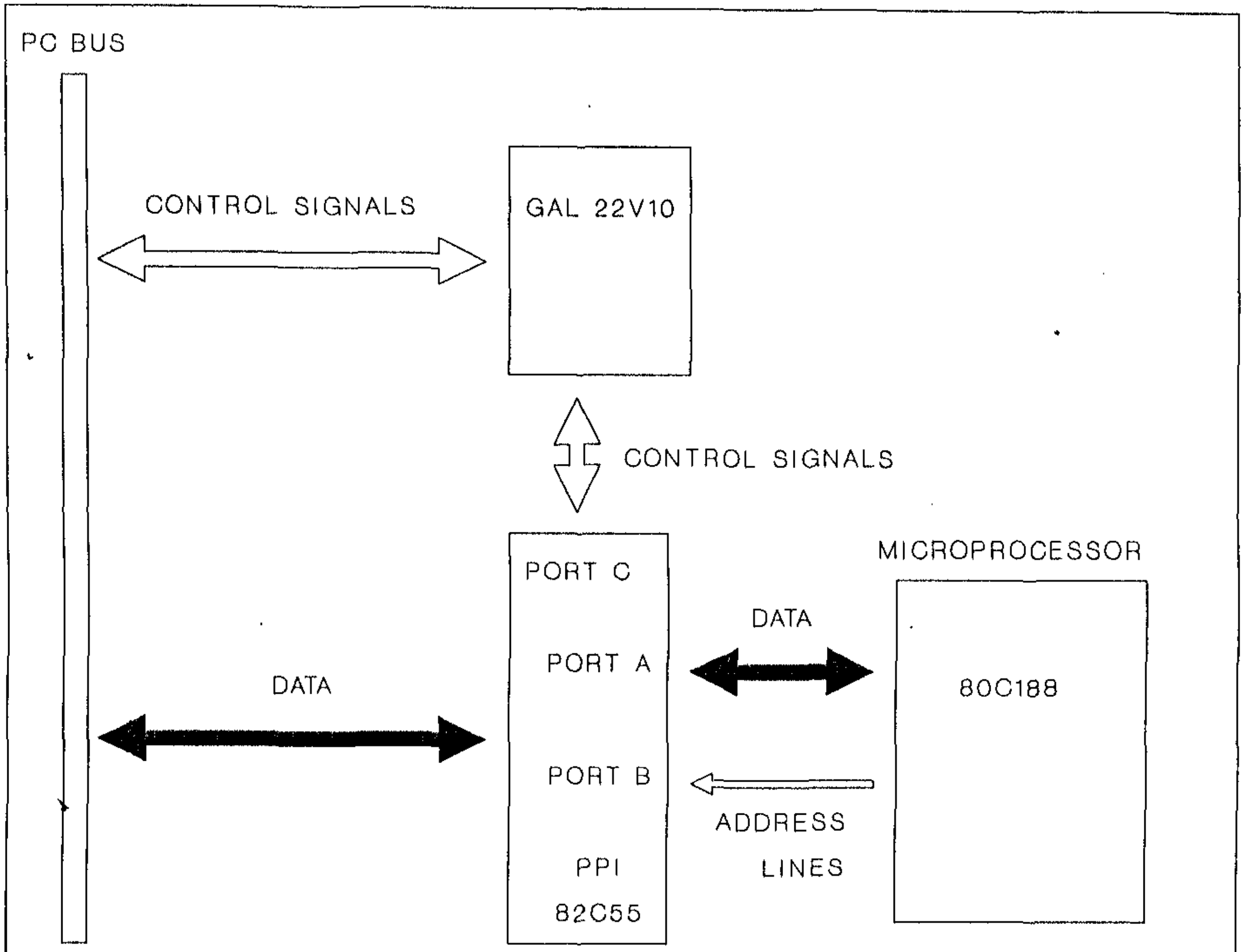


FIGURE 18 _ PPI INTERFACE

because the PPI has tri-state buffers. No wait states are necessary when the PPI (8255) is used with the 80C188.

11.1.4.2 INTERRUPTS

11.1.4.2.1 Interrupt on the PC (Hardware interrupt)

IRQ 5 is a hardware interrupt which is not used in the standard PC's interrupt vector space. The PPI activates this interrupt on the PC. No interrupt acknowledge signal exists on the expansion slot for the hardware interrupt. Since the interrupt is activated by the PPI on the Fax card, an acknowledge signal is sent via one of the ports. **Figure 19** illustrates the circuit diagram that activates the interrupt on the PC.

11.1.4.2.2 Interrupts on the Microprocessor

The microprocessor (80C188) can service interrupts generated by software or hardware. Two types of hardware interrupts are provided on the microprocessor i.e maskable (INT0....INT3) and non-maskable (NMI).

The non-maskable interrupt of the microprocessor on the card is not used.
The INT0 interrupt (nIRQ) of the microprocessor is activated by the Fax modem (R96EFX). This can be seen in **Figure 20.**

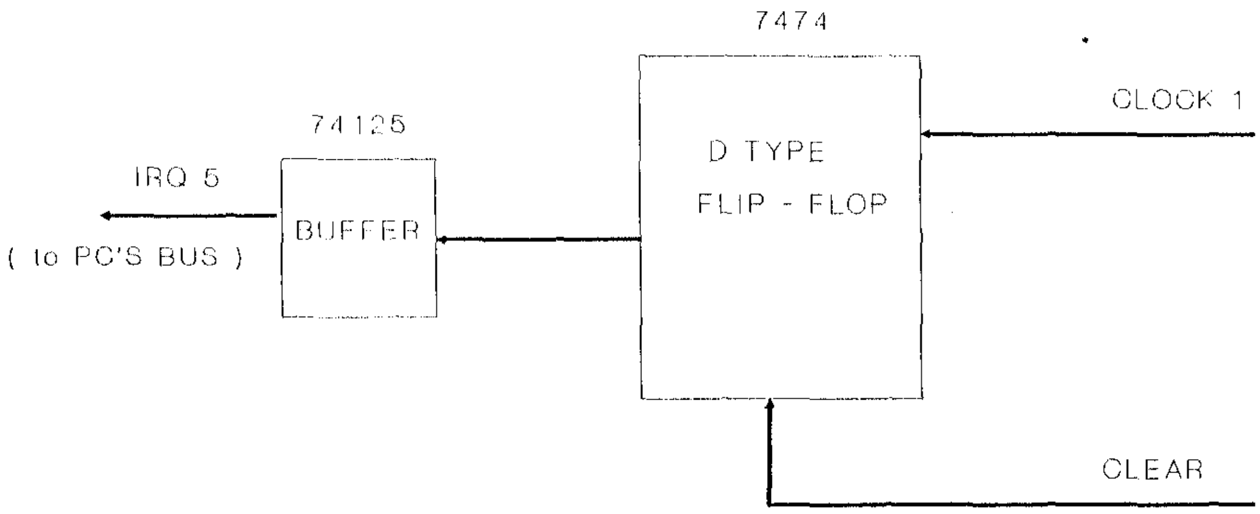


FIGURE 19 _ INTERRUPT ON PC

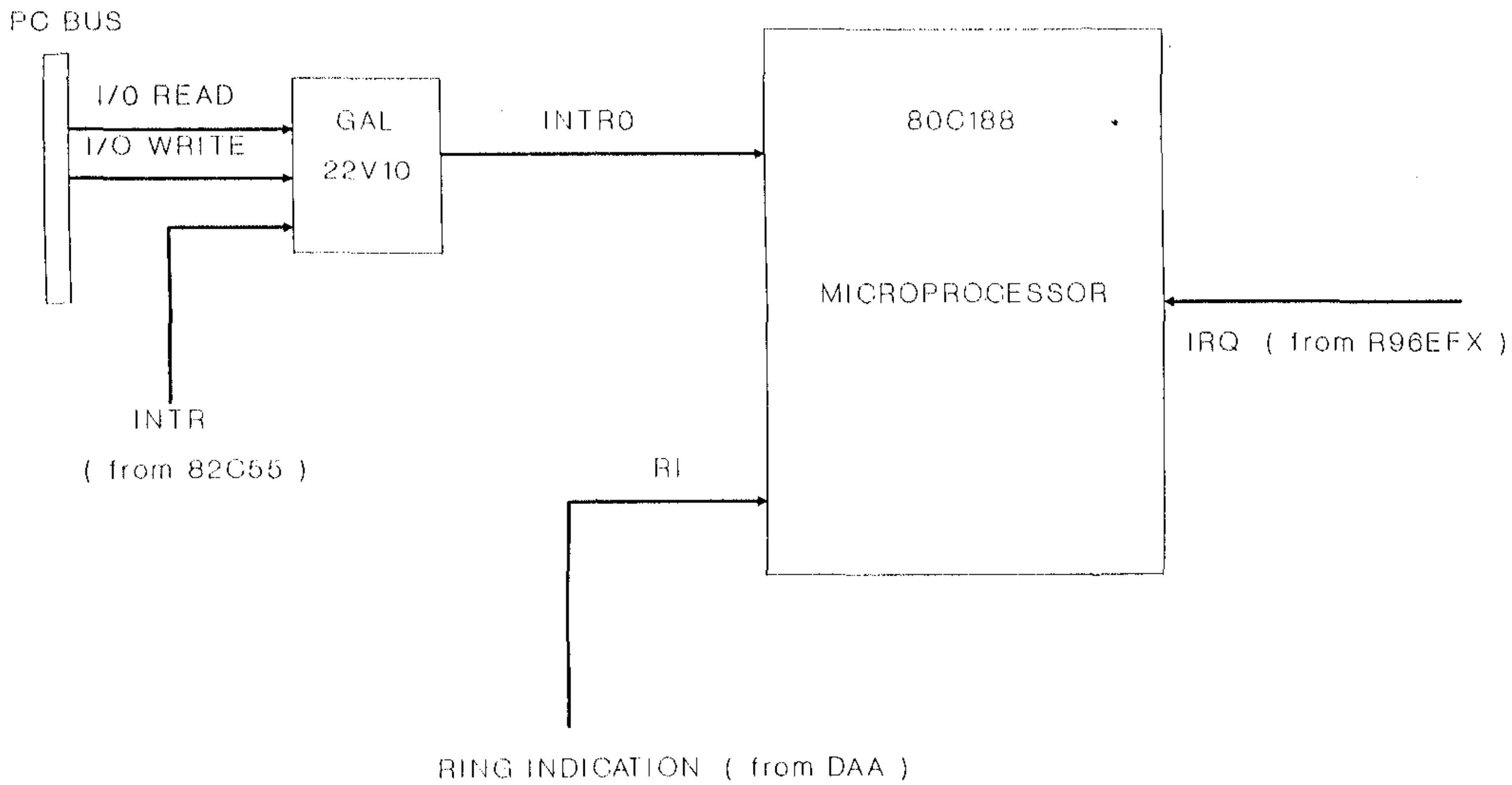


FIGURE 20_ INTERRUPTS ON MICROPROCESSOR

The INT1 interrupt (INTR) is activated by the PPI (8255).

11.1.5 Transmission Block

11.1.5.1 R96EFX

The Rockwell R96EFX MONOFAX modem is a synchronous 9600 bits per second (bps) half-duplex modem with error detection. The modem is housed in a single VLSI device package.

The modem can operate over the public switched telephone network (PSTN) through line terminations provided by a data access arrangement (DAA).

The R96EFX is design for use in GROUP 3 and GROUP 2 facsimile machines.

The modem satisfies the requirements specified in the CCITT recommendations V.29, V.27 ter, V.21 Channel 2, T.3 and T.4 and satisfies the binary signalling requirements of T.30.

The modem can operate at 9600, 7200, 4800, 2400, or 300 bps, and also includes the V.27 ter short training sequence option .

The modem can also perform high level data link control (HDLC) framing according to T.30 at 9600, 7200, 4800, 2400, or 300 bps.

The modem includes three programmable tone detectors which operate concurrently with the V.21

channel 2, GROUP 2, and voice mode receivers.

For modem mode setup, tonal signal send/ receive and receive signal verification, the microprocessor directly controls the modem, through the data bus, without intervention of the interface.

The modulation and demodulation functions of the R96EFX MONOFAX are listed in **Table 13**.

TABLE 13 : Modulation and Demodulation

NO	Com. mode	Baud rate	Modulation method	Mod. speed	Carrier freq.	CCITT Recom.
1	G3	9600BPS	16 value QAM	2400BPS	1700Hz	V29
2	G3	7200BPS	8 value QAM	2400BPS	1700Hz	V29
3	G3	4800BPS	8 value PSK	1600BPS	1800Hz	V27ter
4	G3	2400BPS	4 value PSK	1200BPS	1800Hz	V27ter
5	G3	300BPS	FSK	300	1650 / 1850	V21
6	G2		AM-PM-VSB		2100Hz	T3

In addition to the above functions , it has the following tone transmit / detection functions. See **Table 14** shows.

TABLE 14: Tone transmit function.

NO	Signal name	Frequency
1	CED	2100Hz
2	GI	1850Hz
3	GC	2100Hz
4	CFR	1650Hz
5	MCF	1650Hz
6	LCS	1100Hz
7	EOM	1100Hz
8	PIS	462Hz

TABLE 15: Tone detection function

NO	Signal name	Frequency
1	GI	1850Hz
2	· CFR, MCF	1650Hz
3	GC	2100Hz

The functions are controlled by accessing the interface memory inside the MODEM through data bus from the microprocessor.

The interface memory is composed of 32, 8-bit registers and are controlled by bank select. The registers are therefore selected with 4-bit register select signal and chip select signal. The main items controlled by the registers are as follows:

i) Configuration register

Mode setting for V.29, V.27, FSK tone delivery.

ii) Option register

Equalizing method of the equalizer, carrier detection threshold, addition of echo suppressor protect tone, setting the transmit/ receive mode.

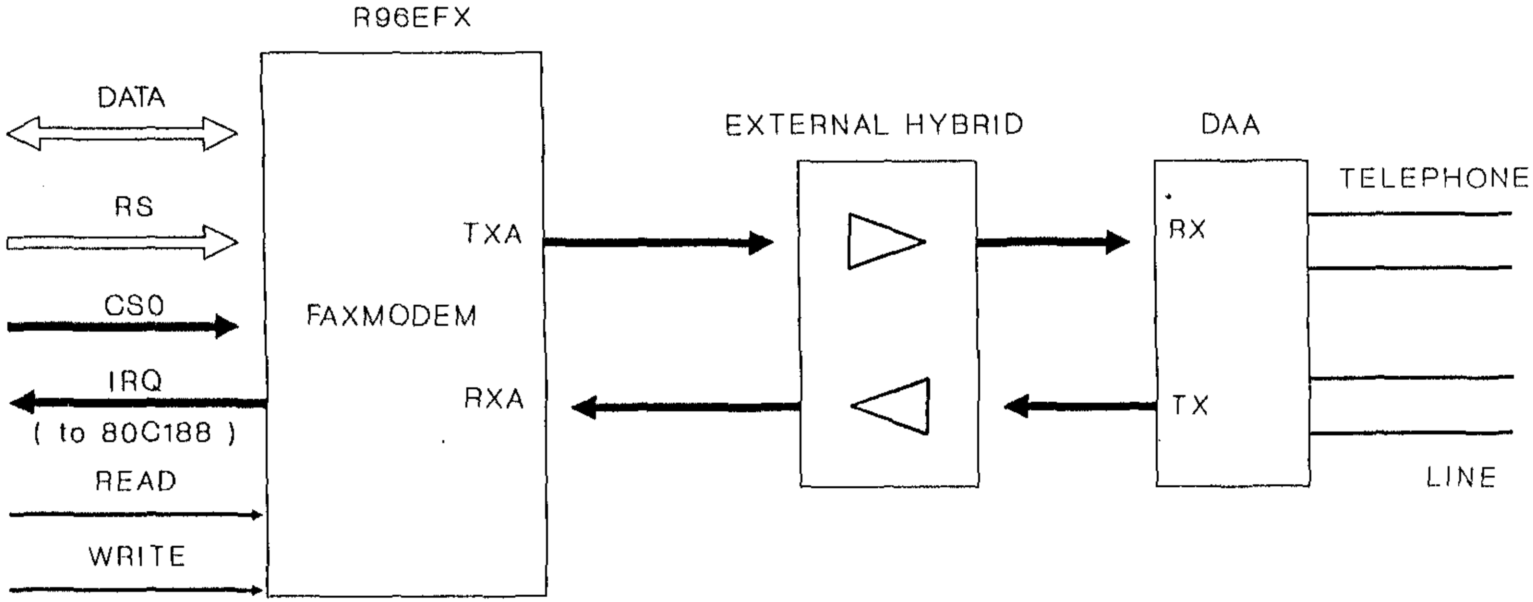


FIGURE 21 _ R96EFX

iii) Others

AGC control, tone frequency setting.

Data in these registers are read through the data bus to perform MODEM (R96EFX) state monitoring, such as tone detection and tone pattern detection.

11.1.5.2 Transmit / Receive Operations

Transmit/receive operations are described in the following:

i) In transmit operation, transmit data are passed from the microprocessor to the modem, synchronized with data clock **(DCLK)** where they are modulated in the modem and then passed through transmit analog output **(TXA)** to the line interface.

ii) In receive operation, receive analog input (RXA) supplied from the line interface are passed to the modem, where they are demodulated. Received data are synchronized with data clock (DCLK) and passed to the microprocessor. All above operations are perform by two signal processors and one analog LSI in the R96EFX MONOFAX chip.

Figure 21 illustrates the interconnection of the R96EFX with the rest of the circuitry. The interface signal is shown in **TABLE 16.**

TABLE 16: INTERFACE SIGNAL

Signal name	I/ O	Pin No.	Description
AGND1	GND	22	Connect to Analog Ground
AGND2	GND	24	Connect to Analog Ground
DGND1	GND	13	Connect to Digital Ground
DGND	GND	49	Connect to Digital Ground
+5VD	PWR	10	connect to Digital +5V power
+5VA	PWR	31	connect to analog +5V power
-5VA	PWR	25	connect to analog -5V power
POR	I/ O	5,43	Power on reset
D7	I/ 0	50	Data bus line 7
D6	I/ O	51	Data bus line 6
D5	I/ O	52	Data bus line 5
D4	I/ O	53	Data bus line 4

D3	I/ O	54	Data bus line 3
D2	I/ O	55	Data bus line 2
D1	I/ O	56	Data bus line 1
D0	I/ O	57	Data bus line 0
RS4	I	62	Register select (5 bit)
RS3	I	63	Register select
RS2	I	64	Register select
RS1	I	1	Register select
RS0	I	2	Register select
CS	I	60	Chip select
READ	I	61	Read enable
WRITE	I	59	Write enable
nIRQ	O	58	Interrupt request
CABS1	I	32	Cable select 1
CABS2	I	33	Cable select 2
TXA	O	28	Send analog output
RXA	I	37	Receive analog input
AUXIN	I	26	Additional analog input

11.1.5.3 Line Interface

The data modem and the fax share the same line interface.The data modem has an option of enabling/disabling the internal hybrid of the 89024 modem chip set as mentioned in section 6.7, however the R96EFX does not have such a facility. An external hybrid must be included in the transmission path of the fax.

11.1.5.3.1 Hybrid

The signal on the telephone line is the sum of the transmit and receive signals. The hybrid subtracts the transmitted signal from the signal on the line to form the received signal. It is important to match the hybrid impedance as closely as possible to the telephone line to produce only the received signal. The hybrid also acts as a first order, low-pass, anti-aliasing filter.

With a higher loss transformer, some degradation in performance at lower signal levels will occur, specially with the bit error rate. When operating at receive signals below -40db min, the presence of noise, will be higher. An external hybrid circuit, shown in **Figure 22**, can be used to overcome these losses and achieve maximum performance.

The external hybrid circuit uses two operational amplifiers (LM1458), one in the transmit path and the other in the receive path. Under ideal conditions, with no loss in the transformer and perfect line matching, the signal level at the line will then be the desired value. In practice however there is impedance mismatch and a loss in the coupling transformer. Therefore it may be desired to provide a gain in the transmit and receive paths to overcome the loss. The receive gain $\mathbf{G_R}$ and transmit gain $\mathbf{G_T}$ are set by the ratios of resistors R27, R26, R4 and R24, R25, R1 respectively (**Figure 22**).

The circuit can be analysed as follows:

$$V_R = [-\frac{R26+R27}{R4}]\, V_{TR} + [(1+\frac{R26+R27}{R4})\,(\frac{R31}{R30+R31})]\, V_Y \quad (1)$$

$$V_Y = -\frac{R24+R25}{R1} V_X \quad (2)$$

If (R24 + R25)is chosen to equal the loss in the transformer, it can be assumed that $\mathbf{V_Y}$ is twice as high as $\mathbf{V_{TX}}$ (transmit portion of the total line signal).

V_X= Output voltage of faxmodem chip (R96EFX)

V_R= Input voltage to faxmodem chip (R96EFX)

V_Y= Output voltage of transmit operational amplifier

Since $\mathbf{V_{TR}=V_{TX} + V_{RX}}$ and $\mathbf{V_Y = 2V_{TX}}$,

$$V_R = \left(-\frac{R26+R27}{R4}\right)(V_{TX}+V_{RX}) + \left[1+\frac{R26+R27}{R4}\right]\left[\frac{R31}{R30+R31}\right]2V_{TX} \quad (3)$$

$$= -\left(\frac{R26+R27}{R4}\right)V_{RX} + \left[\left(1+\frac{R26+R27}{R4}\right)\left(\frac{2R31}{R30+R31}\right) - \frac{R26+R27}{R4}\right]V_{TX} \quad (4)$$

To eliminate any transmit signal from appearing at the received signal input, the second term in equation (4) must be set to zero, giving :

$$\left[\left(1+\frac{R26+R27}{R4}\right)\left(\frac{2R31}{R30+R31}\right) - \frac{R26+R27}{R4}\right] = 0 \quad (5)$$

$$\left(1+\frac{R26+R27}{R4}\right)\left(\frac{2R31}{R30+R31}\right)=\frac{R26+R27}{R4} \tag{6}$$

Solving for $\frac{R30}{R31}$ (7)

$$\frac{R30}{R31}=1+\frac{2R4}{R26+R27} \tag{8}$$

Additionally,

$$G_R=\frac{R26+R27}{R4} \tag{9}$$

and

$$G_T=\frac{R24+R25}{R1} \tag{10}$$

These equations can be solved to select component values that satisfies the desired requirements.

For example, if the transmit and receive loss in the coupling transformer is 2,5db, then;

$$\frac{R26+R27}{R4}=INVlog(\frac{G_{Rdb}}{20})=INVlog(\frac{2,5}{20})=1,333 \qquad \textbf{(11)}$$

Similary,

$$\frac{R24+R25}{R1}=1,333 \qquad \textbf{(12)}$$

and

$$\frac{R30}{R31}=2,5 \qquad \textbf{(13)}$$

5dB loss transformer

$$\frac{R26+R27}{R4}=1,778 \qquad \textbf{(14)}$$

therefore $$\frac{R30}{R31}=2.125 \qquad (15)$$

(Reference : SC11006 Modem reference manual.)

11.1.5.4 FAX MODEM LEVELS

11.1.5.4.1 Transmit level

The transmitter output level is programmable in the DSP RAM from 0 dbm to -15 dbm and is accurate to ± 1,0dbm. The modem adjusts the output level by digitally scaling the output to the transmitter's digital-to-analog converter.

11.1.5.4.2 Receive Dynamic Range

The receiver satisfies PSTN performance requirements for received line levels from 0dbm to -43dbm measured at the Receiver Analog Input (RXA) input. An external input buffer and filter are supplied between RXA and RXIN.(For further details see line interface circuit diagram

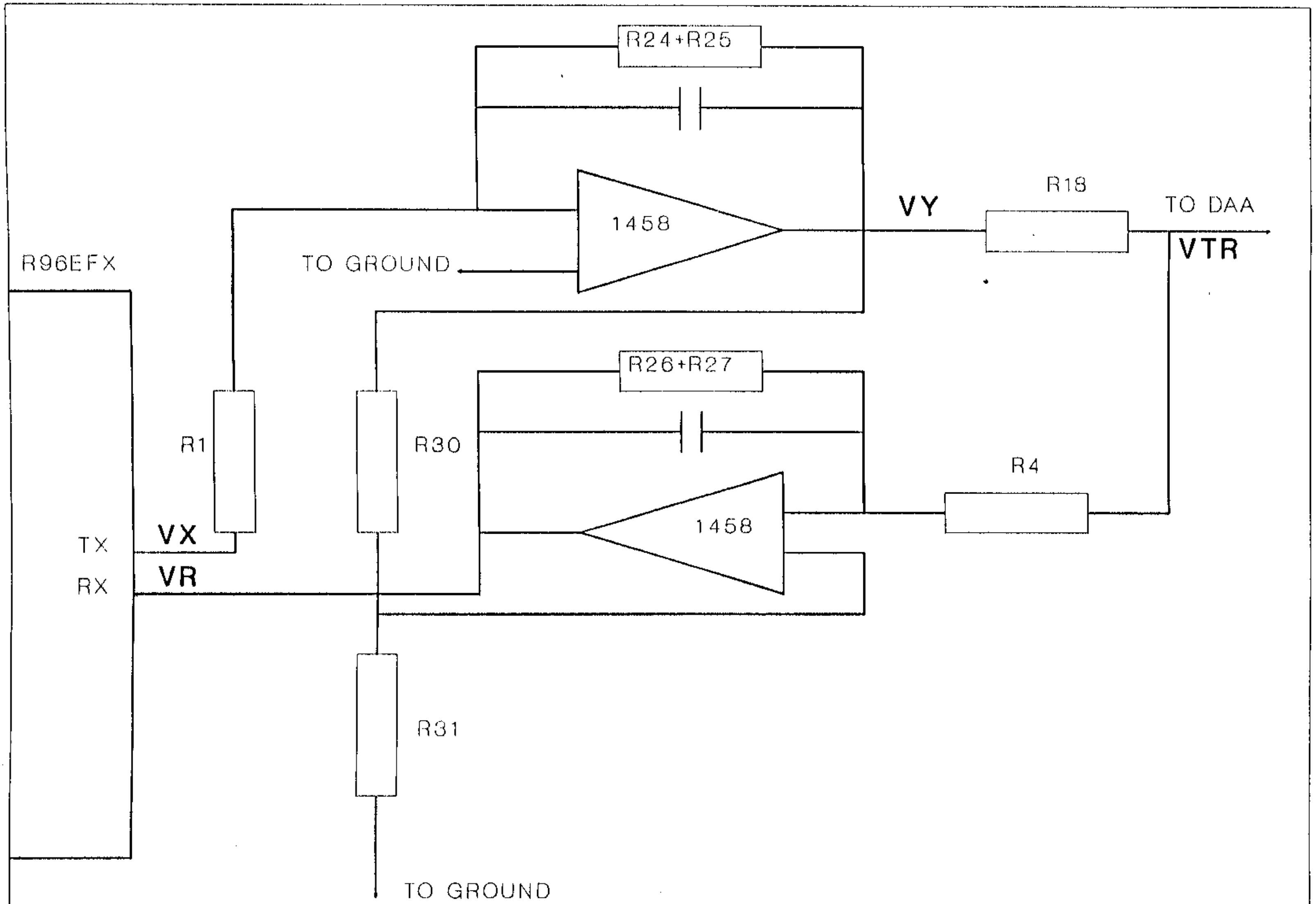


FIGURE 22 _ EXTERNAL HYBRID

APPENDIX E).

11.1.5.5 Equalizers

11.1.5.5.1 Automatic Adaptive Equalizer

An adaptive equalizer in V.29 and V.27 ter modes compensates for transmission line amplitude and group delay distortion.

11.1.5.5.2 Compromise Cable Equalizers

Modems may be connected by direct wiring, such as leased telephone cable or through the PSTN, by means of data access arrangement. In either case, the modem analog signal is carried by copper wire cabling for at least some of the route.

To minimize the impact of this copper wire passband shaping, a compromise equalizer, with more attenuation at the lower frequencies, than at the higher frequencies can be placed in series with the analog signal. The modem includes three such equalizers designed to compensate for cable distortion. When selected, the equalizers are inserted in the transmit path when transmitting, and in the receive path when receiving.

Compromise equalization can improve performance when operating over low quality lines. Equalizer characteristics for cable lengths of 0, 1.8, 3.6, or 7.2 km are software selectable (see

CABLE1 and CABLE2 signal description in **TABLE 17**). The selected filter operates in both transmit and receive paths.

TABLE 17: CABLE EQUALIZING

CABLE			GAIN (db)*			
CABLE2	CABLE1	Length	700Hz	1500Hz	2000Hz	3000Hz
Low	Low	0,0km	0,00	0,00	0,00	0,00
Low	High	1,8km	-0,99	-0,20	+0,15	+1,43
High	Low	3,6km	-2,39	-0,65	+0,87	+3,06
High	High	7.2km	-3.93	-1.22	+1.90	+4.58

* Relative to 1700Hz for length of 0,44 mm cable.

11.3 Fax Transmission/ Reception Protocol

The complete **fax transmission /reception protocol** sequence is divided into five phases as follows :-

PHASE A: Call Establishment

This phase extends from the moment dialling is initiated until the connection is made through to the remote facsimile, i.e. up to the point when CED is issued.

PHASE B: Pre - message Procedure

The pre-message procedure consists of the identification of capabilities and the commanding of the chosen conditions as well as the confirmation of acceptable conditions. As an option, it can also contain subscriber identification.

PHASE C: Message Transmission

This phase starts with image data (usually prefixed with the TTI information) and ends with the return to control (RTC) signal. High speed signalling (V29 and V27) is used throughout.

PHASE D: Post - message Procedure

The post-message procedure contains signals to indicate what is required to be done after a page of data was sent. For example, more pages to be sent, no more pages to be sent, change parameters before next page etc. It also includes information as to the quality of the received copy.

PHASE E: Call Release

This is simply the automatic or manual release of the call.

Figure 23 depicts the **G3 FAX PROCEDURE.**

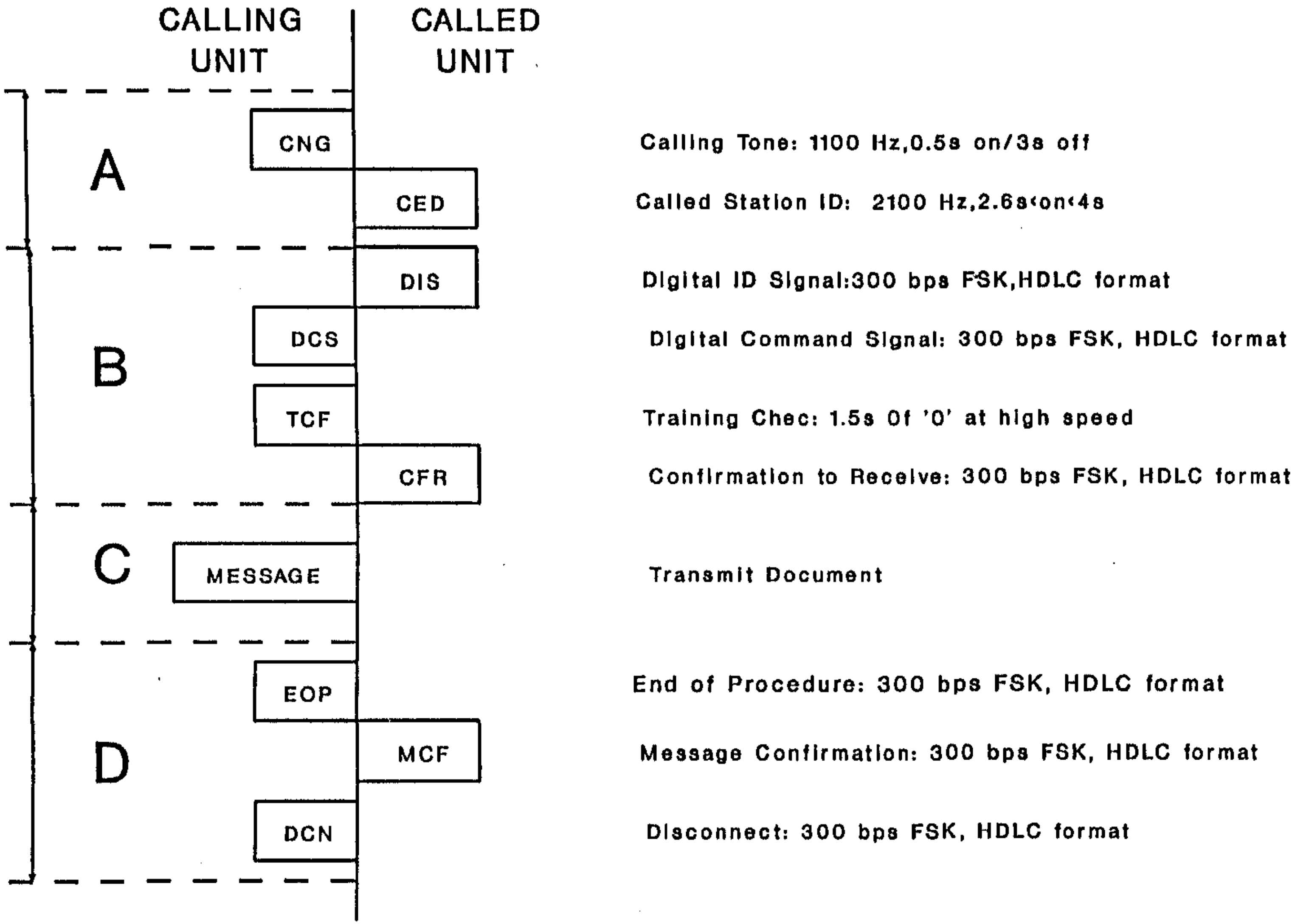


FIGURE 23 _ G3 FAX PROCEDURE

CHAPTER 12

POWER AND GROUND

All power for the faxmodem card is taken from the PC bus. The analog power supplies are regulated before fed to the,data modem (89024) and the fax (R96EFX). The faxmodem requires three power supplies i.e. +5V digital, +5V analog and -5V analog. The +5V analog is derived from LM7805 +5V regulator and the -5V analog is derived from LM7905 -5V regulator. Since a portion of the faxmodem is analog, the board requires two separate grounds, i.e. one for analog and one for digital. See **Figure 24.**

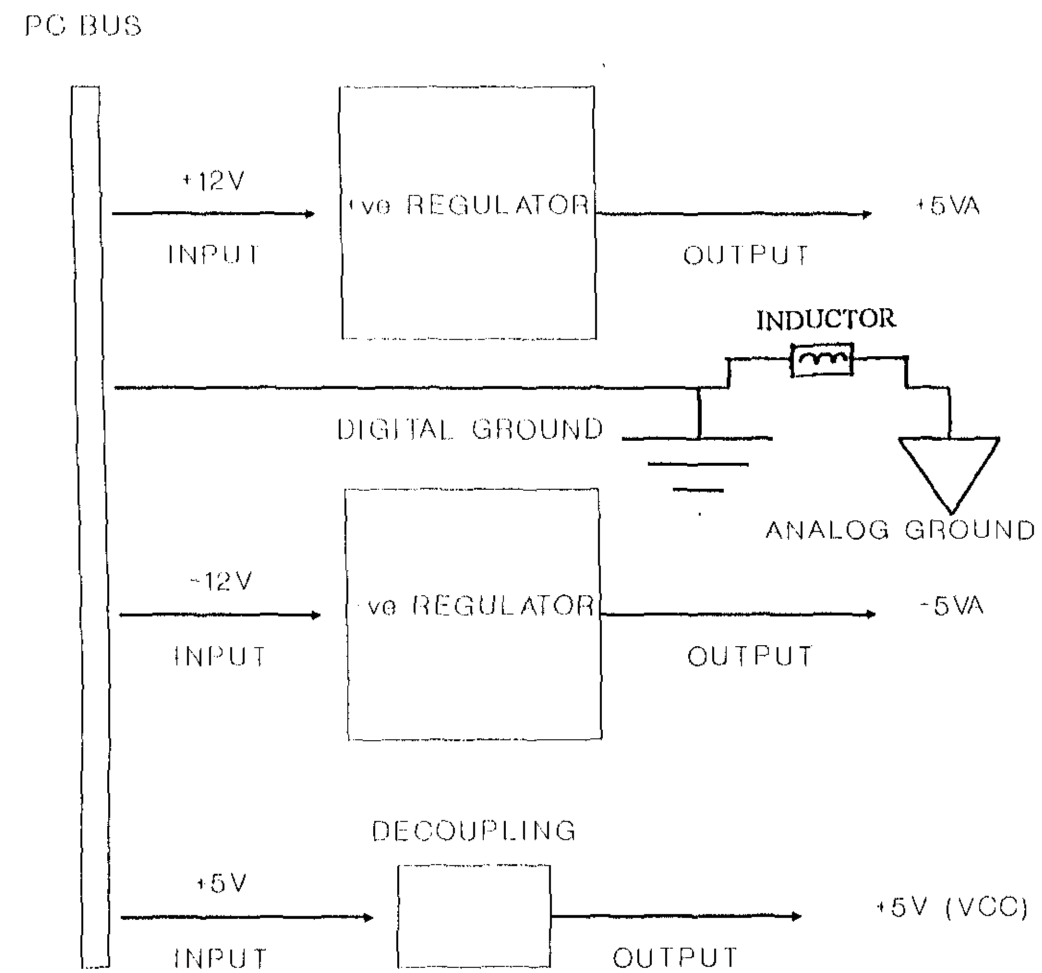


FIGURE 24_ POWER

CHAPTER 13

PROBLEMS ENCOUNTERED

This chapter describes the problems encountered during the design of the **FAXMODEM** card.

13.1 Feasibililitv studv

During the feasibility study and system analysis stages of this project great difficulty was found in obtaining general information regarding facsimile machines. This was due to the lack of literature available on the subject and the reluctance of private companies to assist in providing such information. Most of the private companies that were approached by means of pre-arranged interviews or telephone discussions, were extremely willing to assist until they discovered that the proposed project was a business threat.

13.2 Handshaking between the PC and the Faxmodem card

To ensure that the faxmodem card is ready to accept the data from the PC, or vice versa, it is vital that synchronization between the PC and the Faxmodem card is always maintained.

Interrupt IRQ 5 was used to interrupt the PC, as discussed earlier, in the section interrupt on the PC. Whenever the fax card interrupted the PC, there was no acknowledgement of the interrupt, due to the fact that the expansion slot of the PC does not provide an interrupt acknowledge signal. This problem was overcome by means of a software procedure, writing to the fax card address 301h whenever an interrupt was received on IRQ 5. The fax card in turn will then read port 301h to determine the status of the PC.

13.3 Memory and I/O Control

The 80C188 processor provides ALE, RD, and WR bus control signals. The RD and WR signals are used to strobe data from memory or I/O to the 80C188 or to strobe data from 80C188 to memory or I/O. The 80C188 local bus controller does not provide a memory-I/O signal. Since more than 512k RAM memory locations are used, memory and I/O spaces overlapping occured. The problem was overcome by using the S2 (status) signal to enable or disable the 3/8 decoder (74ls138) for RAM selection. The S2 signal changes state, from a logic '1' to a logic '0' during memory and I/O operations.

13.4 Routing and PCB manufacturing

Great difficultly was experienced routing such a high density printed circuit board, because of the limited available board space. The problem was overcome by using a more professional CAD (Computer Aided Design) software package. The art work was sent to a private company, Photo circuit Ltd, for the manufacturing of the printed circuit board.

CHAPTER 14

Test Results

Facsimili messages were sent from the faxmodem card (**Fax:** 903-4549) in Kuilsriver to the fax machine, Panasonic Panafax UF-150, (**Fax:** 461-6115) at Telkom RDC/MIS section in Cape Town and vice versa.

The received faxes clearly shows readability of the characters and the good quality of the picture. The quality of the fax sent through the modem card compares favourably with the standard of a normal fax. See **Appendix E.**

CHAPTER 15

CONCLUSIONS AND RECOMMENDATIONS

Based on the findings of this thesis project, the following conclusions can be drawn:

i) The **FAXMODEM** card conforms to all the specifications required in the objective at the beginning of this thesis.

ii) The hardware forms an intelligent interface between the PC and up to seven different communications media, which was not mentioned in the specification of the design requirement. The 80C188 microprocessor allows a further five more peripheral devices to be connected to the personal computer, without any further decoding. The PC's processing time is not degraded and all fax format conversions can be performed by the microprocessor on the faxmodem card. The communication card uses only one of the PC's expansion slot.

The **FAXMODEM** card discussed in this thesis is a prototype and is open to further development and enhancements.

Suggestions on future hardware enhancements or improvements follows:

i) With the introduction of the new DATA/FAXMODEM chip set, **89C124FX,** and available surface mounted components, the size of the printed circuit board and the cost to manufacture the faxmodem card can be greatly reduced.

ii) Using a few supporting analog-to-digital converters in conjunction with the on-board microprocessor, a scanner port can be incorporate on the card. The scanner input port, used with the required software, enables a hand scanner to scan documentation to the card.

iii) The R96EFX fax chip has the following features :

Programmable tone detection.

Programmable tone generation.

Using above features with the required software support, the faxmodem card can be transformed into an answering machine.

The experience and knowledge gained by undertaking this project has greatly enriched each and every individual that took part in it. This experience and knowledge gained will contribute significantly to the success of future projects.

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LIST OF ABBREVIATIONS :

ALE	-Address Latch Enable
CCITT	-The International Telegraph and Telephone Consultive Committee
CED	-CallED station identification
CFR	-ConFirmation to Receive
CLK	-Clock
CPU	-Central processing unit
CRC	-Cyclic Redundancy Check
CTS	-Clear To Send
DIS	-Digital Identification Signal
DSR	-Data Set Ready
DMA	-Direct Memory Access
Db	-Decibel
EOM	-End of Message
EPROM	-Erasable Programmable Read Only Memory
FREQ	-Frequency
GC	-Group Command
GI	-Group Identification
GND	-Ground
HDLC	-High Level Data Link Control
I/O	-Input/Output
LCS	-Line Condition Signals
LS I	-Large Scale Intergration

MCF	-Message ConFirmation
Mod.	-Modulation
PC	-Personal Computer
PIS	-Procedure Interrupt Signal
PPI	-Programmable Peripheral Interface
PPI	-Programmable Peripheral Interface
PSK	-Phase Shift Keying
QAM	-Quadrature Amplitude Modulation
REC.	-Recommendation
ROM	-Read Only Memory
SRAM	-Static Random Access Memory
SIO	-Serial Input/Output
VLSI	-Very Large Scale Intergration

APPENDIX

APPENDIX A

GENERIC ARRAY LOGIC

APPENDIX B

CONFIGURATION REGISTERS

APPENDIX C

TEST PROGRAMS

APPENDIX D

CIRCUIT DIAGRAMS

APPENDIX E

TEST FACSIMILI PRINTS

APPENDIX A

GENERIC ARRAY LOGIC

```
EL 4.00  -  Device Utilization Chart        Tue Dec  1 15:10:09 1992

irdecno fax

 ==== P22V10 Programmed Logic ====

EL      = (  !AB0 & !AB1 & !AB2 & !AB3 & !AB4 & !AB5 & !AB6 & !AB7 & AB8
                  & AB9 & !AEN );

EL      = (  AB0 & !AB1 & !AB2 & !AB3 & !AB4 & !AB5 & !AB6 & !AB7 & AB8
                  & AB9 & !AEN );

S      = !(  AB3 & AB4 & AB5 & AB6 & AB7 & AB8 & AB9 & !AEN & !PSEL
                #   AB3 & AB4 & AB5 & AB6 & AB7 & !AB8 & AB9 & !AEN & PS

R      = (  !AR );

Q4      = (  INT & !PSEL );

Q3      = (  INT & PSEL );

RQ      = (  !IRQ );
```

ddrdecno fax

```
                ==== P22V10 Chip Diagram ====


                          P22V10

                +---------\       /---------+
                |          \     /          |
                |           -----           |
         AB0    |  1                    24  |   Vcc
                |                           |
         AB1    |  2                    23  |   INT
                |                           |
         AB2    |  3                    22  |   NIRQ
                |                           |
         AB3    |  4                    21  |   NAR
                |                           |
         AB4    |  5                    20  |   AR
                |                           |
         AB5    |  6                    19  |   IRQ4
                |                           |
         AB6    |  7                    18  |   IRQ3
                |                           |
         AB7    |  8                    17  |   MCS
                |                           |
         AB8    |  9                    16  |   SSEL
                |                           |
         AB9    | 10                    15  |   DSEL
                |                           |
         AEN    | 11                    14  |   IRQ
                |                           |
         GND    | 12                    13  |   PSEL
                |                           |
                -----------------------------


               SIGNATURE: N/A
```

addrdecno fax

==== P22V10 Resource Allocations ====

Device Resources	Resource Available	Design Requirement	Part Utilization	Unused
Dedicated input pins	12	15	12	0 (0 %
Combinatorial inputs	12	12	12	0 (0 %
Registered inputs	-	0	-	-
Dedicated output pins	-	7	-	-
Bidirectional pins	10	0	10	0 (0 %
Combinatorial outputs	-	7	-	-
Registered outputs	-	0	-	-
Reg/Com outputs	10	-	7	3 (30 %)
Two-input XOR	-	0	-	-
Buried nodes	-	0	-	-
Buried registers	-	0	-	-
Buried combinatorials	-	0	-	-

EL 4.00 - Device Utilization Chart Tue Dec 1 15:10:09 1992

drdecno fax

==== P22V10 Product Terms Distribution ====

Signal Name	Pin Assigned	Terms Used	Terms Max	Terms Unused
SEL	15	1	10	9
SEL	16	1	12	11
CS	17	2	14	12
AR	21	1	12	11
RQ4	19	1	16	15
RQ3	18	1	16	15
IRQ	22	1	10	9

==== List of Inputs/Feedbacks ====

ignal Name	Pin	Pin Type
B0	1	CLK/IN
B1	2	INPUT
B2	3	INPUT
B3	4	INPUT
B4	5	INPUT
B5	6	INPUT
B6	7	INPUT
B7	8	INPUT
B8	9	INPUT
B9	10	INPUT
EN	11	INPUT
R	20	BIDIR
RQ	14	BIDIR
NT	23	BIDIR
SEL	13	INPUT

drdecno fax

==== P22V10 Unused Resources ====

in mber	Pin Type	Product Terms	Flip-flop Type
-	-	-	-

EL 4.00 - Device Utilization Chart Tue Dec 1 15:10:09 1992

drdecno fax

==== P22V10 Unused Resources ====

in mber	Pin Type	Product Terms	Flip-flop Type
-	-	-	-

EL 4.00 - Device Utilization Chart Wed Jan 27 12:44:58 1993

```
 ==== P22V10 Programmed Logic ====

TB      = !(  !IOW & DSEL );

CK      = !(  !IOR & DSEL );

TAT      = !(  !IOR & SSEL );

K2      = !(  !IOW & SSEL );

K1      = (  !SSEL & !RSET
        #   IOR & !RSET
        #   NOBF & !QDATA
        #   NOBF & NIBF );

    = (  !IOR & SSEL
        #   RSET );

SET      = (  !RSET );

I      = (  !RI );

H      = (  !OH );
```

==== P22V10 Chip Diagram ====

```
                          P22V10

               +---------\       /---------+
               |          \     /          |
               |           -----           |
          IOW  |  1                    24  |  Vcc
               |                           |
          IOR  |  2                    23  |
               |                           |
         SSEL  |  3                    22  |  NOH
               |                           |
         DSEL  |  4                    21  |  CLK2
               |                           |
               |  5                    20  |  NRSET
               |                           |
        QDATA  |  6                    19  |  CL
               |                           |
         RSET  |  7                    18  |  CLK1
               |                           |
         NOBF  |  8                    17  |  RSTAT
               |                           |
         NIBF  |  9                    16  |  NACK
               |                           |
           OH  | 10                    15  |  NSTB
               |                           |
           RI  | 11                    14  |  nRI
               |                           |
          GND  | 12                    13  |
               |                           |
               -----------------------------
```

SIGNATURE: N/A

==== P22V10 Resource Allocations ====

Device Resources	Resource Available	Design Requirement	Part Utilization	Unused
dicated input pins	12	10	10	2 (16 %)
mbinatorial inputs	12	10	10	2 (16 %)
gistered inputs	-	0	-	-
dicated output pins	-	9	-	-
directional pins	10	0	9	1 (10 %)
mbinatorial outputs	-	9	-	-
gistered outputs	-	0	-	-
g/Com outputs	10	-	9	1 (10 %)
o-input XOR	-	0	-	-
ried nodes	-	0	-	-
ried registers	-	0	-	-
ried combinatorials	-	0	-	-

EL 4.00 - Device Utilization Chart Wed Jan 27 12:44:58 1993

==== P22V10 Product Terms Distribution ====

Signal Name	Pin Assigned	Terms Used	Terms Max	Terms Unused
TB	15	1	10	9
CK	16	1	12	11
TAT	17	1	14	13
K2	21	1	12	11
K1	18	4	16	12
[illegible]	19	2	16	14
SET	20	1	14	13
I	14	1	8	7
H	22	1	10	9

==== List of Inputs/Feedbacks ====

gnal Name	Pin	Pin Type
W	1	CLK/IN
R	2	INPUT
EL	3	INPUT
EL	4	INPUT
BF	8	INPUT
BF	9	INPUT
[illegible]	10	INPUT
ATA	6	INPUT
ET	7	INPUT
[illegible]	11	INPUT

==== P22V10 Unused Resources ====

in mber	Pin Type	Product Terms	Flip-flop Type
5	INPUT	-	-
13	INPUT	-	-
23	BIDIR	NORMAL 8	D

==== I/O Files ====

dule: 'intdeco'

put files
=========
EL PLA file: intdeco.tt3
ctor file: intdeco.tmv
vice library: P22V10.dev

tput files
==========
port file: intdeco.doc
ogrammer load file: intdec.jed

APPENDIX B

CONFIGURATION REGISTERS

CONFIGURATION REGISTERS

Register	Range	Units	Default	Description
S0*	0 - 255	rings	00	Ring to Answer 0n
S1	0 - 255	rings	00	Ring count
S2	0 - 127	ASCII	43	Escape Code Character
S3	0 - 127	ASCII	13	Carriage Return Character
S4	0 - 127	ASCII	10	Line Feed Charater
S5	0 - 32,127	ASCII	08	Back Space Charater
S6	2 - 255	seconds	02	Wait For Dial Tone
S7	1 - 255	seconds	30	Wait Time For Data Carrier
S8	0 - 255	seconds	02	Pause Time for Comma
S9	1 - 255	1/10 seconds	06	Carrier Detect Responds Time
S10	1 - 255	1/10 seconds	14	Lost Carrier to Hang-up Delay
S11	50 - 255	ms	75	DTMF Dialing Speed
S12	0 - 255	1/50 seconds	40	Escape Code Guard Time

*This S-Register is stored in the modem NVRAM upon receipt of the &W command so that the contents are preserved when modem power is removed.

Reading a Register Value

To read the current value of a register :

1. Type Sr ? with r being the register number (0 - 27)

2. Press ENTER

The modem responds with the decimal value of the register, in three - digit forms.

To read values from more than one register :

1. Type **AT Sr? Sr?** from the **Command Mode.**

2. Press **ENTER** .

Changing a Register Value

To change a register value, use the **Sr = n** command, with :

* r being the register number

* n being the new value you want to assign.

For example, to have the modem automatically answer incoming calls after the forth ring :

1. Type **AT S0 = 4** from the command mode.

2. Pres **ENTER** .

Register	Range	Units	Default	Description
S14*	Bit Mapped	none	AA hex	Bit Mapped Options Register
S16	Bit Mapped	none	80 hex	Modem Test Options
S18*	0-255	seconds	00	Test Timer
S21*	Bit Mapped	none	00	Bit Mapped Options Register
S22*	Bit Mapped	none	76 hex	Bit Mapped Options Register
S23*	Bit Mapped	none	17 hex	Bit Mapped Options Register
S25*	0-255	0.1 or 1 seconds	05	Delay to DTR
S26*	0-255	0.01 seconds	1	RTS to CTS Delay Interval
S27*	Bit Mapped	none	40 hex	Bit Mapped Options Register

APPENDIX C

TEST PROGRAMS PAGE

TEST PROGRAMS

BASIC Data Transfer Performance

The following are two BASIC language data-transfer loops that have been timed. One loop reads data from a port and puts the data in an array. The other reads data from an array and writes them to an I/O port. In both cases, it is assumed that the data are always taken and available so that no interlock control signals are needed. In both loops, the maximum data rate measured was 4.75 millisecinds per byte transfer, or approximately 210 bytes per second.

READ FROM PORT LOOP

```
10 DIM BUF (1000)
20 FOR CNT = 0 TO 1000
30 BUF (CNT) = INP (&H 300)4.75 ms/byte
40 NEXT
50 END
```

WRITE TO PORT LOOP

```
10 DIM BUF  (1000)
20 FOR CNT = 0 TO 1000
30 OUT &H300, BUF (CNT)4.75 ms/byte
40 NEXT
50 END
```

Assembly Language Data Transfer

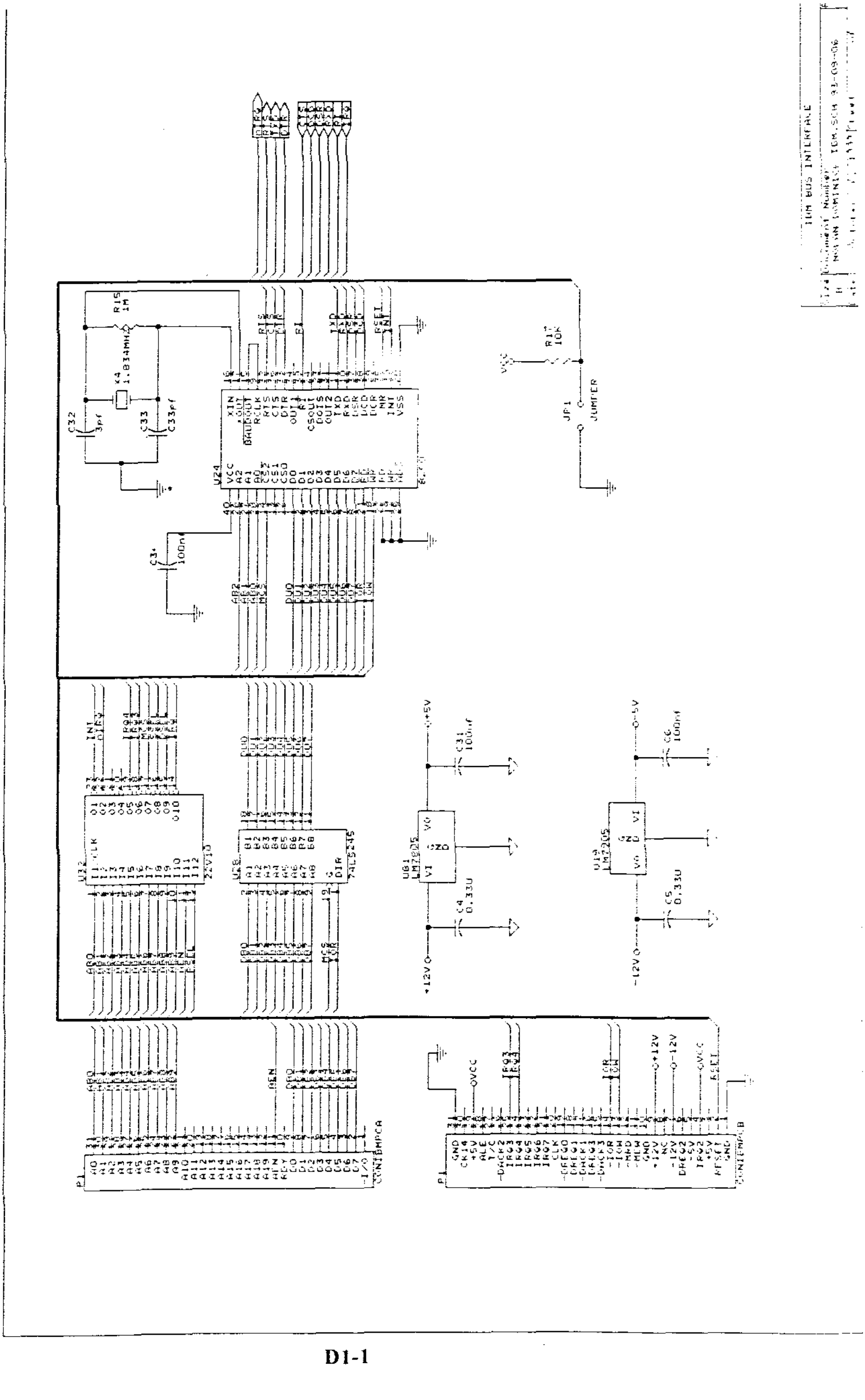
The following is an example of an assembly language data - transfer loop. In this loop, data are transferred from memory address and maintains a byte count that is tested during each transfer cycle. This loop assumes that the data will be accepted as fast as they can be sent.

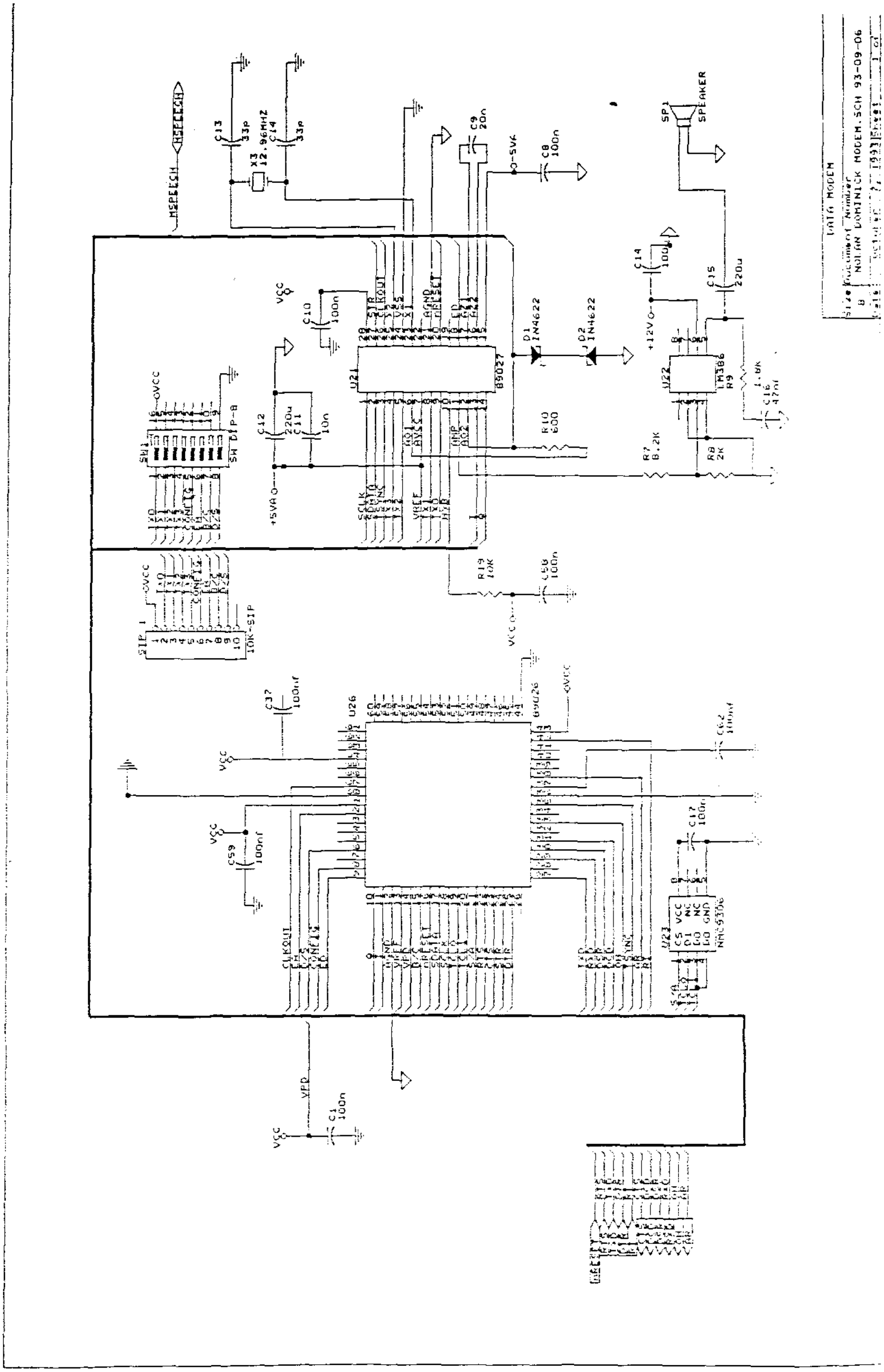
```
START:    MOV DX, PORT; LOAD DX REG WITH PORT ADDRES
          MOV BX, BUFFER     ; LOAD BX REG WITH BUFFER ADDRESS
          MOV CX,, COUNT     ; LOAD CX WITH LOOP COUNT
LOOP:     MOV AL, [ BX ]     ; LOAD AL REG WITH DATA FROM BUFFER
          OUT DX             ; WRITE AL REG DATA TO PORT
          INC BX             ; INCREMENT BUFFER ADDRESS
          DEC CX             ; DECREMENT LOOP COUNT
          JNZ LOOP           ; LOOP IF COUNT NOT EQUAL TO ZERO

          WAIT
```

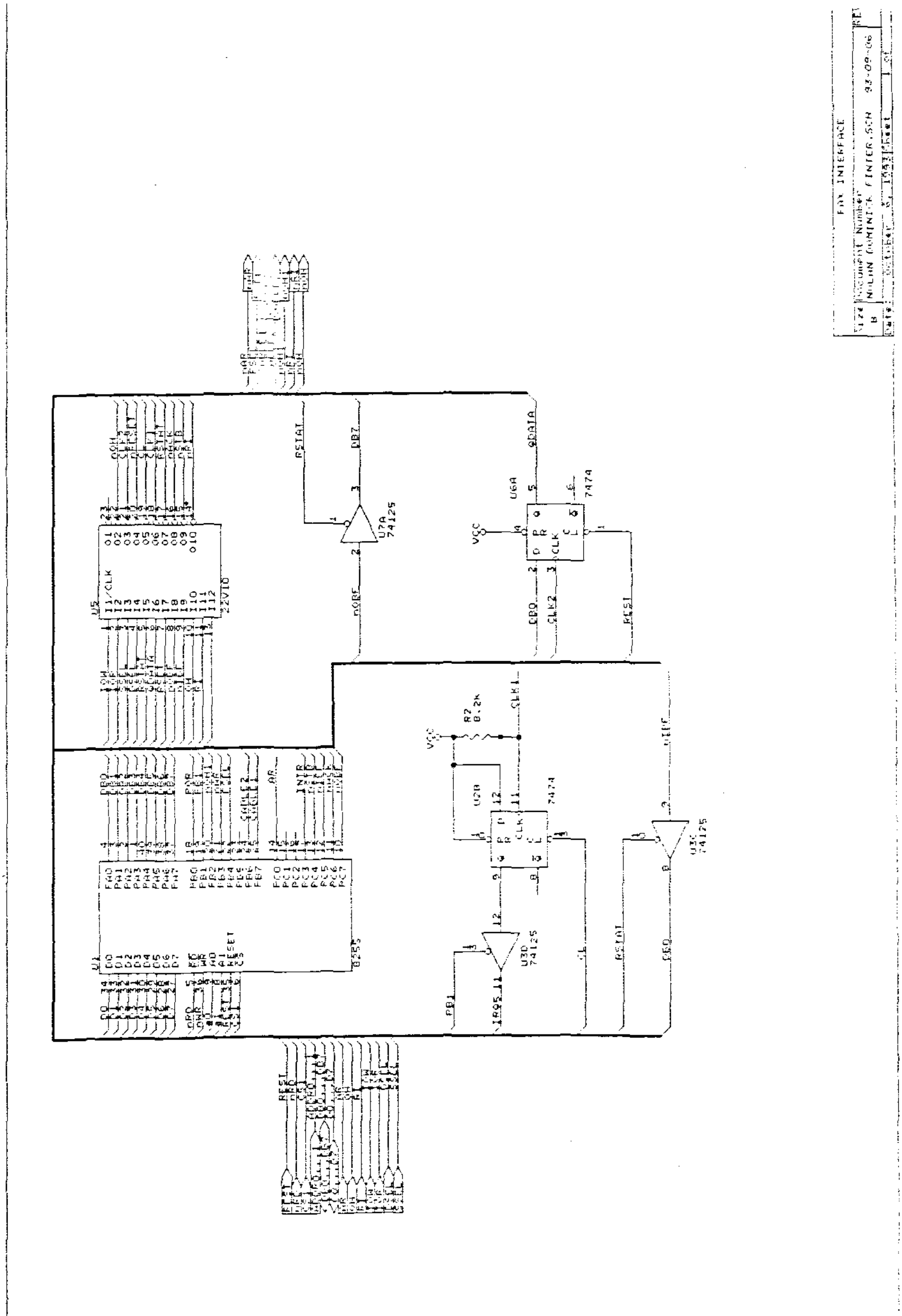
This data-transfer loop was measured and it transferred data at a rate of 11.5 microseconds per byte, or 86.95 kilobytes per second. This is over 400 times faster than the equivalent BASIC data- transfer loop.

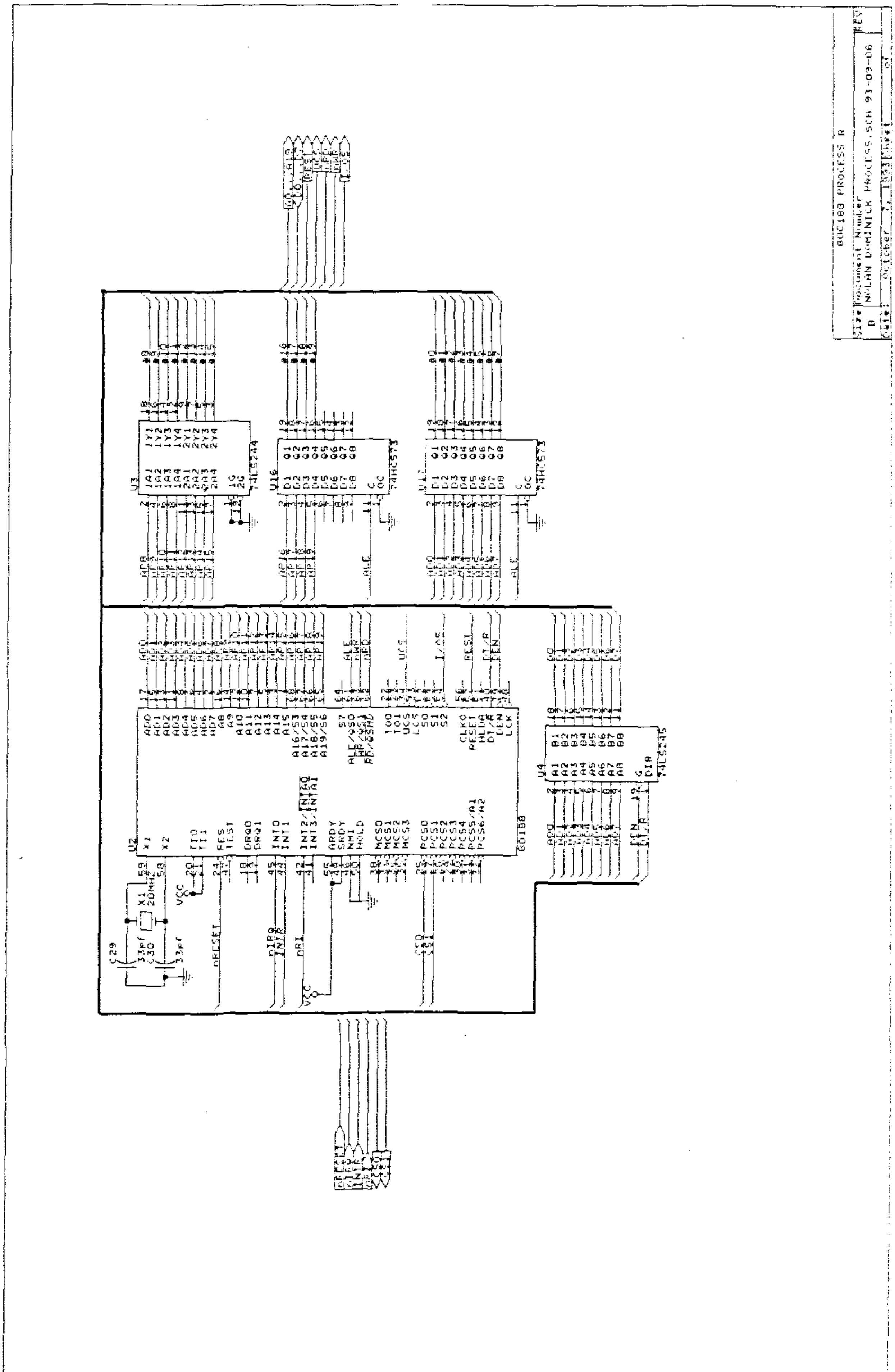
APPENDIX D

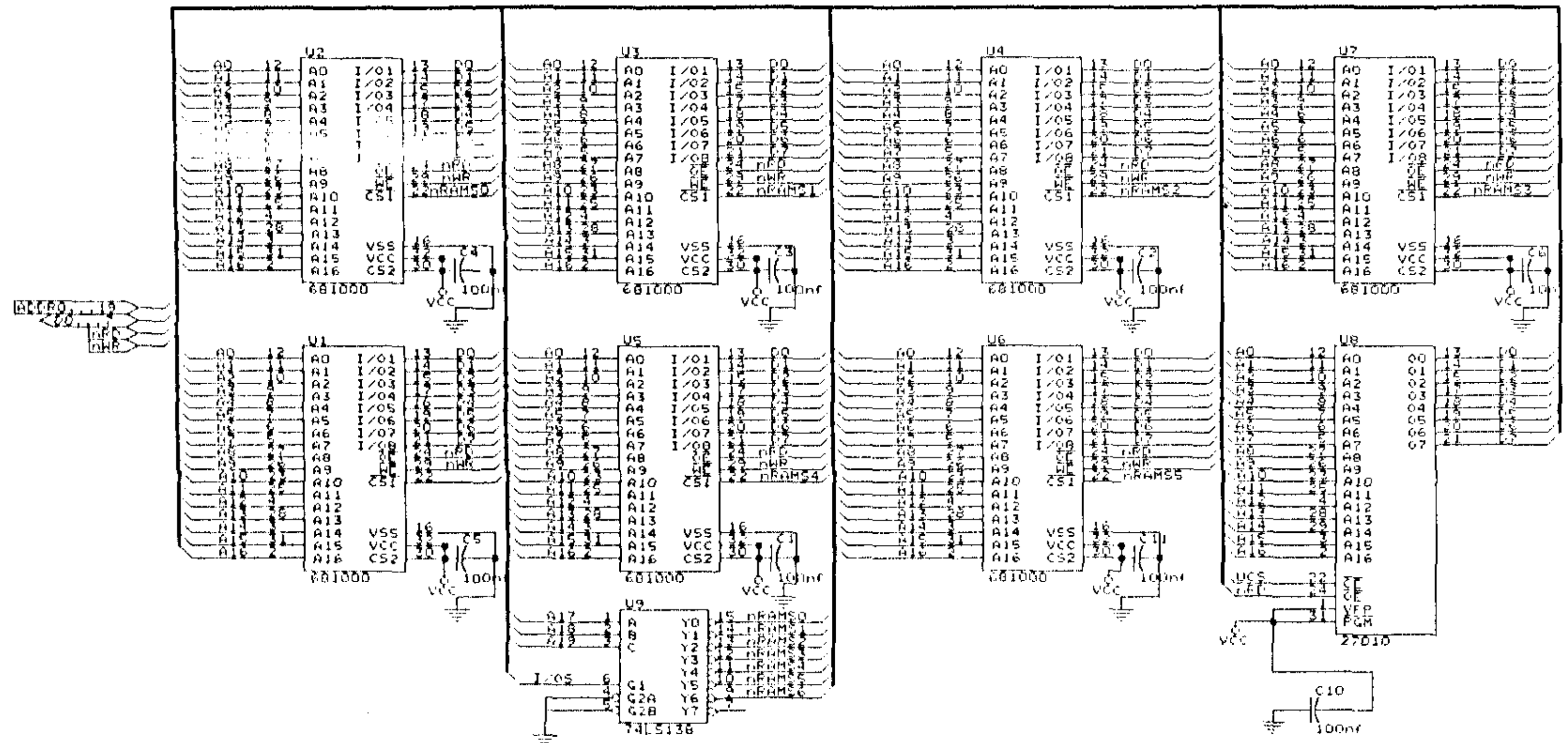
CIRCUIT DIAGRAMS **PAGE**


IBM BUS INTERFACE
JUMPER
74LS245
22V10


DATA MODEM
NOLAN DOMINICK MODEM.SCH 93-09-06
SPEAKER
SP1
X3
12.96MHZ
89027
89026
U21
U22
U23
U26
LM386
NMC9306
SW DIP-8
10K-SIP
IN4622
+12V
VCC
VPD

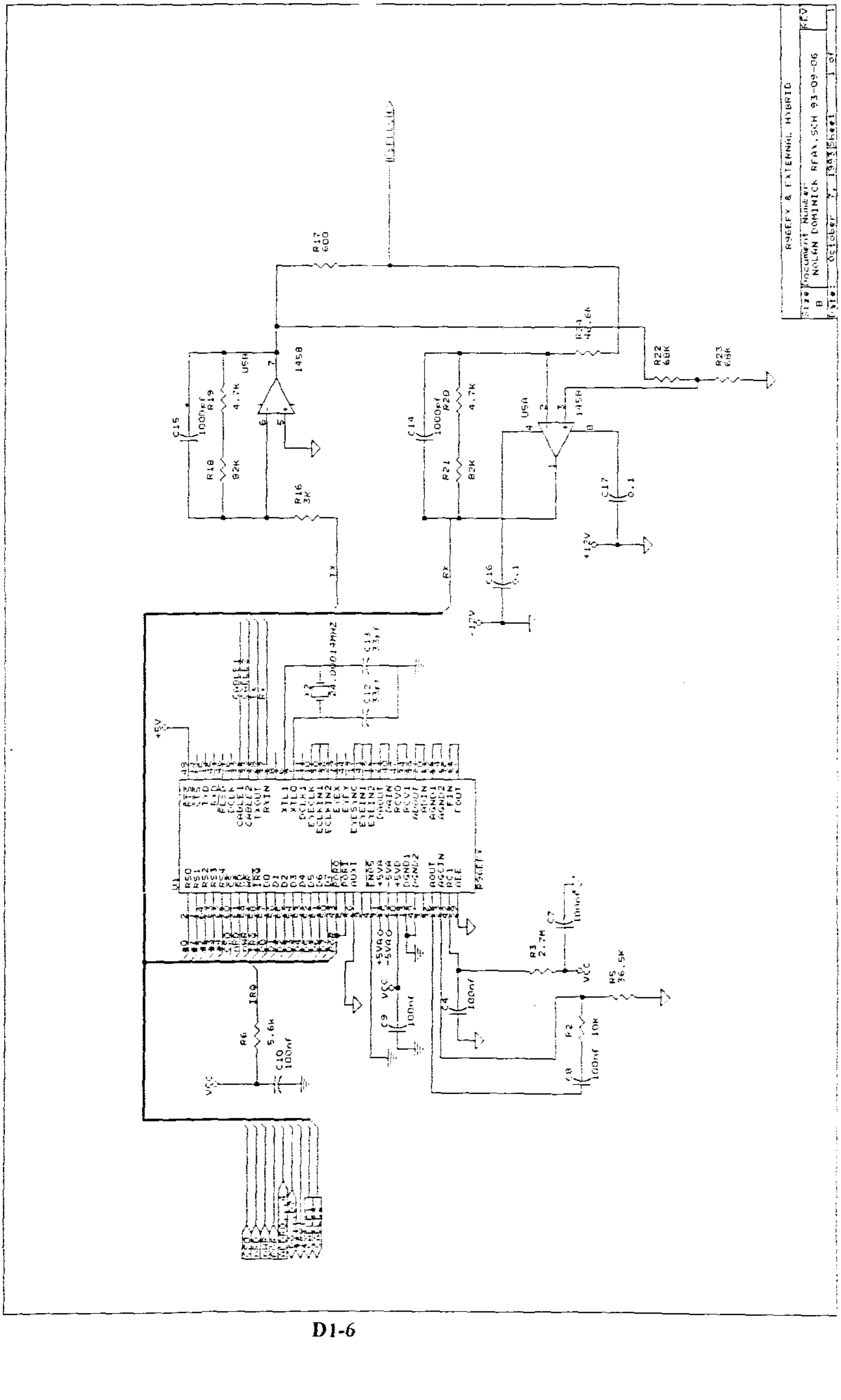

FAX INTERFACE
U5
22V10
U1
8255
U7A
74125
U6A
7474
U2B
7474
U3D
74125
U3C
74125
R2
8.2K
VCC

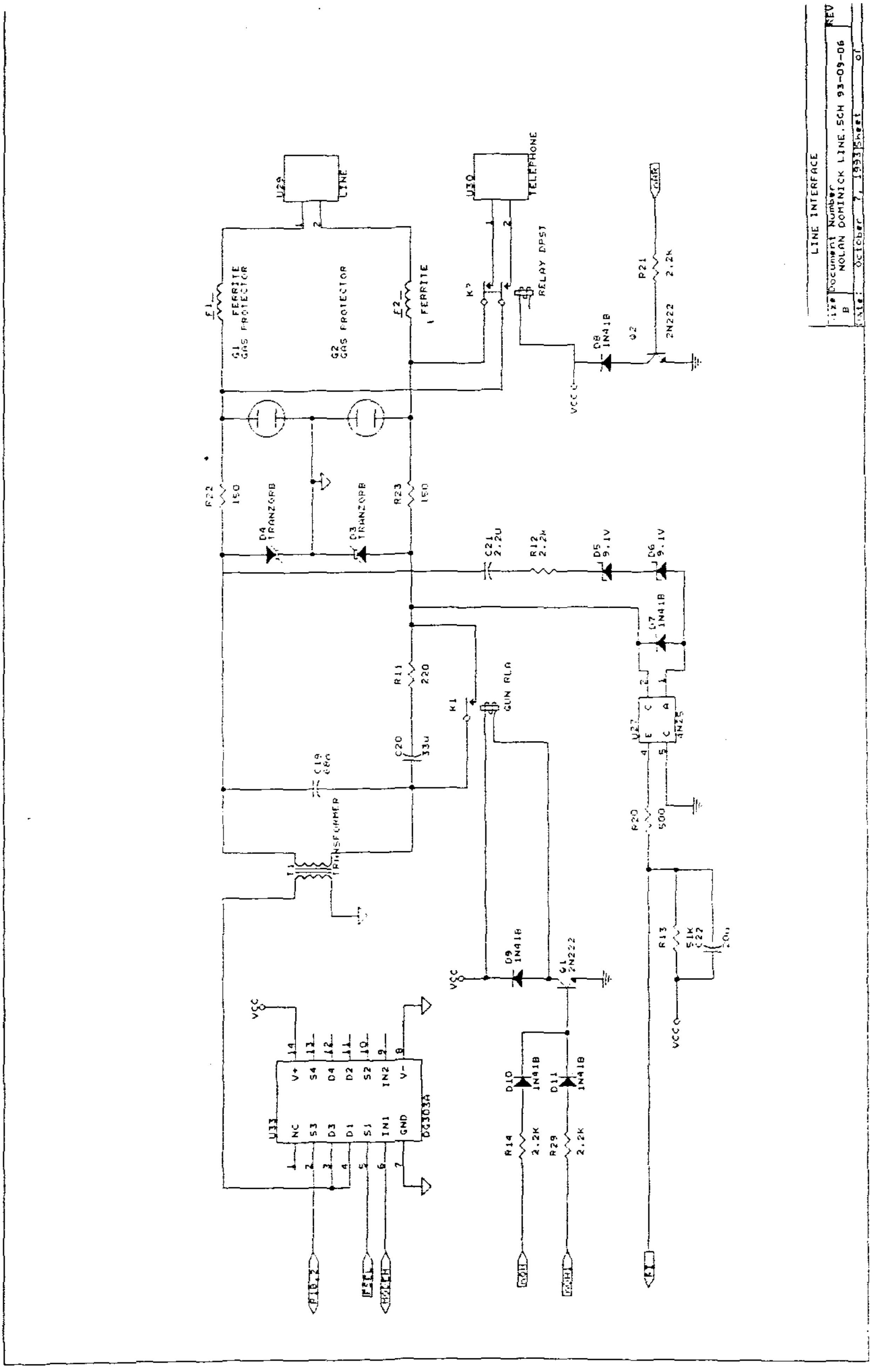

80C188 PROCESS R
NOLAN DOMINICK PROCESS.SCH 93-09-06
74LS244
74HC573
74LS245
80188
20MHz



MEMORY INTERFACE

Size	Document Number	REV
B	NOLAN DOMINICK MEM.SCH 93-09-06	
Date:	October 6, 1993 Sheet 1 of 1	


R96EFX & EXTERNAL HYBRID
Size B
Document Number
NOLAN DOMINICK RFAX.SCH 93-09-06
REV 1
Date: October 7, 1993 Sheet 1 of 1
R17 600
R18 82K
R19 4.7K
R20 4.7K
R21 82K
R22 68K
R23 68K
R16 3K
C15 1000nf
C14 1000nf
C17 0.1
C16 0.1
U5B 1458
U5A 1458
+12V
-12V
TX
RX
+5V
24.00014MHZ
R6 5.6k
C10 100nf
R3 2.7M
R5 36.5k
R2 10K
C4 100nf
C9 100nf
C8 100nf
C7 100nf
VCC



LINE INTERFACE
Document Number
NOLAN DOMINICK LINE.SCH 93-09-06
REV
LINE
TELEPHONE
FERRITE
GAS PROTECTOR
RELAY DPST
TRANZORB
TRANSFORMER
GUN RLA
DG303A
2N222
1N418
4N25
VCC

APPPENDIX E

TEST FACSIMILI PRINTS

i) Faxmodem card to Fax machine.

ii) Fax machine to faxmodem card.

FAX COVER SHEET

Fri Feb 04 1994 10:32 am

To: TELKOM RDC
Attn: NOLAN DOMINICK
Fax #: 461 6115

From:

Fax: 4 pages and a cover page.

```
                                        ; 2 = 10ms at 3.85 l/mm: T7.7 = T3.85
                                        ; 4 = 5ms  at 3.85 l/mm: T7.7 = T3.85
                                        ; 3 = 10ms at 3.85 l/mm: T7.7 = 1/2 T3.85 ->DIS
                                        ; 6 = 20ms at 3.85 l/mm: T7.7 = 1/2 T3.85 ->DIS
                                        ; 5 = 40ms at 3.85 l/mm: T7.7 = 1/2 T3.85 ->DIS
                                        ; 7 = 00ms at 3.85 l/mm: T7.7 = T3.85
EXT1            DB      ?       ; Extend field
HRATE           DB      ?       ; 2400 bit/s handshaking
UNCOMP          DB      ?       ; Uncompressed mode
ERRCOR          DB      ?       ; Error correction mode
FSIZE           DB      ?       ; Frame size for Error correction mode
                                ; 0 = 256 octets, FF = 64 octets --> DCS
                                ; Set to "0" -->DIS/DTC
ERRLIM          DB      ?       ; Error limiting mode
                DB      ?       ; Reserved for G4 capability on PSTN
                DB      ?       ; Unassigned
EXT2            DB      ?       ; Extend field
VALRECW         DB      ?       ; IF = FF -> VRES means Higher Resolution
                                ; Validity of RECWIDTH1           -->DIS/DTC
                                ; 0 = RECWIDTH1 valid             -->DIS/DTC
                                ; FF= RECWIDTH1 invalid           -->DIS/DTC
                                ; Recording width                        -->DCS
                                ; 0 = rec width indicated by RECWIDTH1   -->DCS
                                ; FF= rec width indicated by RECWIDTH2-5 -->DCS
RECWIDTH2       DB      ?       ; 1216 pixels along scan line length =151mm ->DIS
                                ; Middle 1216 elements of 1728 pixels     -->DCS
RECWIDTH3       DB      ?       ;  864 pixels along scan line length =107mm ->DIS
                                ; Middle  864 elements of 1728 pixels     -->DCS
RECWIDTH4       DB      ?       ; 1728 pixels along scan line length =151mm ->DIS
RECWIDTH5       DB      ?       ; 1728 pixels along scan line length =107mm ->DIS
                DB      ?,?     ; Reserved for future recording width capabilit
                DB      ?       ; Extend field
INFO_TBL        ENDS

; DCS
; digital command signal received from / to be transmitted to remote machine
DCSINFO         INFO_TBL        <>      ; Allocate INFO_TBL structure

; DIS/DTC
; remote FAX machine's RECEIVE/TRANSMIT capabilities
DISINFO         INFO_TBL        <>      ; Allocate INFO_TBL structure

; FAX MODE of local machine
FAX_MODE        LABEL   BYTE
Rx_OPERATION    DB      ?       ; 2 = T.3 operation   3 = T.4 operation
Tx_OPERATION    DB      ?       ; 2 = T.3 operation   3 = T.4 operation
RETRAIN_FLAG    DB      ?       ; FF = busy retrianing
DATA_Rate       DD      ?       ; data signalling rate (2400,4800,7200,9600)
HAND_Rate       DB      ?       ; handshaking rate (20h = 300, 09 = 2400)
Vert_RES        DB      ?       ; 0 = normal  FF = 7.7 line/mm
CODINGMODE      DB      ?       ; 0 = one dim FF = two dimensional
REC_Width       DW      ?       ; recording width (864,1216,1728,2048,2432)
Scan_Width      DW      ?       ; scan line length (107,151,215,255,303)mm
Max_Length      DW      ?       ; max record length (0:unlin,297mm:A4,364mm:B4)
Min_Scan_Time   DB      ?       ; minimum scan line time (0,5,10,20,40ms)
Uncomp_Mode     DB      ?       ; 0 = compressed     FF = uncompressed mode
ECMODE          DB      ?       ; 0 = normal         FF = Error correction mode
ELMODE          DB      ?       ; 0 =                FF = Error limiting mode
Frame_size      DW      ?       ; frame size  (64,256)
FAX_MODE_len    EQU     Offset Frame_size - Offset Rx_OPERATION + 2

; HIGH SPEED TRANSMIT PROCEDURE
MSG_PROCn       DB      ?
DATA_FLAG       DB      ?
LAST_FLAG       DB      ?
```

```
EOL_CTR         DB      ?
RTC_FLAG        DB      ?
EOL_FLAG        DB      ?
ZERO_CTR        DB      ?
FILB_CNT        DB      ?

; SYSTEM TIMER
SYS_CTR         DW      ?       ; 1s counter
SYS_TIME        DD      ?       ; system time and date in seconds
YEAR            DW      ?
MONTH           DW      ?
DAY             DW      ?
RECFAXCNT       DW      ?

LINE_CNT        DW      ?
LINE_CTR        DW      ?

; FAX DOCUMENT INFO
DOCPAGEINFOLEN  EQU     MAXPAGE                 ; 2 bytes needed per PAGE
FAXPACKINFOLEN  EQU     31 + DOCPAGEINFOLEN     ; length of packed info header
PAGECNT         DB      0       ; number of pages RECEIVED/TRANSMITTED
PAGECTR         DB      ?       ; current page
DOC_RES         DB      ?       ; current page resolution
DOC_CODING      DB      ?       ; current page coding method
DOC_START       DD      ?       ; document pointer
DOC_END         DD      ?       ; end of document
DOC_TYPE        DB      ?

HEADBUF         LABEL   BYTE
DOC_NAME        DB      'FAX00001'      ; file name
DOC_TELNO       DB      30 DUP (?)      ; telephone number
DOC_TIME        DB      '23:59:58'      ; time received  send
DOC_DATE        DB      '1993-12-31'    ; date received /send
DOC_RECWIDTH    DW      1728    ; recording width
DOC_LENGTH      DW      297     ; document page length
DOC_PAGECNT     DB      ?       ; number of pages in document
DOC_PAGEINFO    DW      DOCPAGEINFOLEN DUP (?)      ; coding/vres of each page
                ; b0->b13  = line count             } #lines page 0
                ; b14    0 - norm    ; 1 - high res  } vres    page 0
                ; b15 -  0 = 1 dim   ; 1 = 2 dim     } coding page 0
HEADEND         LABEL   BYTE
HEADLEN         EQU     OFFSET HEADEND   OFFSET HEADBUF
FAXTBL          DB      MAXFAX DUP (FAXPACKINFOLEN DUP (?))

; FAX MESSAGE BUFFER
SAVE_FLAG       DB      ?
BITCNT          DB      ?
DATA_BYTE       DB      ?
PAGESTART       DD      ?       ; points to start of page
FAXPNT          DD      ?
FAXEND          DD      ?
FAXNO           DB      ?
FAXCNT          DB      ?
EOL_ONLY        DB      ?
TOP_OF_FAXBUF   DW      ?
FAXBUF_OVF      DB      ?

; 8255 IO ...
IBF_flag        DB      ?
OBF_flag        DB      ?
PutPnt_Inp      DW      ?
GetPnt_Inp      DW      ?
PutPnt_Out      DW      ?
GetPnt_Out      DW      ?
PC_DISABLE      DB      ?
```

```
; Bottom of RAM :- vector table and system buffers and variables
FSTSEG          SEGMENT AT      0       'DATA'
INTR_VECT_TBL   DD      32 DUP (?)      ; 32 interrupt vectors
TOP_OF_RAM      DW      ?
;
; R96 interrupt service routine variables
; HDLC
ABIDL_REC       DB      ?       ; FF = ABort /IDLe being received
RATE            DB      ?       ; conf. code for next configuration change
R96ISR          DB      ?       ; 1=HDLC_Rx, 2=HDLC_Tx, 3=MSG_Rx, 4=MSG_Tx
R96BUF_OVF      DB      ?       ; FF = R96 buffer overflow
R96BUF_CNT      DW      ?       ; byte count
R96BUF_PNT      DW      ?       ; R96 buffer pointer
R96BUF          LABEL   BYTE
FADDR           DB      0FFh    ; FF = PSTN
FCTRL           DB      0C8h    ; C0 = non final, C8 = final frame in procedure
FCF             DB      ?       ; DIS / DTC / CRP etc
FIF             DB      R96BUF_LEN DUP (?)  ; buffer for HDLC signals
TxFIF           DW      15 DUP (?)  ; Tx buffer for FIF
ID_FLAG         DB      ?           ; FF = Remote station id has been received
TSI_INFO        DB      30 DUP (?)
CSI_INFO        DB      30 DUP (?)
;
; STRUCTURE definition for DIS/DTC and DCS info tables
; Unless specified otherwise , 0FFh = capable : 00 = not capable -->DIS/DTC
;                              0FFh = enable  : 00 = disable     -->DCS
INFO_TBL        STRUC
Tx_T2           DB      ?       ; Transmitter - T.2 operation  -->DIS/DTC
Rx_T2           DB      ?       ; Receiver - T.2 operation
IOC             DB      ?       ; 00 = 264 / FF = 176 :T.2 Index Of Cooperation
Tx_T3           DB      ?       ; Transmitter - T.3 operation  -->DIS/DTC
Rx_T3           DB      ?       ; Receiver - T.3 operation
                DB      ?,?,?   ; Reserved for future T.3 operation features
Tx_T4           DB      ?       ; Transmitter - T.4 operation  -->DIS/DTC
Rx_T4           DB      ?       ; Receiver - T.4 operation
DRATE           DB      ?       ; Data signalling rate
                                ; 0 = V.27ter fallback mode          -->DIS/DTC
                                ; 1 = V.27ter -> 4800 or 2400bits/s -->DIS/DTC
                                ; 2 = V.29    -> 9600 or 7200bits/s -->DIS/DTC
                                ; 3 = V.27ter and V.29               -->DIS/DTC
                                ; 0 = 2400 bit/s V.27 ter  ------>DCS
                                ; 1 = 4800 bit/s V.27 ter  ------>DCS
                                ; 2 = 9600 bits/s V.29     ------>DCS
                                ; 3 = 7200 bits/s V.29     ------>DCS
                DB      ?,?     ; Reserved for new modulation system
VRES            DB      ?       ; Vertical resolution = 7.7 line/mm or High RES
CODING          DB      ?       ; Two-dimensional coding
RECWIDTH1       DB      ?       ; Recording width capabilities
                                ; 0 = 1728 pixels, scan line length =215mm ->DIS
                                ; 1 = 1728/215mm, 2048/255mm, 2432/303mm   ->DIS
                                ; 2 = 1728/215mm and 2048/255mm            ->DIS
                                ; 3 = 1728/215mm, 2048/255mm, 2432/303mm   ->DIS
                                ; 0 = 1728 pixels, scan line length =215mm ->DCS
                                ; 1 = 2432 pixels, scan line length =303mm ->DCS
                                ; 2 = 2048 pixels, scan line length =255mm ->DCS
MAXLEN          DB      ?       ; Maximum recording length capability
                                ; 0 = A4 (297mm)          --> DIS/DTC
                                ; 1 = Unlimited           --> DIS/DTC
                                ; 2 = A4 and B4 (364mm) --> DIS/DTC
                                ; 0 = A4 (297mm)          --> DCS
                                ; 1 = Unlimited           --> DCS
                                ; 2 = B4 (364mm)          --> DCS
SCANTIME        DB      ?       ; Min scan line time capability at the receiver
                                ; 0 = 20ms at 3.85 l/mm: T7.7 = T3.85
                                ; 1 = 40ms at 3.85 l/mm: T7.7 = T3.85
```

```
OUTBUF          DB      OUTBUFSIZ DUP (?)
INPBUF          DB      INPBUFSIZ DUP (?)

; Softuare Timers 3 & 4
COUNT_T3        DW,     ?          ; counter
MAXCNT_T3       DW      ?          ; max count
CONT_T3         DW      ?          ; b15 = en    b5 = mc
COUNT_T4        DW      ?          ; counter
MAXCNT_T4       DW      ?          ; max count
CONT_T1         DW      ?          ; b15 = en    b5 = mc

; Software timers for RING detection
RINGTMR         DW      ?          ; timer :resets to 2700ms
RINGCNT         DB      ?          ; number of ring bursts detected
RINGPROC        DB      ?          ; ring detection procedure
RINGFLAG        DB      ?          , ring indicator
RINGTIM         DW      ?          ; timer :resets to 1000ms

; MODEM
AR_FLAG         DB      ?          ; indicate MODEM activity
NUMBER_of_RINGS DB      ?          ; same as s0 register in MODEM
WAIT_for_CARRIER DW     ?          ; same as s7 register in MODEM

; FAX Auto-dialing
DIAL_TYPE       DB      0          ; 00 = pulse dialing, 01 = DTMF dialing
NUMBER          DB      40 DUP (?)      ; number buffer = 40 digits long

; Misc
RESULT          DB      0          ; 00 = Yes  FF = No
TEMP            DB      0,0,0,0

FAX_START       DB      ?          ; FAX_START last entry in segment
FSTSEG          ENDS
```

Regional Developement Centre
Western Cape
TQ3C6
Phone: (021) 461-6112
Fax: (021) 461-6115

Fax Message

To: TELKOM SPECIAL INVESTIGATIONS

For Attention: CHRIS STUURMAN

Fax No: 903 4549

Number of pages, including this one: 5

Date: 31-01-1994

Message:

BEST REGARDS

NOLAN.

The high and the low on computer work stations

Adrian van Tonder

The health effects of visual display terminals (VDTs or VDU's) are frequently questioned. Ionizing radiation in particular is of concern since users feel that exposure may result in damage to reproductive systems and also cause cancer.

Poor ergonomics biggest problem

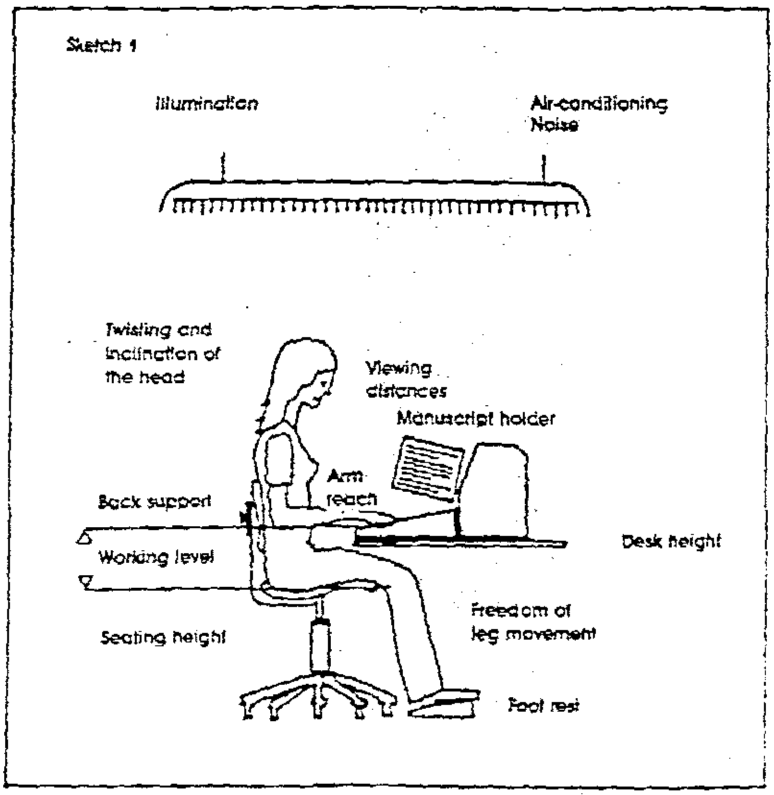
...dies in the USA proved conclusively ...t emissions of ionizing radiation (x-rays) and non-ionizing radiation (microwaves, ultrasonic sound, optical radiation) are well below levels where health could be adversely affected. Yet, in spite of these results users complain of neck, shoulder and low back pain, of headaches, irritability, difficulty to sleep, of feeling stressed and overworked. Red eyes, eye irritation and vision deterioration are also common complaints. These symptoms and complaints are typical of poor ergonomics of workplace design and job demands.

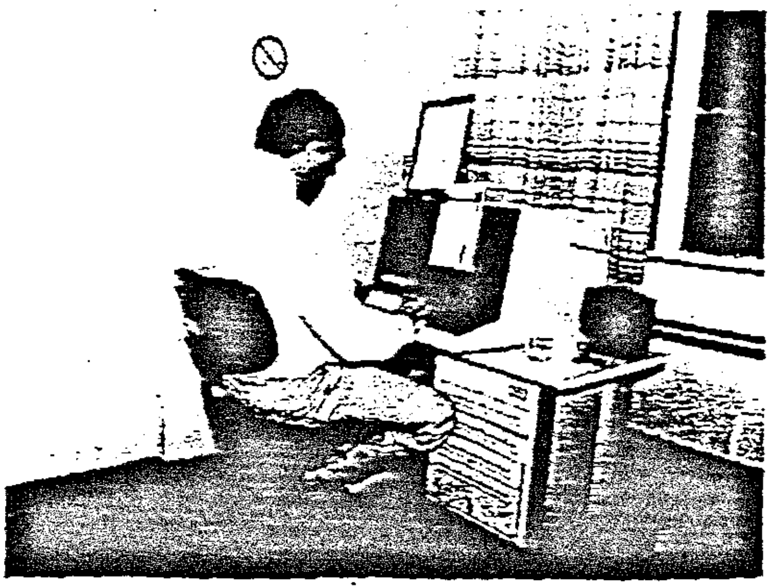
The objective of ergonomics is to adapt work situations to the physical, physiological and mental capabilities of human beings in order to improve efficiency, accuracy and safety. Therefore consideration is given to size and ...ngth (anatomy), expenditure of ...ergy and effects of environmental factors on body functions (physiology) and mental capability (skill and occupational psychology) when designing workplaces and determining work procedures. Well designed workplaces and work procedures reduce physical and mental fatigue, boredom and stress and thereby eliminate real as well as psychosomatic illnesses.

Important design factors

The factors that need to be considered in the design of computer work stations and work procedures are indicated in sketch 1 and the list below:

- Work breaks
- Shift work
- Physical exercise
- Acuity of vision
- Software friendliness
- Performance demands





An example of a workplace that does not "fit" the user

ERGONOMICS

Anatomy

Here one is concerned with selection of desk and chair and with arrangement of equipment such that:

- Body posture during work is optimised in order to minimise strain on and subsequent fatigue of muscles and spine by eliminating static muscular effort. This includes elimination of factors which cause strain on eye muscles.
- All equipment is within reasonable reach and repetitive movements outside normal, comfortable reach are minimised.
- The display screen and work documents are within the ergonomical preferred field of vision.
- Employees with varying body dimensions can adjust the workplace to their requirements, and
- adequate work space is available.

Equipment selection

Equipment should be adjustable in order to obtain the ergonomically preferred work postures. The adjustable ranges given here were determined in a European study and should only be used as an indication of requirements. South African anthropometric data suggests that a wider range of adjustability may be required.

The range of adjustments required depends on sex, ethnic group and anthropometric size distribution.

If exceptionally large or small people have to be accommodated or if adjustment range of available equipment is too limited, base equipment selection on the dimensions of the persons who use the equipment most frequently and supply interchangeable equipment where possible.

The "tuning" of a work station to a specific individual's requirements can be done by means of a combination of adjustable chair, adjustable desk surfaces and adjustable footrest.

Seating

Height should be adjustable such that an angle of slightly larger than 90° is obtained at the elbow when fingers are resting on the home keys (row A, S, D, F, J, K, L).

Shoulders must be in a relaxed position with forearms and hands parallel to the table surface (beware of upturned wrists). This implies a height adjustability range of at least 450 to 520 mm.

If the seat is fitted with arm rests, these should not interfere with arm position. The "working level" range of 200 to 300 mm should be kept in mind.

Feet should be placed flat on the floor with the angle at the knee joint larger than 90°. If the chair is too high due to the required arm position then a footrest should be supplied. The footrest should preferably be adjustable in height (0 - 50 mm) and inclination (10 - 15°). It should be large enough to cover the entire usable leg area and should be skid resistant to prevent skidding away from the optimum position.

Seats should have backrests which are adjustable up-and-down as well as for inclination. The back rest and seat surface should be contoured (see sketch 2) and firm. Lumbar support must be provided by the back rest at a height of 10 to 20 cm above the seat surface.

The seat surface should slope downwards at the front in order to reduce pressure on the back of the legs near the knee.

A correct seating posture should allow an angle larger than 90° between the abdomen and thighs.

Desks

Desks with various height-adjustable work surfaces are preferred but in most instances one would have a fixed desk height.

Desk height may vary but the important aspect is that 10 to 20 cm free space between thighs and desk top is available after the seat height has been correctly set. In practice this could be achieved by keeping the keyboard (home keys) 720 - 750 mm from the floor and adjusting seat height for correct arm position.

Difficulty may be experienced with typewriters and keyboards fixed to screens as these are usually higher than the keyboards used on most personal computers. Flat detachable keyboards are essential for good ergonomics.

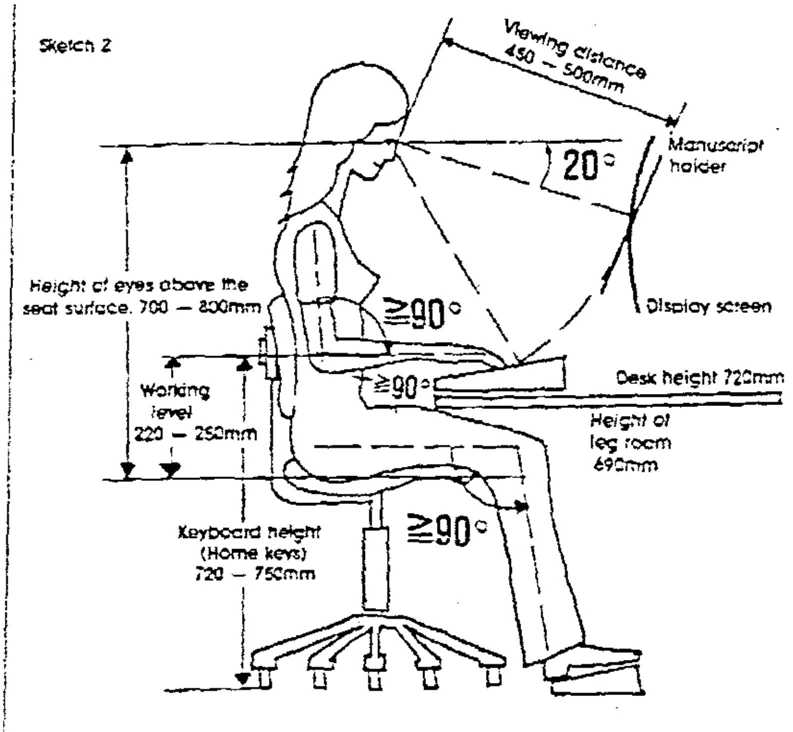
Screens

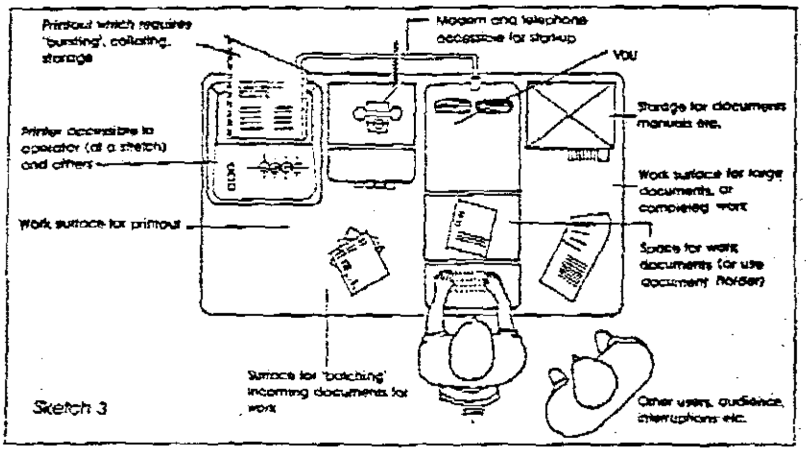
The VDU screen and document holder should be placed such that, when seated correctly and looking at the screen the head and eyes are held approximately at their natural relaxed angles below the horizontal. This results in a head tilt of approximately 20° below the horizontal when looking at the centre of the screen (sketch 2).

The viewing distance to the screen and document holder should be in the order of 500 mm (further than 700 mm and nearer than 300 mm is not recommended). However, consider the user's visual acuity and figure size on screen.

Problems with achieving correct head/eye inclination and viewing distance can be expected when using equipment where keyboards are fixed to screens. Once again detachable keyboards are highly recommended.

Sketch 2





Sketch 3

Workspace layout

Workspace on the desk should be adequate to accommodate the CPU (central processing unit), VDU (video display unit), keyboard, work documents, printer and should have some additional storage space (see sketch 3).

Arrangement of equipment should be such that twisted and other abnormal body postures are avoided, eg. adequate legroom to enable the operator to sit directly in front of the keyboard.

The back keys of the keyboard should be at a suitable distance from the desk's front edge in order to accommodate arm reach. *A space of approximately 60 mm between front edge and keyboard should be allowed in order to prevent a "cutting" action between desk (or keyboard) edge and wrists.*

Work documents and the VDU screen should be arranged such that head movements in the horizontal plane and especially in the vertical plane are minimised. Twisting and holding of the head to one side should be eliminated as much as possible. One should also minimise the need for visual accommodation (focal distance) and adaption (luminance adjustment) when the eyes are moved from screen to documents to screen.

In order to achieve good document to screen arrangement, the use of a document holder situated *in the same horizontal plane as the screen* is recommended. *Document holders should preferably be adjustable for vertical inclination and have a line marker. Placement to the right of the screen is recommended if notes need to be made on documents but otherwise to the left of the screen is appropriate.*

Because the keyboard is situated in a position where abnormal strain can be placed on neck and eye muscles, it is recommended that all regular computer users be trained to touch type in order to reduce the need for frequent looking at the keyboard. This also has the advantage of speeding up the work rate.

The work environment

In this instance we are mainly concerned with creating a work environment where lighting, noise and temperature are optimised in order to reduce work interference and physical fatigue. *This should then improve worker comfort which will lead to improved accuracy, efficiency and safety.*

Lighting

Poor quality lighting causes eye strain which results in lowered efficiency. In the long term, permanent vision deterioration may occur. In order to arrange for optimum lighting conditions one should keep the following terminology in mind:

- illumination - the amount of light falling onto an object.
- luminance - the amount of light reflected by or emitted from an object.
- glare - is caused by bright light sources shining directly into the eyes or being reflected into the eyes.

The objective of the lighting arrangement is then to provide adequate illumination which avoids glare and which results in adequate luminance and correct luminance ratios for the central and peripheral fields of vision. It is recommended that a knowledgeable person assist with this aspect. However, the guidelines listed below should be followed:

- Mean illumination (artificial plus daylight) should be approximately 500 lux over the computer work station area.
- Situate light fittings (luminaires) or the computer work station such that lights do not shine directly into the operator's eyes. *An angle of larger than 30 to 45° in the vertical axis may be required. Also avoid situations where operators face into bright windows or where windows intrude into their peripheral vision.*
- *Fit* luminaires with prismatic or grid type glare shields in order to reduce direct and reflected glare. Curtains can be used at windows but select to complement room luminance contrasts.
- The VDU screen should be placed such that reflection of luminaires or windows from the screen is prevented. This obscures the figures on the screen and causes extreme eye strain.
- The luminance ratios in the central field of vision *(eg. document to screen to keyboard) should not exceed 1:3 and in the peripheral field (eg. screen to walls) not 1:10.* Colours, surface types etc. should be selected with this in mind. Care should be taken when mesh or other types of glare shields are used on screens as it may have a significant negative effect on the luminance ratios for document to screen.
- Fluorescent lights should be electrically connected out of phase with each other (duo or tri-phase) in order to reduce "invisible" flickering. Any light which flickers visibly should be replaced immediately.

Note:

- *If figures on the screen become distorted, flickers, blurrs or the image is unstable in any way, have the VDU serviced as soon as possible.*
- *One's eyes should occasionally be relaxed by looking away from the screen to a distant object*
- *Avoid highly reflective VDU screens which act as a mirror. The reflected images may cause interference with the visual task and result in eye strain.*

Noise

The noise that is of concern in this instance is usually not at a level that causes hearing impairment. However, it fits in with the definition of "unwanted sound" in the sense that it causes disturbances.

Sound is of a disturbing nature when:

- it is constantly loud enough to intrude on one's concentration or interfere with verbal communication (eg. telephone conversations).
- it is intermittent or cyclical.
- it is 5 to 10 decibels louder than the "ambient" background sounds and specifically if it has a notable pure tone component.

- It is of low frequencies and is structure born resulting in it being heard as well as being felt through vibration.
- It has information content, then it tends to demand attention, eg. human voices.

Some typical examples are given below. If such situations are identified it is recommended that a knowledgeable person be consulted about abatement procedures or one may end up with a situation where, for instance, expensive double glazed windows are installed but which are then opened for ventilation.

Examples:

- Air-conditioner noise or noise entering via ventilation louvres or ducting.
- Traffic in corridors (human) or streets (vehicles).
- Office equipment such as printers, typewriters, audio signals, intercoms or telephones.
- Sounds coming from adjacent offices or tea rooms.
- Noise from nearby workshops or machine rooms.
- Construction activities.

Ventilation

A lot can be written about correct design of ventilation/air-conditioning systems but at least the following aspects should be kept in mind:

- The system should provide an adequate quantity of clean, fresh air.
- It should remove stale air, odours and cigarette smoke effectively.
- The temperature should be controllable over a comfortable range.
- *Air distribution should be effective but draughts should be avoided especially where it may cause discomfort, disturb papers or irritate eyes.*
- *Humidity should be maintained such that discomfort and drying of mucous membranes are avoided.*

Psychology

So far we have only considered factors which cause physical stress and fatigue. In computerised work situations it is very easy to overlook the mental factors which affect work accuracy, efficiency and safety. It is desirable to create a work situation which provides mental challenge and avoids boredom, but which does not exceed the individual's capabilities and cause frustration or dissatisfaction.

Excessive mental stress may manifest itself in symptoms such as weariness, anxiety, sleeplessness, headaches, irregular heart beat and digestive troubles. These ailments will result in decreased work output and efficiency as well as an increase in absence from work.

Causes

The avoidance of psychological stress factors is largely concerned with good, fair management practices. The factors listed below *may not always be that obvious to identify but can certainly be recognised as typical management problems. All possible factors cannot be discussed in this article but it is important that managers be aware of mental stress factors* and attempt to eliminate them as far as practicable.

- The big brother syndrome: Is the computer used to supervise the employee by counting and reporting key depressions per day, CPU time utilised or errors made and corrected? If used incorrectly it is a certain way to turn the computer into the operator's aggressive opponent rather than friendly tool.
- *Is adequate time allowed for batch entry of data or is computer time restricted such that rush jobs with a high potential for error are frequently* required. If this technique is used to "improve" work output one could expect employee frustration and stress.
- Frequent computer or peripheral breakdown results in long periods of inactivity (boredom) and is then followed by high pressure rush jobs to meet targets. This can be reduced by having back-up facilities on site or available on loan from service agents.
- Slow computer response time, especially where extensive networking exists, *causes boredom and frustration. The operator cannot pace his work to suit his capabilities and available time.*
- Stress can be caused by disturbance of one's natural circadium rhythm. In this respect one should identify excessive demands on individuals for overtime work and shift work. Overtime and shiftwork (nightwork) should allow for normal social and family activities by restricting it to short cycles followed by long cycles of normal work hours.
- Repetitive work with little variety done over long periods of time will cause mental stress. It has been adequately demonstrated that more planned work breaks than standard tea times result in improved work output and accuracy. It is also recommended that where possible, work variety be introduced by training employees in more than one task and alternating such tasks between various employees.
- Social isolation of employees should be avoided by allowing work breaks and social contact. This would especially be necessary for individuals who work alone in offices and may be required to spend long continuous periods at their work station.
- Software user friendliness is a stress factor that can easily be overlooked. The adverse situations that one should be aware of are:
  - Complicated operating procedures and command instructions that need to be remembered or frequently looked up. Screen menus and help instructions are fortunately becoming more commonplace in software packages.
  - Displays that need excessive mental orientation ability, i.e. the layout one sees on screen is not what is eventually printed.
  - Excessive information content and cluttered displays may cause visual as well as mental stress.

Training

This last aspect is probably the most important factor in achieving an ergonomically optimised work situation. One can spend a lot of time and money on adjustable equipment and correct work area design but if the employee is not trained in and regularly reminded of the correct use of these facilities, an optimised work situation will not be achieved. *Managers need to constantly apply the ISMEC principles (Identify, set standard, measure, evaluate, correct) to these work situations.* Training is part of correcting, and should include details regarding correct work postures and procedures. §

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