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BASIC 2000

REVISION 0

Canon

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Application

This manual has been issued by Canon Inc. to provide information necessary to self-study to technicians who service facsimile products. This manual covers all localities where the facsimile products are sold. For this reason, there may be information in this manual that does not apply to your locality.

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PREFACE

This manual describes the general technology and principles of CANON facsimile operation so that those studying facsimiles for the first time and those already servicing facsimiles can gain a further understanding of these equipment.

Chapters 1 and 2 describe an overview of telephony and facsimile operation. Chapter 3 onwards describes the reading section, recording section, communications and electrics in more detail. Those studying facsimiles for the first time should begin their studies with Chapters 1 and 2. Those already servicing facsimiles or those who already understand facsimiles to a certain extent may refer to chapters that meet their particular requirements.
This manual is made up of the following chapters:

Chapter 1: BASIC OF TELEPHONE
Chapter 2: GENERAL DESCRIPTION OF A FACSIMILE
Chapter 3: READING SECTION
Chapter 4: RECORDING SECTION
Chapter 5: G3 FACSIMILE COMMUNICATIONS
Chapter 6: FACSIMILE SYSTEM
APPENDIX

The appendix is followed by a glossary with supplementary explanations of technology that could not be described in the main text. Refer to this glossary as necessary.

Words colored red in this document are explained in the “GLOSSARY” in the “APPENDIX” of this document.

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1. INTRODUCTION TO THE TELEPHONE

You can't transmit a document unless your facsimile and the receiving facsimile are connected over a telephone line. In this section, let's learn about the basics of telephones and telephone lines.

1.1 Parts of the Telephone

Very few people know the names of the parts of a telephone even though they use it every day. Let's learn the names of the parts on a telephone.

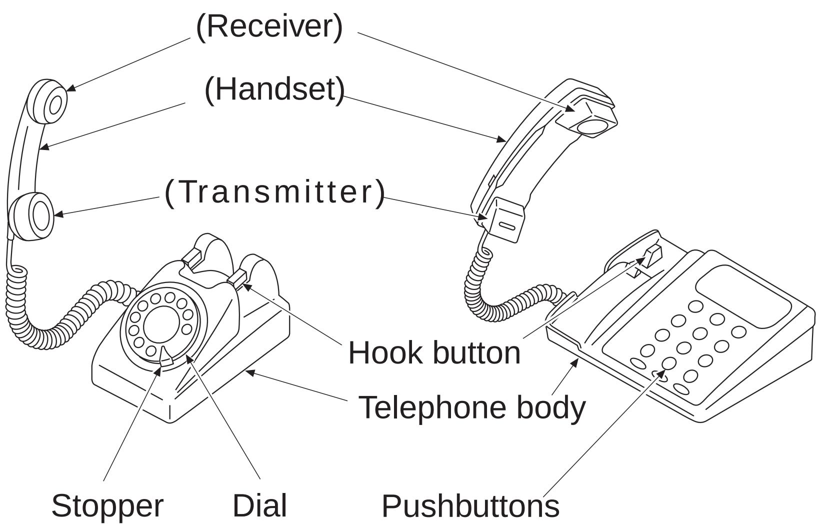


Fig. 1-1 Parts of the Telephone

What we generally refer to as the receiver was in fact the handset.
The "receiver" is the part that we hold against the ear on the handset.
Likewise, the part that we bring near our mouth on the handset is called the transmitter.
Some people mistakenly refer to the handset as the receiver.

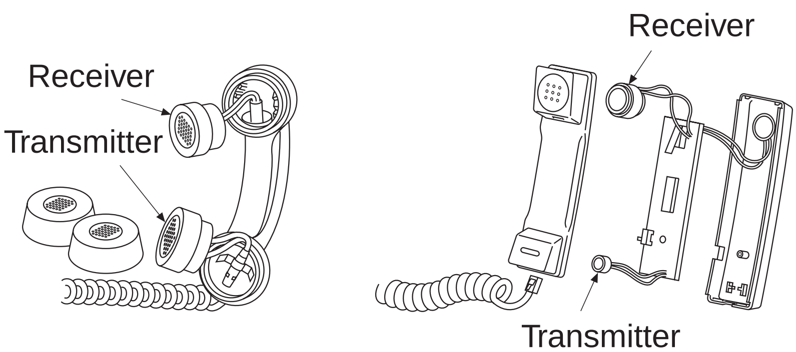


Fig. 1-2 Handset

1.2 Making a Call

There are names for the party being called and the party making the call. When we make a call, one of the two parties must first dial to call up the other party by the bell on its telephone. Making a call in this way, that is, dialing is called the “outgoing call”, and the call that arrives is called the “incoming call”.

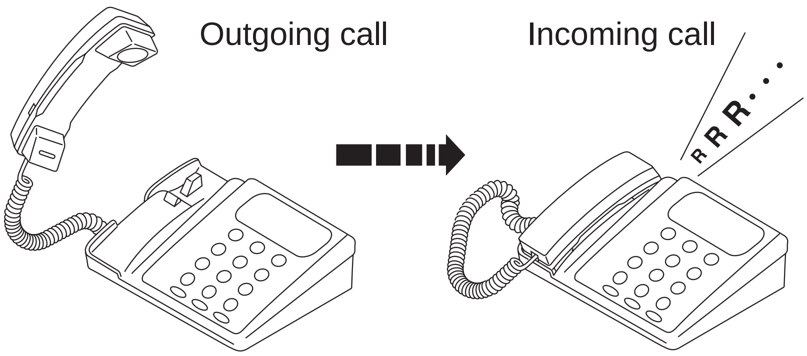


Fig. 1-3 Telephone Call State (1)

When you lift the handset, the handset is “off-hook”. When you hang up, the handset is “on-hook”.
These days, some telephones have an on-hook button. For example, even if the handset is placed on the telephone body, pressing this on-hook button sets the telephone to the same state (on-hook) as when the handset is picked up.

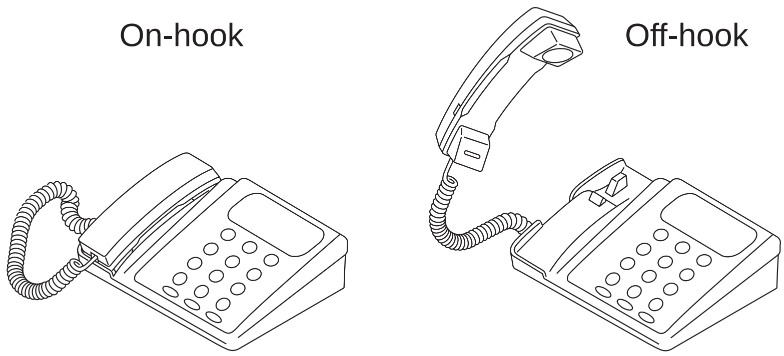


Fig. 1-4 Telephone Call State (2)

1.3 How do you make a call?

When you call someone, you must take various actions.
Let's consider each individual action needed for making a call.

(1) You pick up the handset. This means you are making a calling request. The telephone exchange gets ready to connect you to your party.

(2) The exchange emits the dial tone to indicate it is ready for the called number.

(3) You dial your party's number. This is the dialing signal.

(4) When the telephone exchange receives your dialing signal, it attempts to connect with your party. If your party is free, the exchange will make the connection, and you will hear a ringing tone.

(5) When the other party picks up the handset, the exchange stops sending the ringing tone, so that you can have a conversation.

(6) You have your conversation.

(7) You hang up.

NOTE

When the called number is in use, the calling party hears a busy tone. Even if the called party hangs up while the caller is listening, the calling party will still hear the busy tone. So the calling party needs to dial again.

1.4 Voice Frequencies Carried by the Telephone

The human ear can hear sounds with frequencies between 10 Hz and 15,000 to 20,000 Hz. The human voice is composed of many different frequencies. To be able to transmit the full range of hearing over the phone line would require very high-quality amplifiers and other equipment. Far more than is practical.
The telephone transmits enough voice frequencies to understand what is being said; usually between 300 to 3,400 Hz.

2. STRUCTURE OF A TELEPHONE

A telephone consists of a receiver (speaker), a transmitter (microphone), a voice circuit, a dial, a bell (speaker), and a hook button.

Of these parts, the parts that play the most important roles are the transmitter and the receiver. The transmitter converts human voice to electrical signals, and the receiver converts the electrical signals from the other party to voice.

Here, let's learn about the mechanism of these parts and the roles that they perform.

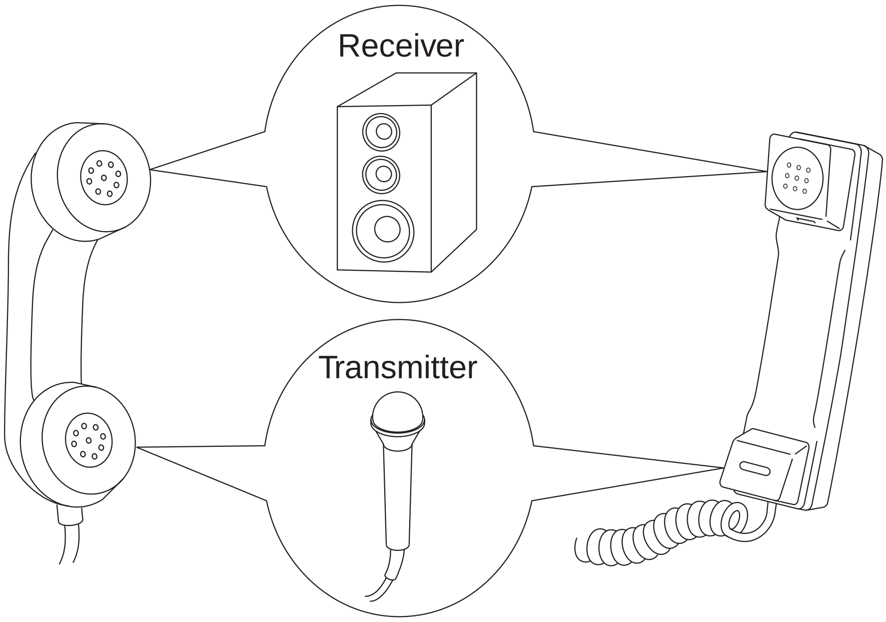


Fig. 1-5 Handset

2.1 Transmitter (Microphone)

The voice vibrates a diaphragm compressing/releasing carbon powder. When carbon powder is compressed, its contact resistance decreases. When the powder is released, its contact resistance increases. So direct current varies corresponding to the change of pressure (voice). This is called “voice current”. Recently, a microphone is applied to the transmitter of the telephone.

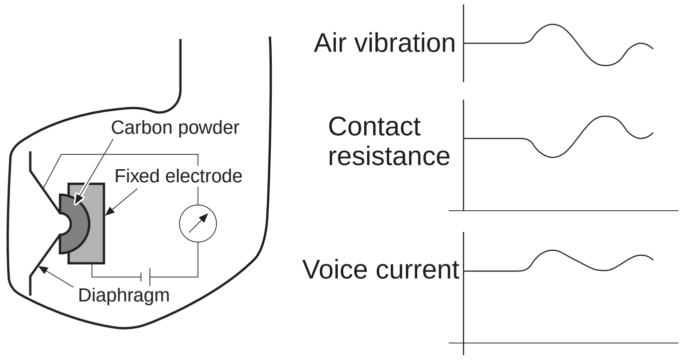


Fig. 1-6 Transmitter and Voice Current

1

2.2 Receiver (Speaker)

The receiver acts just like an electromagnet. The receiver creates voice waves by changing magnetic force, which move a vibrating diaphragm according to the current strength.

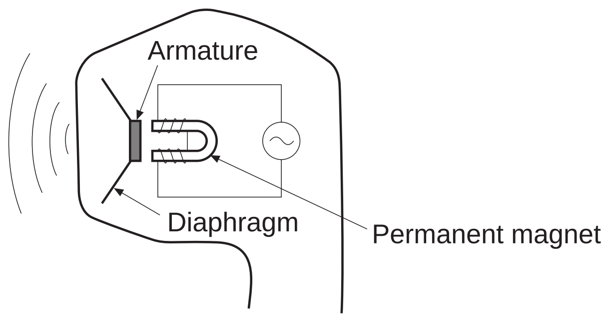


Fig. 1-7 Receiver

2.3 Voice Circuit

When the transmitter and receiver are connected as shown in the Fig. 1-8 to make a voice circuit, voice can be transmitted in both directions along the two wires.

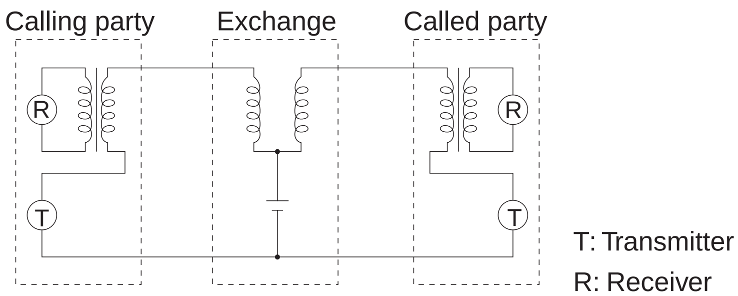


Fig. 1-8 Two-way Circuit (Two Wires)

2.4 Hook Button

When a hook button is closed by picking up a handset, direct current flows to the telephone circuits.

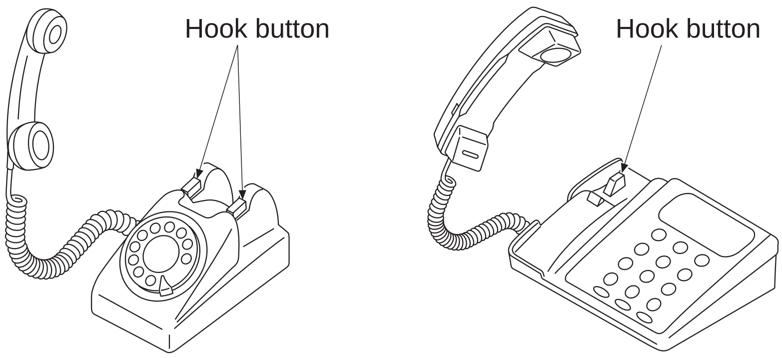


Fig. 1-9 Hook Button

The purpose of this is twofold (i) so that direct current is made to flow to the transmitter to provide current for sending voice when the handset is picked up, and (ii) so that the exchange detects this direct current to recognize that the handset has been picked up.

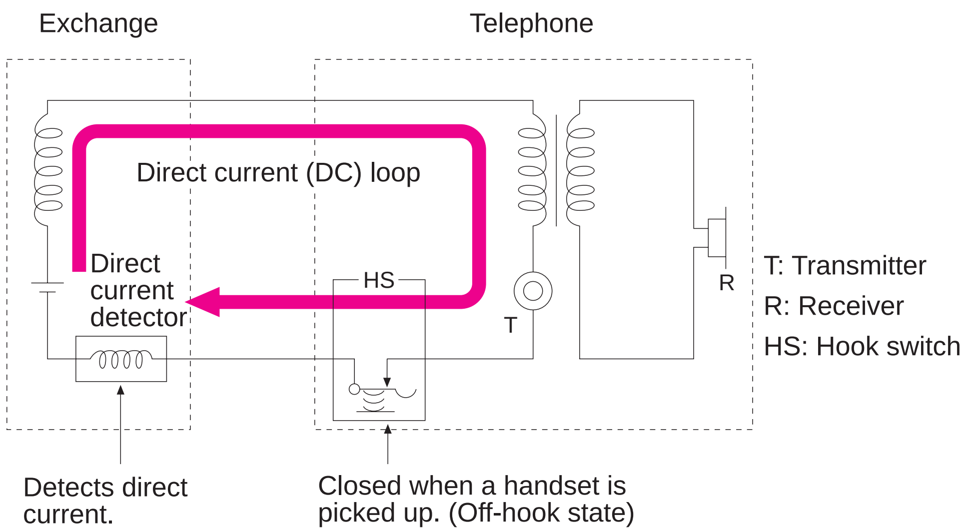


Fig. 1-10 DC Loop

Picking up a handset is called “making a DC loop”. A DC loop lets the exchange know that:

(1) The calling party (the party making the call) is ready to call someone.

(2) The called party answered. (The party receiving the call)

(3) The handset is on-hook.

2.5 Dial

Dialling enables an exchange to connect one party to a requested number according to a dialing signal. “DP” means the Dial pulse contact. The contact is usually closed. When you turn a dial and release it, the contact opens the same number of times as the number you dialed. (When the dialed number is 0, the contact opens 10 times.)
When a DC loop is made as shown in the Fig. 1-11 and the dial returns to its start position after the number “4” is dialed, the DC loop is cut four times. This is called the “dial pulse”.
Dialing using this dial pulse is called “pulse dial” due to the fact that numbers are dialed by this pulse.

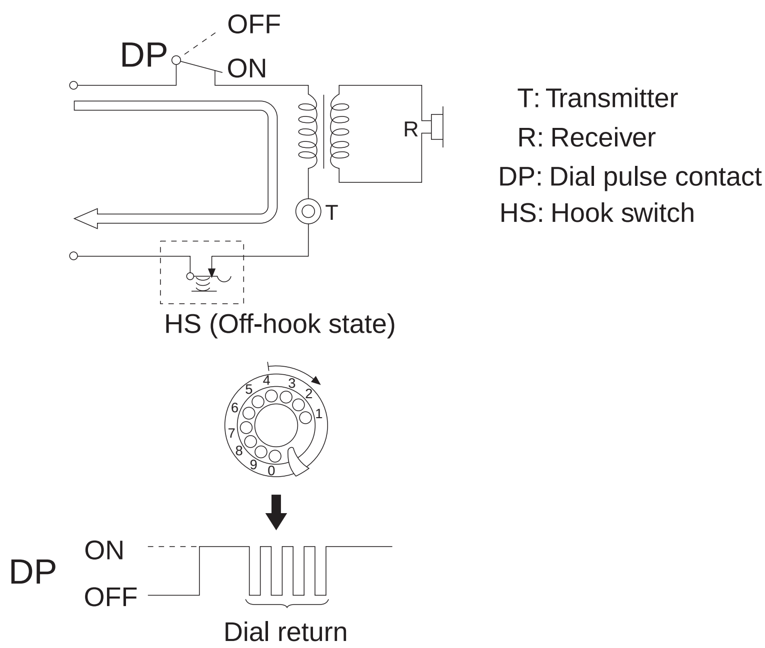


Fig. 1-11 Dial Pulse

The exchange selects and calls up the other party by counting the number of dial pulses.

Dials return to their start position at either of two speeds:

- 10PPS
- 20PPS

PPS (Pulse Per Second) indicates how many dial pulses are generated per second.

NOTE

Here, we have described an example (number of dial pulses = N) where the number of dial pulses is the same as the dialed number (N). However, in some countries, the number of dial pulses is sometimes different as follows:

The number of dial pulses is the dialed number (N) + 1

Dialed number	1	2	3	4	5	6	7	8	9	0
Number of dial pulses	2	3	4	5	6	7	8	9	10	1

The number of dial pulses is the dialed number (N) - 1

Dialed number	1	2	3	4	5	6	7	8	9	0
Number of dial pulses	10	1	2	3	4	5	6	7	8	9

2.6 Bell (Speaker)

The calling identification (CI) signal from the exchange for notifying that you have an incoming call is converted to the ring tone and is output. Recently, a speaker or buzzer is used instead of the bell.

3. TYPES OF TELEPHONES

1

There are three types of telephone: dial telephones and pushbutton telephones that are used on analog lines, and digital telephones that are used on digital lines.
In this section, let's learn about these types of telephones.

3.1 Dial Telephones

The type of telephone having a dial as explained earlier in section 2.5 is a dial telephone.

3.2 Pushbutton Telephones

Pushbutton telephones differ from telephones that are operated by turning a dial in that buttons are pushed to output dialing signals.
Pushbutton telephones have 12 buttons and have an oscillator inside to generate seven different frequencies. For example, if you push button 1, two frequency currents, 697 Hz and 1209 Hz, are sent simultaneously. This is called DTMF (Dual Tone Multi Frequency), and dialing using this DTMF is called "tone dial" due to the fact that numbers are dialed by this tone. Dialing is also referred to as PB (Push Button) due to the fact that buttons are pushed.
The exchange distinguishes numbers by this DTMF.
Of these 12 buttons, the * and # buttons are special buttons, and are used for selecting various handy communications services.

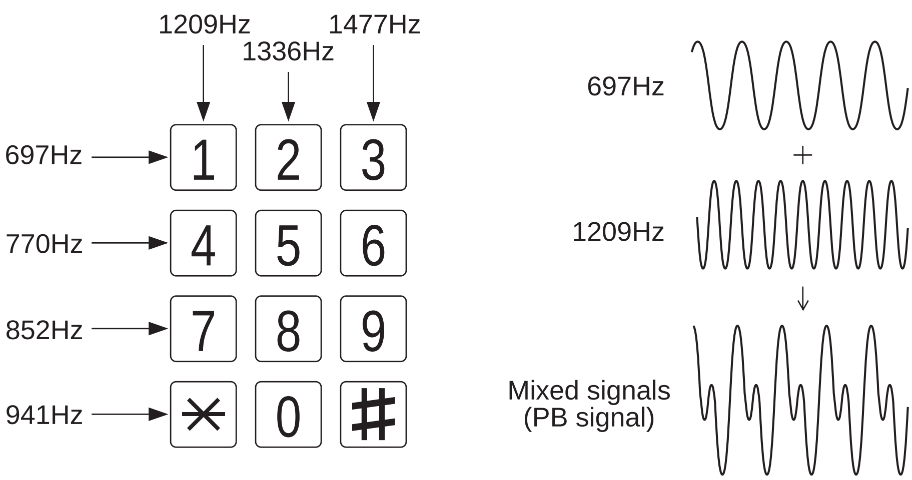


Fig. 1-12 Pushbutton Telephone

NOTE

Some pushbutton telephones have a dial selector switch for selecting between tone dialing (PB) and pulse dialing. With these pushbutton telephones, if the selector switch is set to pulse dialing, the telephone outputs dial pulses even though the telephone looks like a pushbutton telephone.

3.3 Digital Telephones

Though digital telephones also have 12 buttons just like a pushbutton telephone, the dialing signals are output not as a tone (frequency) but as a code comprising a combination of digital 0s and 1s. Also, the signals for ringing the bell on the other party's telephone are sent as a code comprising a combination of digital 0s and 1s.

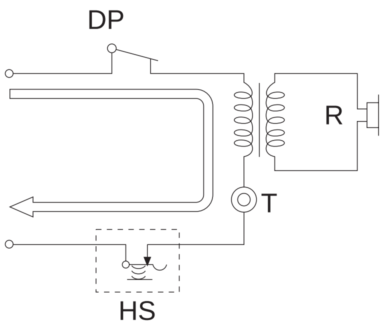
1

4. CIRCUIT DIAGRAM IN THE TELEPHONE

In this section, let’s learn about the basic circuits inside a telephone.

4.1 Dial Telephones

The Fig. 1-13 shows the basic circuit of a dial telephone.

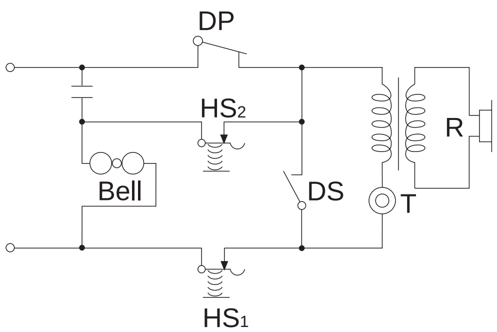


T: Transmitter
R: Receiver
DP: Dial pulse contact
HS: Hook switch

Fig. 1-13 Basic Circuit of Dial Telephone

However, in actual fact, hook switch HS2 is provided in addition to switch HS1 on dial telephones as shown in the Fig. 1-14. The bell circuit is closed and short-circuited by the switch HS2 when the handset is picked up. Ringing of the bell by dial pulses is thus prevented.

Dial telephones are also provided with a dial shunt contact DS to prevent noise caused by the entry of dial pulses on the receiver. The DS closes when you start dialing and opens when the dial has finished returning to its start position.



T: Transmitter
R: Receiver
DP: Dial pulse contact
DS: Dial shunt contact
HS_1: Hook switch 1
HS_2: Hook switch 2

Fig. 1-14 Circuit of Dial Telephone

4.2 Pushbutton Telephone

The Fig. 1-15 shows the basic circuit of a pushbutton telephone.

Basically, the only difference between the circuit of a pushbutton telephone and the circuit of a dial telephone is that the dialing signal generator differs.

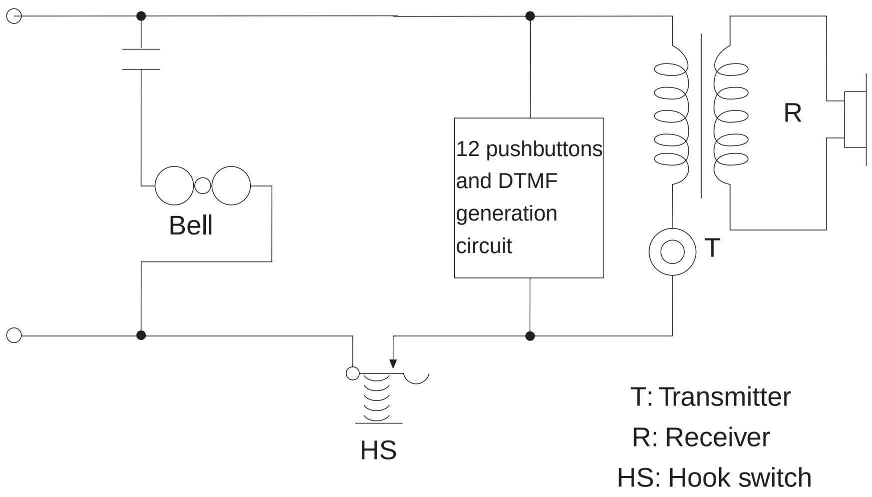


Fig. 1-15 Basic Circuit of Pushbutton Telephone

5. INTRODUCTION TO THE TELEPHONE NETWORK

We can talk to people over a long distance because we have an interlinked telephone network which contains many telephone centers.
In this section, let's learn about the mechanism of a telephone network.

5.1 Parts of a Telephone Network

To communicate over a telephone line, you need two telephones, a telephone line, and an exchange system. The telephone is sometimes called a terminal, because it is at each end of the telephone line.

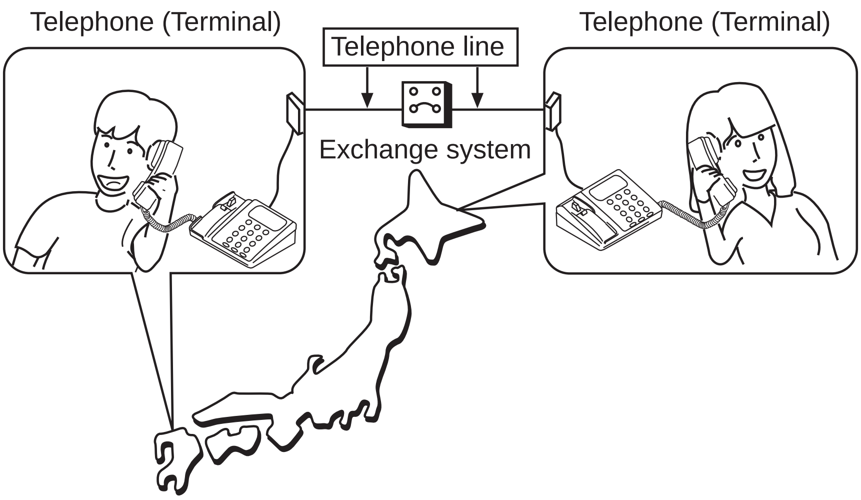


Fig. 1-16 Parts of a Telephone Network

To simply connect two telephones without using an exchange, every telephone must be connected individually to every other telephone. This type of network is called a mesh network.

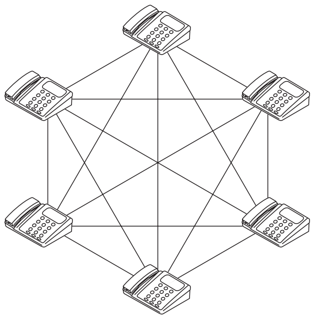


Fig. 1-17 Mesh Network

In a mesh network, you need more telephone lines than telephones.
The number of lines needed to connect telephone is given by n(n-1)/2. (For example, you need about 500,000 lines for 1,000 telephones.)
Clearly, it is impossible to connect many telephones in a mesh network.
So, you can see that a telephone exchange is quite necessary. An exchange connects a line to a telephone when it receives a calling request. In this system, the number of lines can be equal to the number of telephones serviced by the exchange. This network system is called a star network.

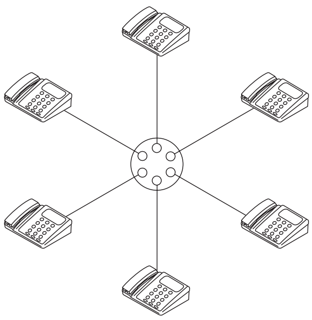


Fig. 1-18 Star Network

So far, we have the mesh network and the star network. These are the basic types of network systems. If we combine both networks into one system, we have a hybrid network.

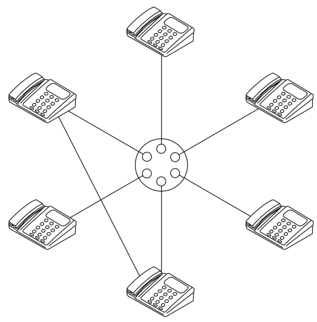


Fig. 1-19 Hybrid Network

In this way, a telephone network consists of telephones used as a terminal for converting voice to electrical signals and electrical signal back again to voice, a telephone line for transmitting electrical signals to places far away, and an exchange system for connecting two telephones.

Telephone lines come in various types: coaxial cable, optical fiber cable, microwaves communications satellites and submarine cable.

The places where the exchange system is located is called the telephone center (or the exchange center).

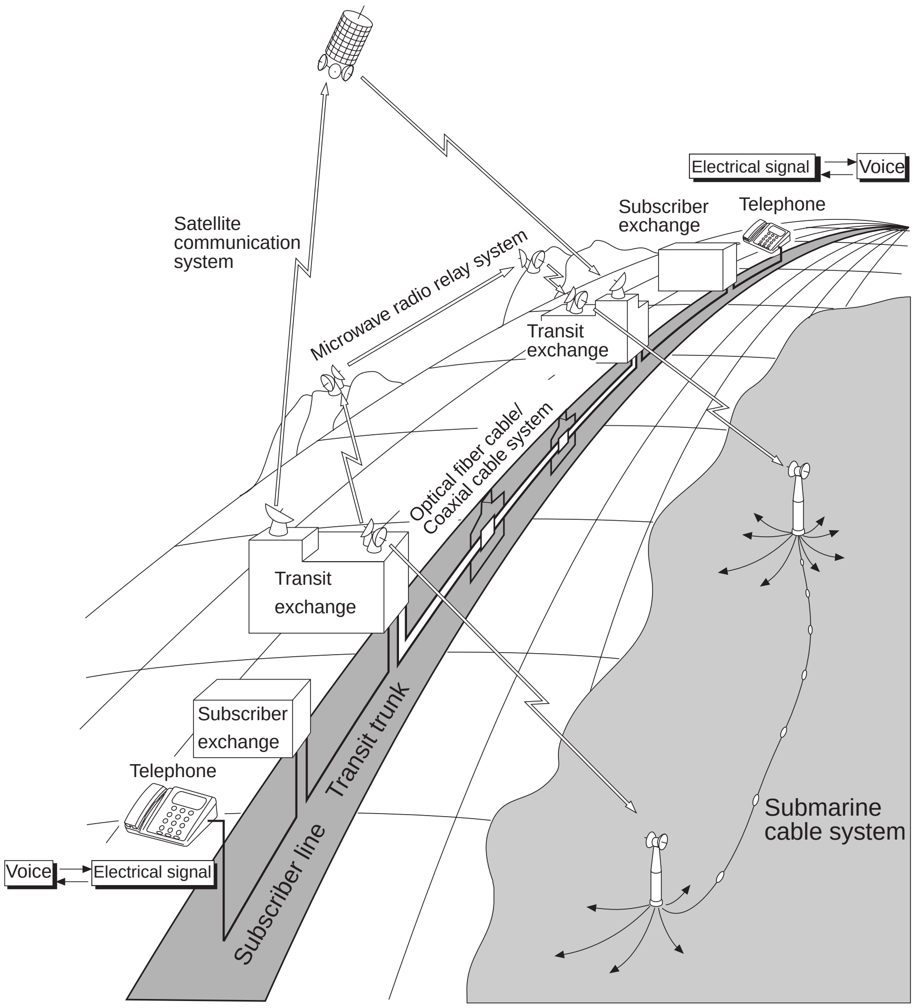


Fig. 1-20 Telephone Network Organization

5.2 Basic Structure of a Telephone Network System

As the number of telephones to be connected to the exchange increases and the conversation area expands, it becomes more economic to set up two or more exchanges and connect between exchanges by telephone lines rather than terminating all of the telephone lines in a single exchange.
The line connecting two exchanges is called a transit trunk.
The line connecting an exchange and a telephone is called a subscriber line.

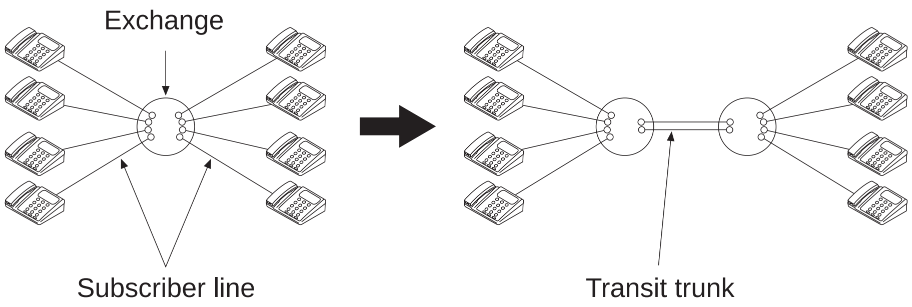


Fig. 1-21 Subscriber Line and Transit Trunk

As the number of telephone centers increases, it becomes more economic to set up an exchange for terminating only the transit trunks and connecting this exchange in the center in shape of a star rather than connecting telephone centers to others in the shape of an interlinked network by directly connected transit trunks.
This kind of exchange is called a transit exchange. An exchange that connects subscriber lines is called a subscriber exchange.

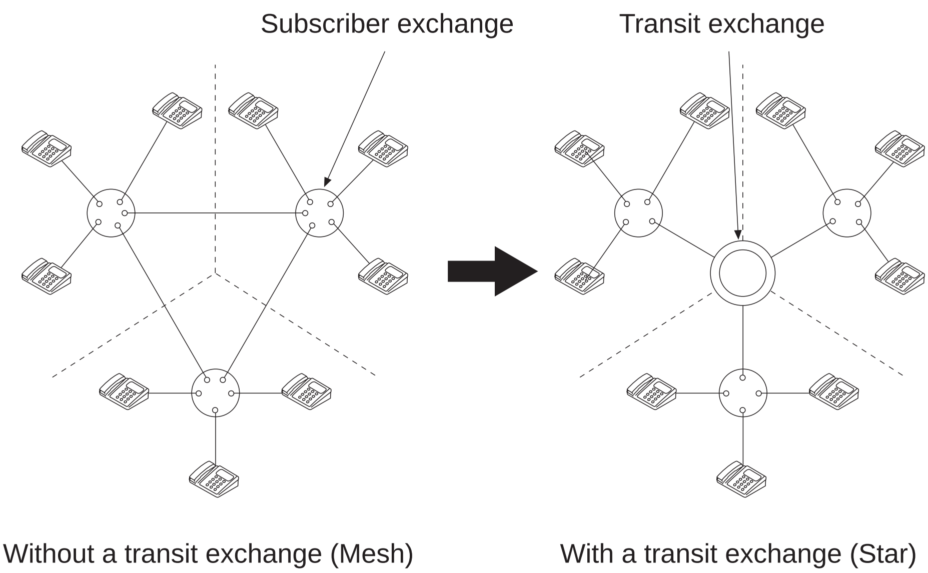


Fig. 1-22 Transit Exchange System

As the transit exchange relay-switches conversations between subscriber exchange, we can consider transit exchange to be ranked (classified) higher than the subscriber exchange. The rank for an exchange is called the grade, and the telephone center is called the center grade. That is, the high grade exchanges can route calls to a wider area.

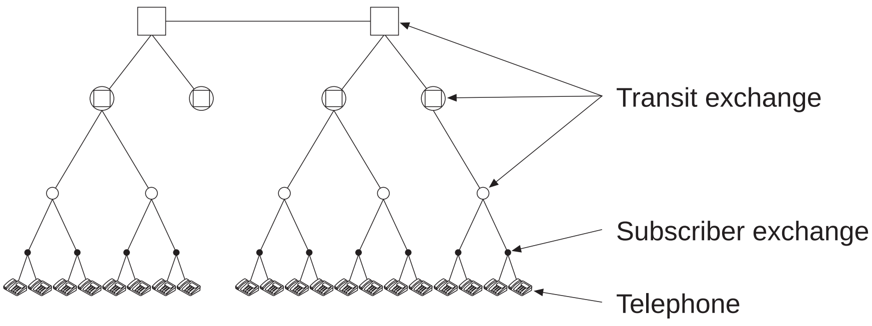


Fig. 1-23 Center Grade

5.3 Nationwide Telephone Network (In case of Japan)

The nationwide network in Japan can be divided into subscriber areas matched with administrative districts. A subscriber area has more than one subscriber exchange to connect all the telephones in the area.
A call within the area is called a local call, and can be made by dialing an exchange number and the subscriber number.

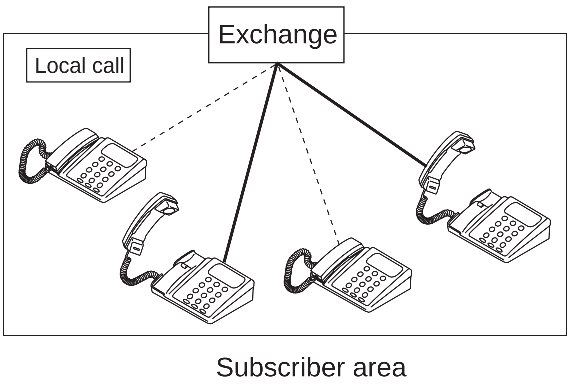


Fig. 1-24 Subscriber Area and Local Call

A call made between subscriber areas is called a long-distance call, and can be made by dialing an area code, an exchange number, and a subscriber number.

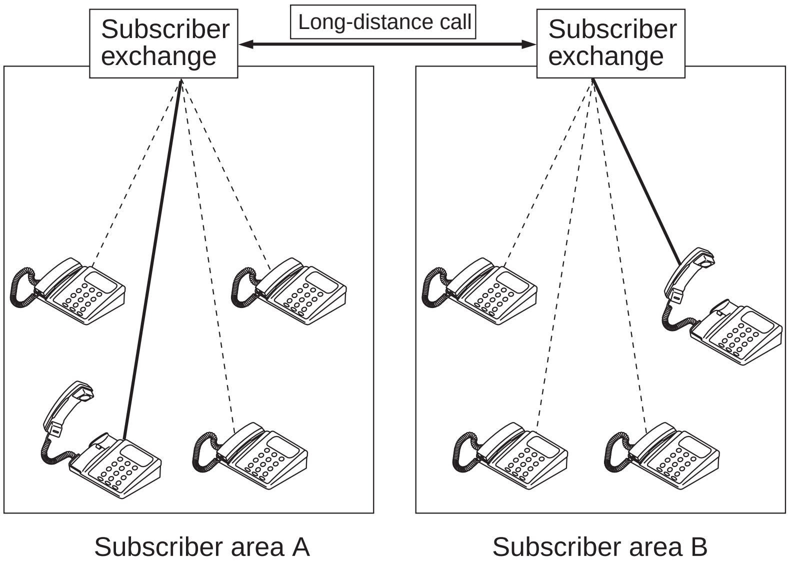


Fig. 1-25 Subscriber Area and Long-Distance Call

The network for local calls is the local network. And the line and the exchange for these calls are called the local line and the local exchange.
The network for long-distance calls is toll network. And the line and the exchange for the long-distance call are called the toll line and the toll exchange.
A toll exchange is classified into three ranks: toll centers, district centers, and regional centers.

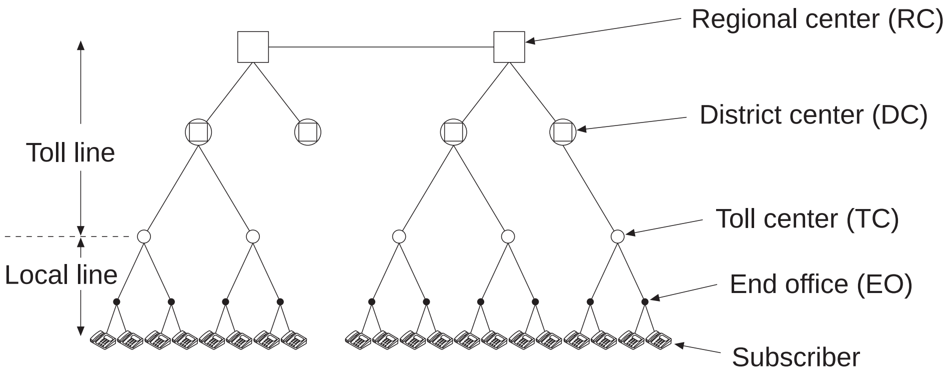


Fig. 1-26 Structure of Telephone Network

- Regional center (RC)

RCs have been established in Sapporo, Sendai, Tokyo, Nagoya, Kanazawa, Osaka, Hiroshima, and Fukuoka.

- District center (DC)
  DCs have been established in every seat of prefectural government of the same rank city.
- Toll center (TC)
  TCs have been established at central towns in a district center area.
- End office (EO)
  An end office (EO) is an office that connects telephones in a subscriber area.

5.3.1 Local telephone network

The subscriber area has one end office, which connects all the telephones in the area. In this case, the subscriber area is called a single office area.

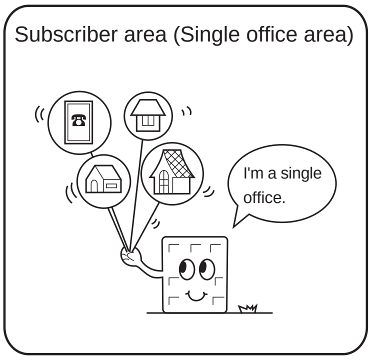


Fig. 1-27 Single Office Area

As the number of telephones increase, there will also be an increase in the number of end offices called branches. These branch offices are connected in a mesh network. In this case, the subscriber area is called a multiple office area.

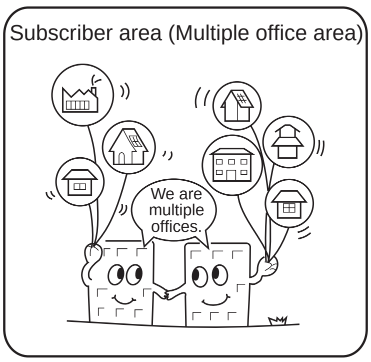


Fig. 1-28 Multiple Office Area

The big cities have a transit exchange (a local tandem exchange office) in a star network. Generally, a hybrid network is formed when many calls concentrate on certain lines.

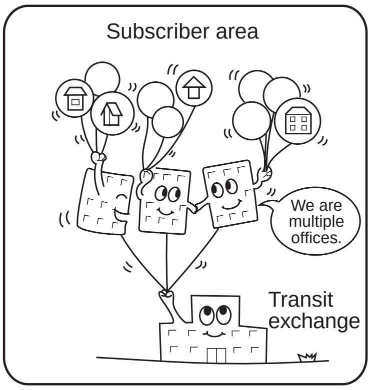


Fig. 1-29 Hybrid Network

5.3.2 Toll network

The toll network is formed by three classes of star networks connected with upper centers and lower centers. The topmost centers form a mesh network. The nationwide toll network hierarchy of toll networks is called the toll band system.

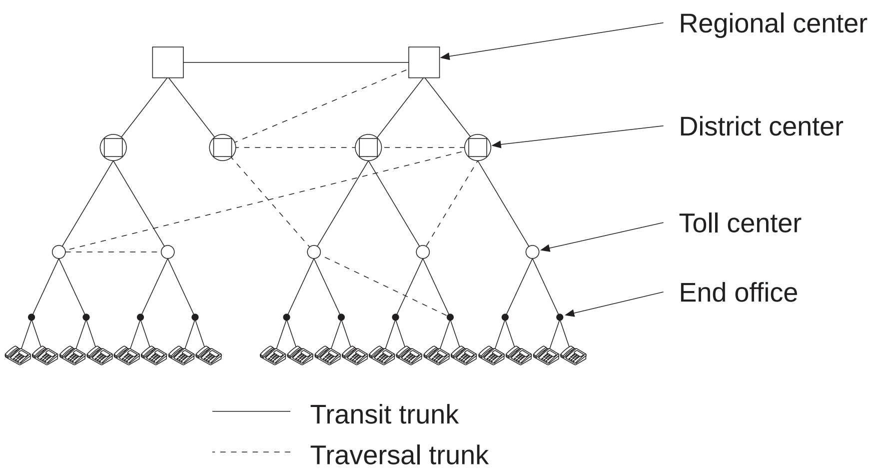


Fig. 1-30 Toll Network

There are two kinds of transit trunk. One is the normal transit trunk, which connects upper and lower centers in the nationwide hierarchy. The other is the traversal trunk, which ignores this hierarchy and connects two centers to handle a great deal of calls. For this reason, there are actually many connection routes, and the quality of a conversation is affected by which route is taken to connect a call.

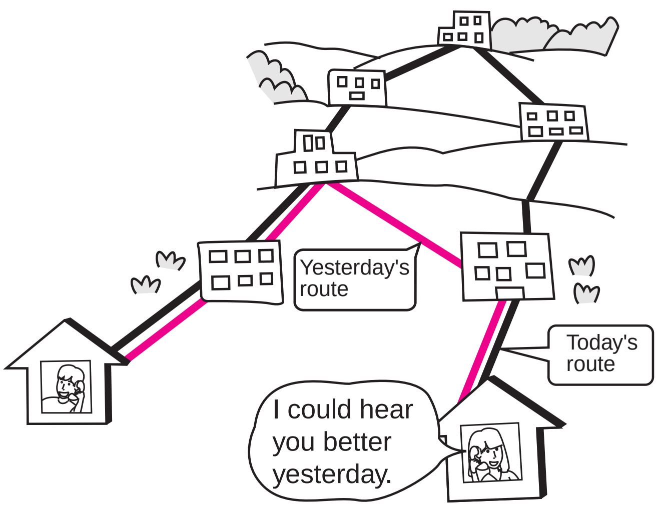


Fig. 1-31 Actual Connection Route

6. TELEPHONE EXCHANGES

The exchange system and the telephone network have made simultaneous progress. At first, people used the manual exchange, but now the automatic exchange has replaced the manual exchange in most offices. In this section, let's learn about the types of telephone exchange and how they work.

6.1 Types of Exchanges

The Fig. 1-32 shows the various types of exchange system.

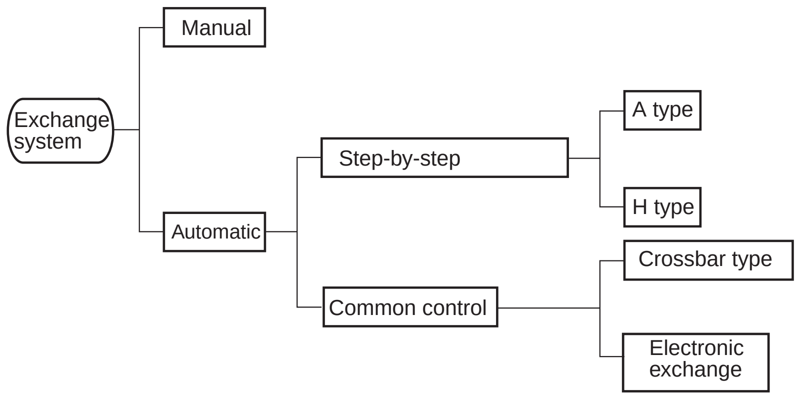


Fig. 1-32 Types of Exchanges

Hardly any manual exchanges are in active use today. So, the following describes digital exchanges.

(1) Step-by-step (S X S) (A type/H type)

- This mechanically proceeds with operation by dial pulses for each dialed digit.
- This has many switch contacts and provides a mechanical exchange. So normal transmission may be disturbed by a lot of noise. This is not suitable for facsimile use.
- As only dial speed 10PPS telephones can be connected, this is already an outmoded type of exchange.

(2) Crossbar type (C type)

- This makes connection only after all digits have been entered.
- This is reliable because it scarcely wears out.
- This has a small amount of switch contacts and provides high quality for calls.
- This is applicable both dial telephones and pushbutton telephones. And this type enables many other services to be used.

(3) Electronic exchange (D type)

- This has the same function as crossbar's. Moreover, the electronic exchange uses a computer as its control unit and provides high reliability.

6.2 The Exchange

An exchange is a device, so it cannot talk or listen like a human being. For this reason, the telephone sends signals that the exchange can understand, and the exchange sends signs to the telephone that a human being can understand.

The Fig. 1-33 shows how an exchange works.

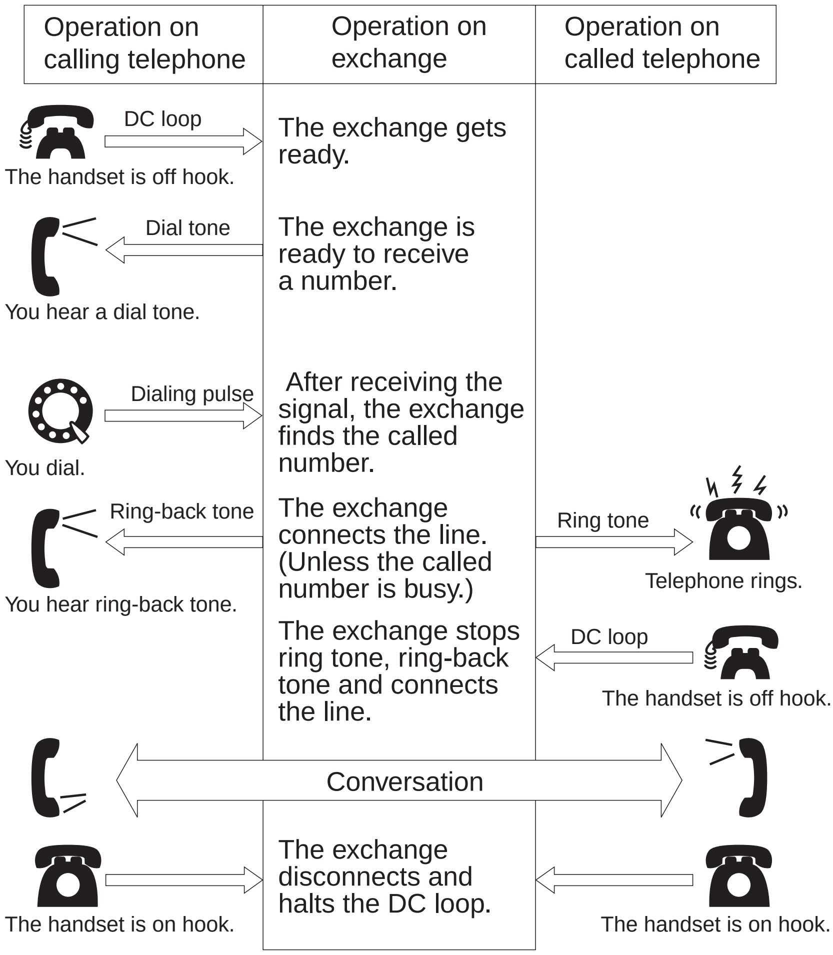


Fig. 1-33 How an Exchange Works

6.2.1 Details of signals and signs sent from the telephone to the exchange

(1) DC loop

This is for notifying the exchange that a person has picked up the handset. A DC loop has the following meaning:

- Calling request and response (when DC loop is made)
- End of conversation (when DC loop is cut)

(2) Dialing signal

This signal is used to find the called party's telephone. The signal is generated by dialing.

6.2.2 Details of signals and signs sent from the exchange to the telephone

(1) Dial Tone

This tone indicates that the exchange is ready and you may send the dialing signals.

(2) Ring Back Tone

This tone indicates to the caller that the other party is being called up.

(3) Busy Tone

This tone indicates to the caller that the other party is busy.

(4) Calling Identification (CI)

This signal notifies the called party that there was a call from a caller.
This signal rings the bell on the called party's telephone.

(5) Re-order Tone

This tone notifies the caller that the called party put down the handset during a conversation and that the conversation was cut.
Some exchange do not output the Re-order Tone.

NOTE

Of these signals that are sent to the telephone from the exchange, the signals (other than the CI) that the caller can hear through the handset are called audio tones.

Notes

CHAPTER **2**

2

GENERAL DESCRIPTION OF A FACSIMILE

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1. WHAT IS A “FACSIMILE?”

A facsimile is a machine that is connected to the telephone line instead of the telephone, and transmits and receives documents instead of holding conversations.
In this section, let’s start with a description of the rules governing facsimiles.

1.1 Established Rules of Communication

The communications equipment used for communications via public telegraph and telephone facilities must be designed to conform to the recommendations specified by the ITU-T. Communications must also conform to ITU-T recommendations.
Facsimiles are designed to conform to these recommendations as they use telephone lines to perform communications.
At this point, let’s consider why established rules of communication (ITU-T recommendations) are necessary. Communications must be possible between facsimiles made by different manufacturers. If facsimiles were designed to conform to individual manufacturers’ standards, we would not be able to transmit or receive documents between facsimiles made by different manufacturers. It is, naturally, very advantageous for today’s modern information society that facsimile communications be possible via telephone lines anywhere there is a telephone using any type of facsimile. This is why established rules of communication (ITU-T recommendations) are required for facsimile communications.

1.2 Control Procedure

The purpose of a facsimile is to transmit a image of a document to another facsimile. Actually, the two facsimiles transmit and receive control procedure signals before and after image signals are transmitted, to notify each other of the communication. Here, let’s bring to mind an instance of someone making a telephone call. Before you state your business, you say “Hello?” or tell other person your name. Facsimiles also perform this same type of transaction using fixed control procedures.
All of these control procedures are specified according to ITU-T recommendations.

1.3 Facsimile Groups

ITU-T recommendations classify facsimiles into groups called “G3” and “G4.” G3 facsimiles enable the transmission of ISO A4-size type documents in about one minute on a public telephone network. G4 facsimiles, as a general rule, enable the error-free reception of documents on a public digital line. Both G3 and G4 facsimiles handle image data as digital signals. Previously, there also existed the G1 and G2 facsimile groups that handled picture data as analog signals. However, these two groups have currently been deleted from the ITU-T recommendations.

These days, mention the word “facsimile” and you are generally referring to a G3 facsimile whose use has spread to households. G4 facsimiles are capable of transmitting pictures faster and at higher quality than a G3 facsimile. Though they are still expensive, their popularity is expected to gain in the future.

1.4 Telephone Lines

A facsimile is a machine that uses telephone lines to transmit images. So, we must understand telephone lines in order to understand facsimiles.

There are various kinds of telephone lines: analog lines, digital lines and Facsimile communication network services.

The telephone line that we use most of the time is an analog line called a PSTN (Public Switched Telephone Network) which has been designed for transmitting speech. The information that a PSTN is capable of transmitting are analog signals that are obtained by converting changes in current or voltage as they are to waveforms. When image data is transmitted on a G3 facsimile, it is converted to analog signals before it is transmitted.

Analog lines have spread throughout the world to the point that any simple mention of telephone lines generally refers to analog lines.

ISDN (Integrated Services Digital Network) is a digital line capable of sending all various media such as speech, documents, video and data as 0 and 1 digital signals. G4 facsimiles are capable of transmitting imae data as it is. When speech is transmitted, the analog signals are converted once to 0 and 1 digital signals before they are transmitted.

As digital lines are capable of transmitting digital signals as they are, transmission speeds are high and there are no transmission errors. For this reason, digital lines are ideal for personal computer-based communications and the Internet, and are expected to expand further in the future.

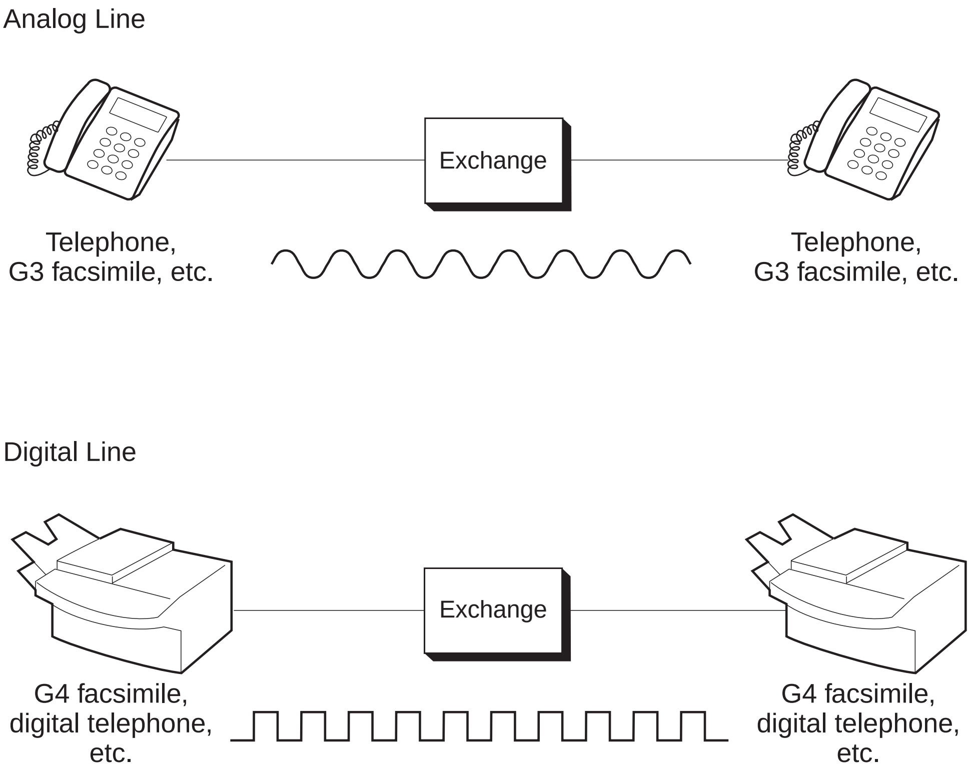

Fig. 2-1 Analog Line and Digital Line

In Japan, there are lines exclusively for facsimile communications called Facsimile communication network services. As a facsimile does not hold conversations simultaneously like a telephone, the facsimile adopts a method of storing the documents to be transmitted on the network, and then transmitting them at once using a high-speed line. By this method, the line is separated from the facsimile after the document is stored, to ensure efficient use of the line. For this reason, you are charged by the number of document sheets that you transmit regardless of the transmission time.

1.5 Types of ITU-T Recommendations

This section describes the main details of recommendations relating to G3 and G4 facsimile.

1.5.1 G3 facsimile-related recommendations

- T.0 (Classification of facsimile terminals for document transmission over the public networks)
  - Terminals for use over the public telephone network (Group 3 terminals)

- T.4 (Standardization of Group 3 facsimile terminals for document transmission)
  - Scanning track
  - Dimensions of terminals
  - Transmission time per total coded scan line
  - Coding scheme
- T.6 (Facsimile coding schemes and coding control functions for group 4 facsimile apparatus)
  - Facsimile coding schemes and coding control functions for black and white images (MMR coding)
- T.30 (Procedures for document facsimile transmission in the general switched telephone network)
  - Description of a facsimile calls
  - Tonal signal functions and formats
  - Binary coded signalling procedure
- T.85 (Application profile for Recommendation T. 82-Progressive bi-level image compression (JBIG coding scheme) for facsimile apparatus)
  - Application profile of single-progression sequential coding machine
- V.8 (Procedures for starting sessions of data transmission over the public switched telephone network)
  - Description of signals to be switched between DCE (Data Communications Equipment) when establishment of a data transmission session is required over the public switched telephone network
- V.17 (A 2-wire modem for facsimile applications with rates up to 14400 bit/s)
  - TC7200 bps, TC9600 bps, 12000 bps and 14400 bps modulation schemes in group 3 image transmission
- V.21 (300 bits per second duplex modem standardized for use in the general switched telephone network)
  - Conditions of transmission equipment relating to the transmission of group 3 procedure signals (300 bps)
- V.27ter (4800/2400 bits per second modem standardized for use in the general switched telephone network)
  - 2400 bps and 4800 bps modulation schemes in group 3 image transmission
- V.29 (9600 bits per second modem standardized for use on point-to-point 4-wire leased telephone-type circuits)
  - 7200 bps and 9600 bps modulation schemes in group 3 image transmission

- V.34 (A modem operating at data signalling rates of up to 33600 bit/s for use on the general switched telephone network and on leased point-to-point 2-wire telephone-type circuits)
  - Conditions of transmission equipment relating to the transmission of group 3 proceudre signals (600 bps, 1200 bps, 2400 bps)
  - 2400 bps, 4800 bps, 7200 bps, 9600 bps, 12000 bps, 14400 bps, 16800 bps, 19200 bps, 21600 bps, 24000 bps, 26400 bps, 28800 bps, 31200 bps and 33600 bps modulation schemes in group 3 transmission

1.5.2 G4 facsimile-related recommendations

- T.0 (Classification of facsimile terminals for document transmission over the public networks)
  - Terminals for use over the public data networks (Group 4 terminals)
- T.6 (Facsimile coding schemes and coding control functions for group 4 facsimile apparatus)
  - Facsimile coding schemes and coding control functions for black and white images (MMR coding)
- T.90 (Characteristics and protocols for terminals for telematic services in ISDN)
  - ISDN B-channel circuit-switched mode
  - ISDN B-channel packet-switched mode
- T.411 (Information technology-Open Document Architecture (ODA) and interchange format: Introduction and general principles
- T.412 (Information technology-Open Document Architecture (ODA) and interchange format: Document structures)
- T.414 (Information technology-Open Document Architecture (ODA) and interchange format: Document profile)
- T.415 (Information technology-Open Document Architecture (ODA) and interchange format: Open Document Interchange Format (ODIF))
- T.416 (Information technology-Open Document Architecture (ODA) and interchange format: Character content architectures)
- T.417 (Information technology-Open Document Architecture (ODA) and interchange format: Raster graphics content architectures)
- T.418 (Information technology-Open Document Architecture (ODA) and interchange format: Geometric graphics content architecture)
- T.431 (Document Transfer And Manipulation (DTAM) -Services and protocols-Introduction and general principles)
- T.432 (Document Transfer And Manipulation (DTAM) -Services and protocols-Service definition)

- T.433 (Document Transfer And Manipulation (DTAM) -Services and protocols-Protocol specification)
- T.503 (A document application profile for the interchange of Group 4 facsimile documents)
  - Clarification of formats to be applied to group 4 facsimile document interchange
- T.521 (Communication application profile BT0 for document bulk transfer based on the session service)
- T.563 (Terminal characteristics for Group 4 facsimile apparatus)
  - Stipulation of general characteristics of group 4 facsimile terminals

1.6 How Images are Transmitted

The sender facsimile transmits the image over the telephone line, and the receiver facsimile receives and prints out the transmitted image.
The figures below illustrate how images are sent.

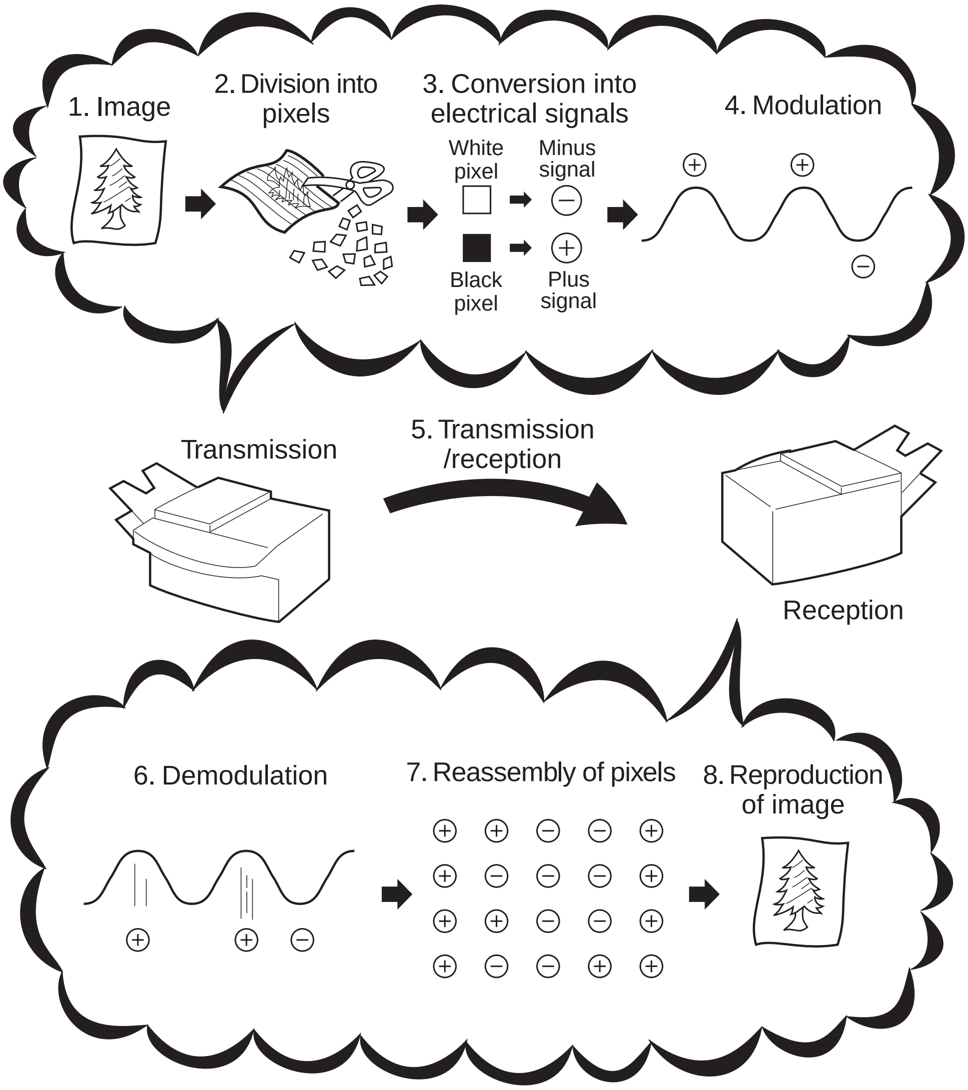

Fig. 2-2 How Images Are Transmitted

(1) Image

This is the original image before it is transmit.

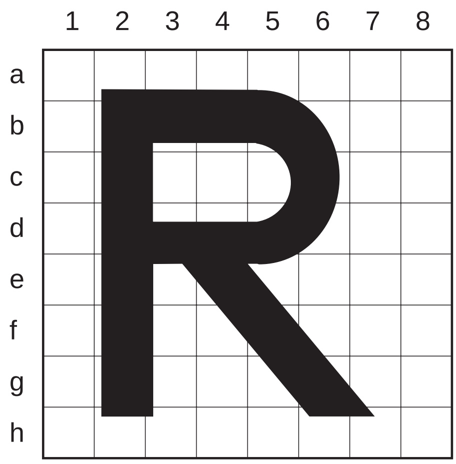

Fig. 2-3 Image

(2) Division into pixels

The image is divided into either white or black pixels.

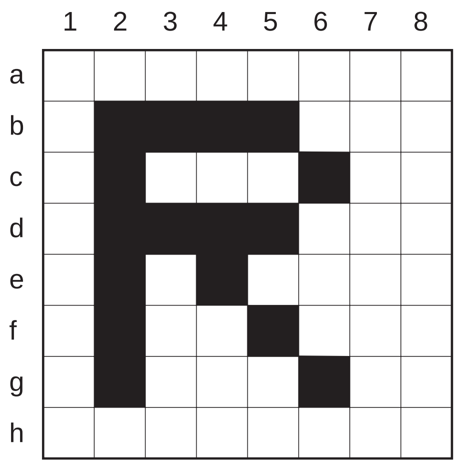

Fig. 2-4 Division of Image into pixels

(3) Conversion into electrical signals

Black pixels are converted into High level signals, and white pixels are converted into Low level signals.

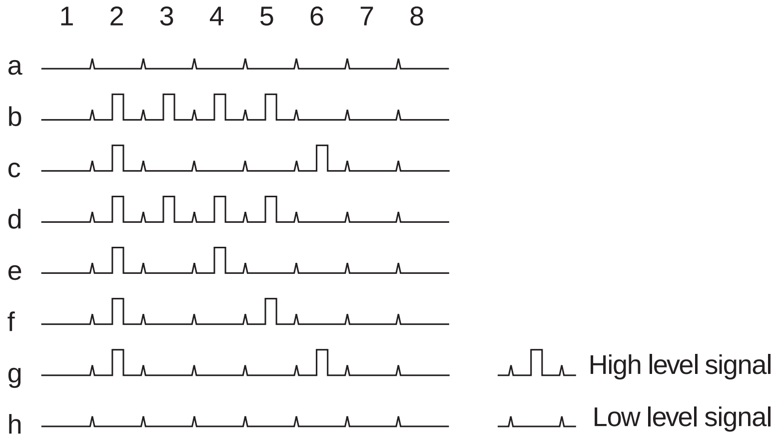

Fig. 2-5 Conversion into Electrical Signals

(4) Modulation

The picture signals are modulated. (This figure shows an example of frequency modulation.)

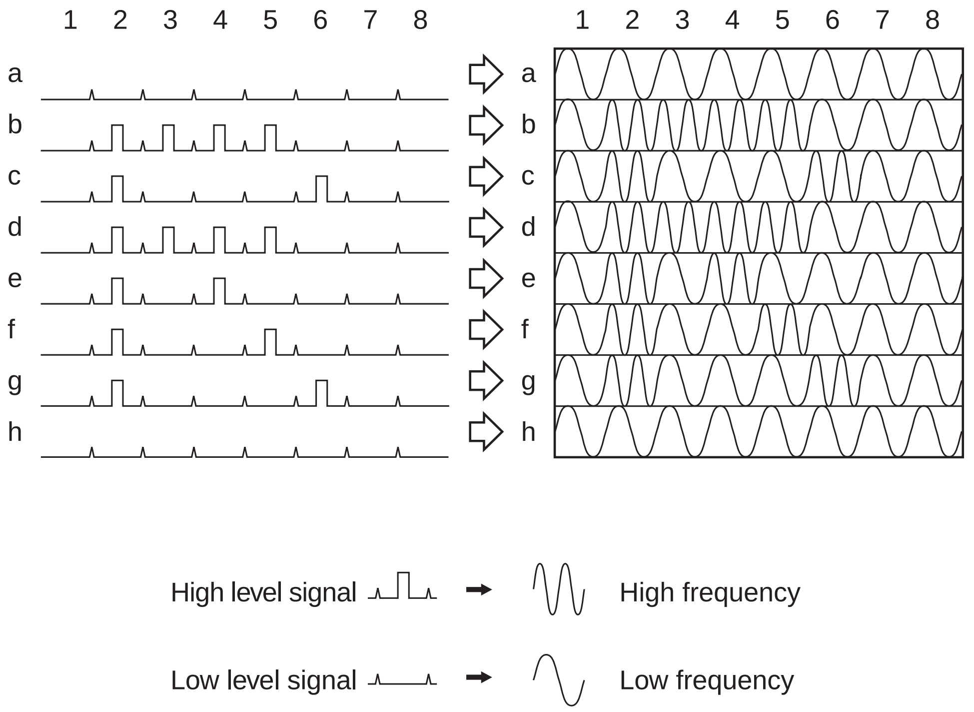

Fig. 2-6 Modulation

(5) Transmission/Reception

Image signals are transmitted in the order of lines a, b through h.

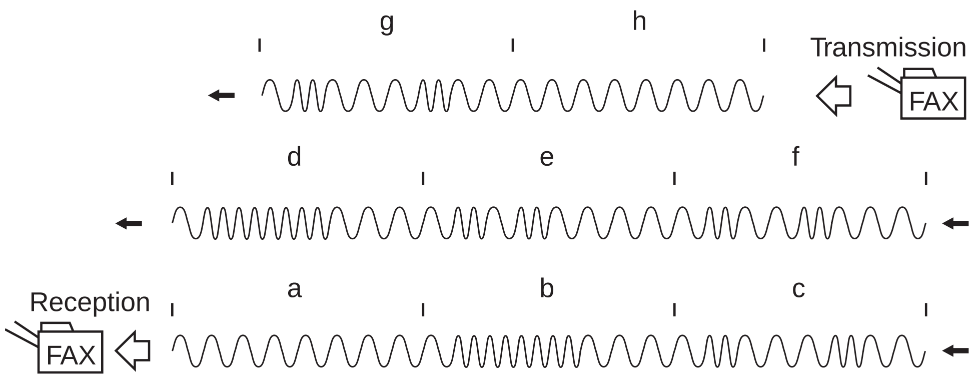

Fig. 2-7 Transmission/Reception

(6) Demodulation

Image signals a through h are sequentially demodulated into the electrical signals that represent black and white pixels.

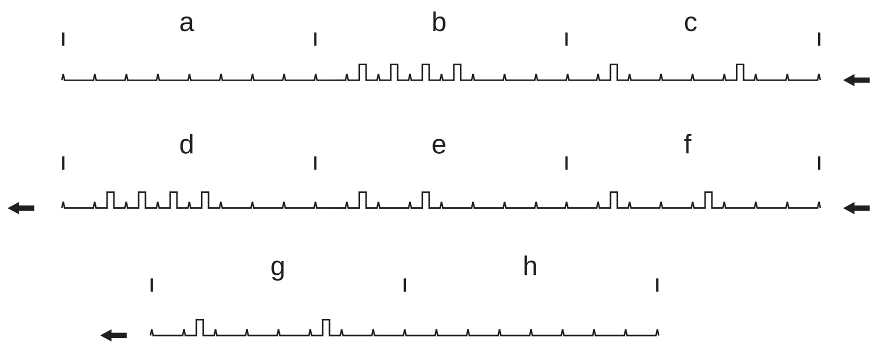

Fig. 2-8 Demodulation

(7) Reassembly of pixels

Demodulated electrical signals are sequentially reassembled.

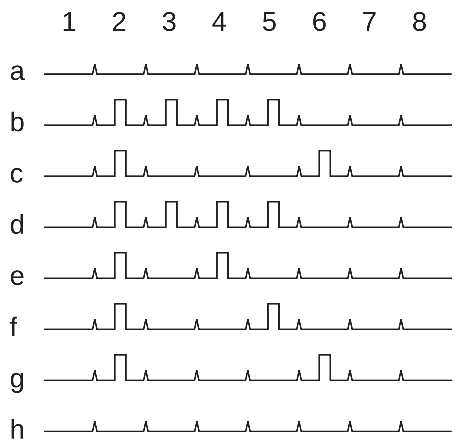

Fig. 2-9 Reassembly of pixels

(8) Reproduction of image

The black and white image information is printed on recording paper according to the electrical signals to reproduce a copy of the original picture.

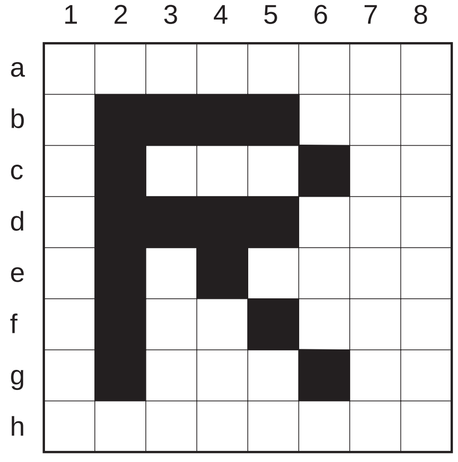

Fig. 2-10 Reproduction of Image

2. STRUCTURE OF A FACSIMILE

Now, let's take a look at the actual structure of a facsimile.
Simply speaking, we could say that a facsimile is structured by integrating a scanner (reading section) and printer (recording section) in a telephone, and providing it with a communications function (modem) for handling data exchange transactions with the other party via a telephone line(NCU board).

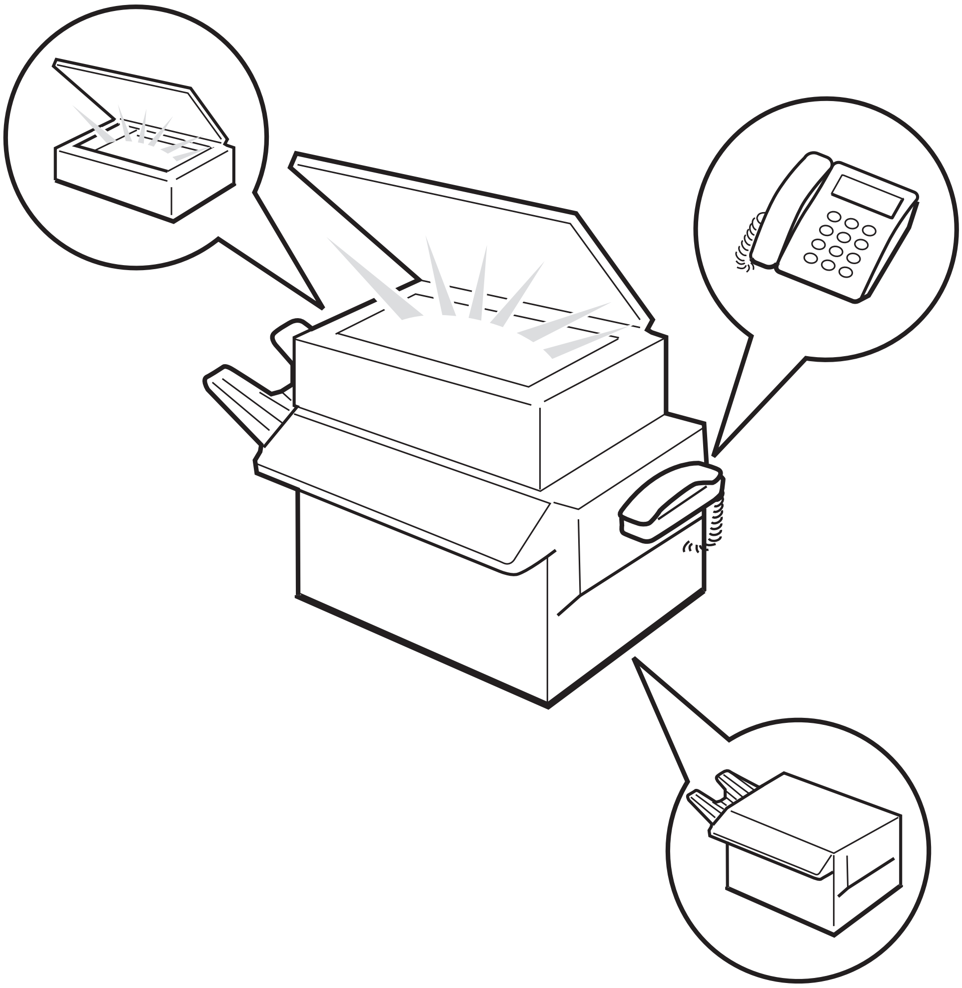

Fig. 2-11 Structure of a Facsimile

Fig. 2-12 is a block diagram of these facsimile's electric systems.

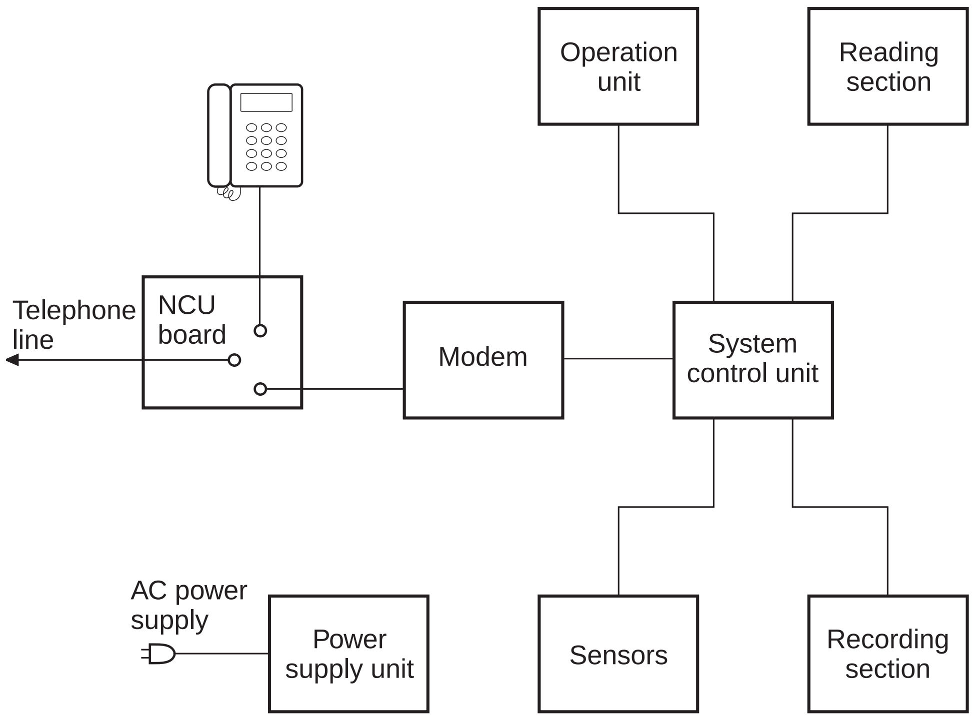

Fig. 2-12 Block Diagram of Facsimile Electric System

The facsimile has a system control section comprising mainly a CPU, and the reading section, recording section, modem and other mechanisms are connected to its periphery.

The system control section comprises mainly a CPU, and has a ROM (Read Only Memory) in which facsimile operations are programmed, and memory area for storing image data and other data such as telephone numbers. The main functions of the system control section include scanning control for accepting image data from the image sensor, drive control for driving the motors and other moving parts, recording control for operating the recording section, image data control for transmitting image data to the modem and receiving image data, and modem control for operating the modem in various other ways.

Let's take a look at the main mechanisms in a little more details.

2.1 Reading Section

The role of the reading section is to read the document(s) to be transmitted to the other party and convert images into electrical signals.
For those used to operating a personal computer, calling the reading section an "image scanner" will be easier to understand.
Reading methods can be broadly classified into the following two methods.

2.1.1 Cylinder scanning

This scanning method uses a single photosensor and a rotating cylinder that enables two-dimensional movement around the sensor.
The document is wound around the cylinder, and the photosensor is moved in the direction of the cylinder shaft while the cylinder is rotated.
The direction that the document rotates is the horizontal scanning and the direction that the photosensor moves is the vertical scanning.
This scanning method was used when facsimiles first appeared on the market, and is now no longer used.

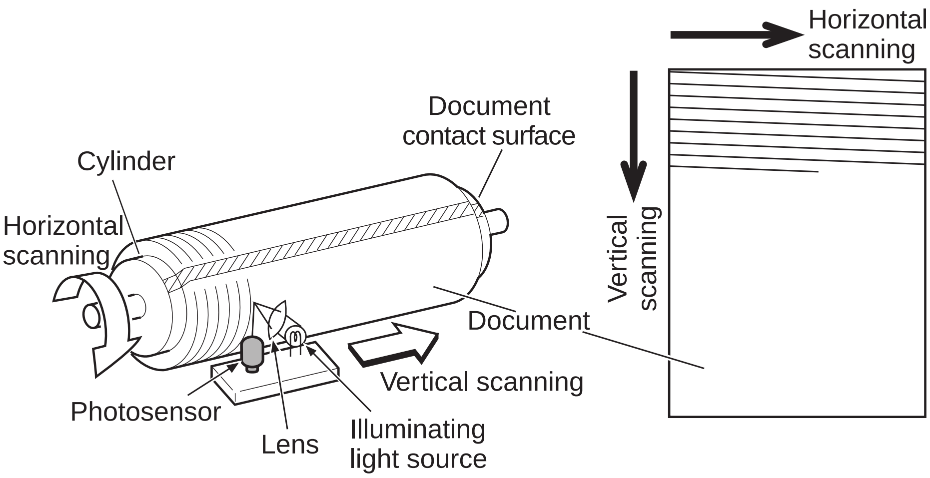

Fig. 2-13 Cylinder Scanning

2.1.2 Flat-bed scanning

By this scanning method, a photosensor comprising linearly arranged sensors is moved in the vertical scanning direction to read the document or the document itself is moved while being scanned by the photosensor.
By this method, the required number of photosensors for reading a single line in the vertical scanning direction is moved to read a single line of the document, and the reading position is moved one line at a time in the horizontal scanning direction to read the entire document. There are two methods of movement in the horizontal direction: movement of the document or movement of the photosensor itself.
CCD image sensors and contact sensors are two types of photosensor used in flat-bed scanning.

(1) CCD image sensor system

Though the CCD image sensor itself is small, the optical path up to the document must be lengthened, which makes CCD image sensors unsuitable for downsizing of reading sections. Nevertheless, this system has the advantage over a contact sensor as its reading speed is faster than that of a contact sensor, and enlargement and reduction processing is performed mechanically. For this reason and for the fact that it demonstrates little image deterioration, this system is widely used on large-size machines even now.

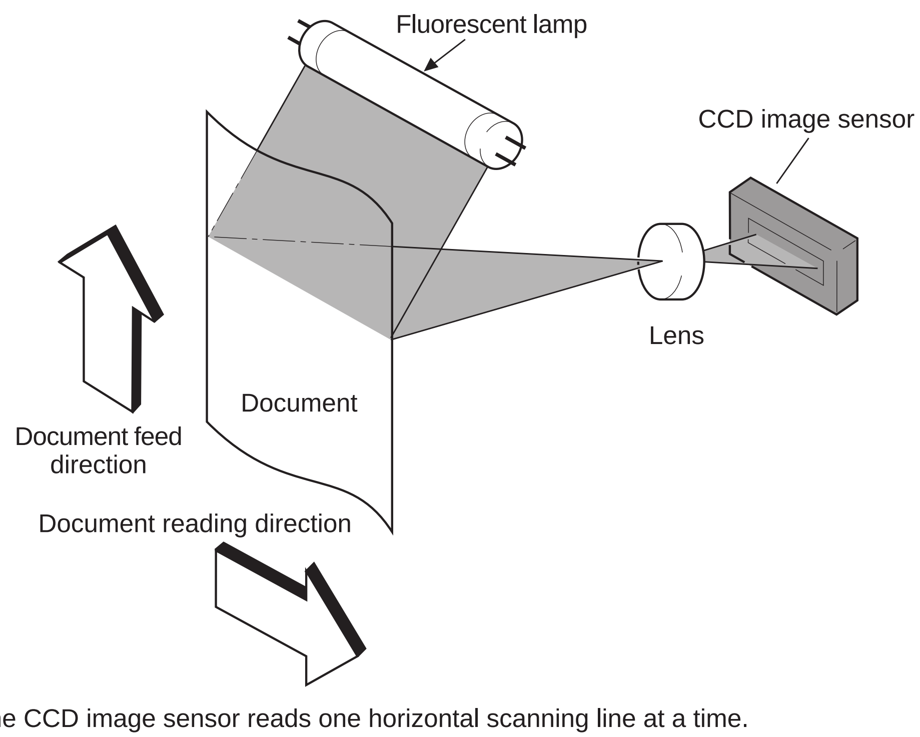

Fig. 2-14 Flat-bed Scanning (CCD image sensor system)

(2) Contact sensor system

Though contact sensors are inferior to CCD image sensors in terms of reading speed, contact sensor systems have the advantage that they can be downsized. This system is used on small-, medium- and large-size machines accompanying progresses in image-processing technology.

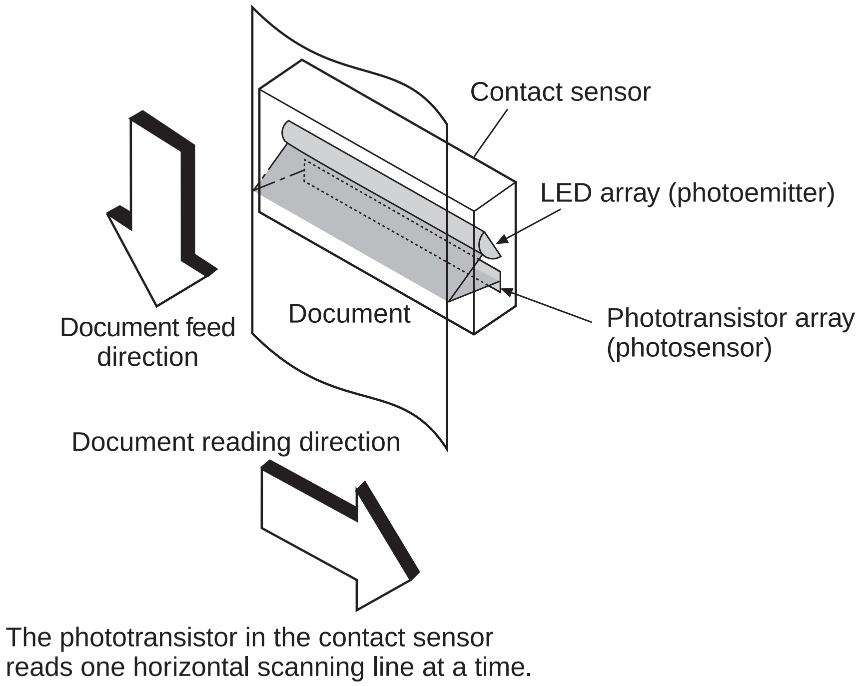

Fig. 2-15 Flat-bed Scanning (contact sensor system)

2.2 Recording Section

This is the so-called printer.

Here, picture data that is sent from the other party is printed on paper.

Generally, the following three methods are used for recording on a facsimile.

2.2.1 Thermal recording method

This recording method uses paper (heat-sensitive paper) that has been coated with a color-forming layer. Color is formed on this paper by the action of heat on its surface. Heat is generated by a thermal element (thermal head) that is held in contact against the surface of the color-forming layer.

This recording method has a drawback in that it is not suitable to long periods of storage as heat-sensitive paper fades with time. However, it has the advantages that facsimiles can be made compact due to its simple structure and is maintenance-free. For these reasons, it is the most widely used of the recording methods in entry facsimile models such as facsimiles for household use.

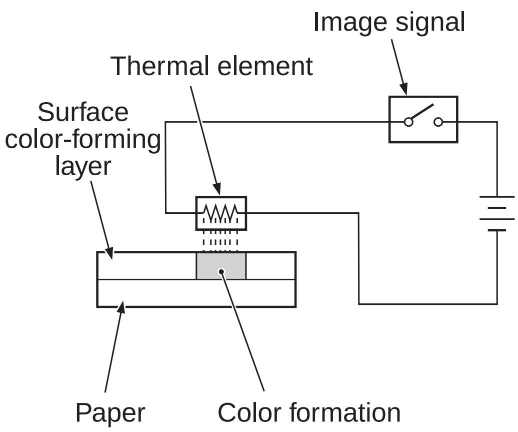

Fig. 2-16 Thermal Recording Method

2.2.2 Ink jet recording method

By this method, particles of ink are dispensed from nozzles to adhere to the recording paper.

As plain paper is used as the recording paper, this method has the advantage that recording paper that has been received can be written and stamped on. It is also ideal for storage as it is not curled up and does not discolor. In spite of the fact that it uses plain paper to record on, its structure is relatively simple, which allows facsimiles to be made compact. For this reason, it is being used more and more in household facsimiles.

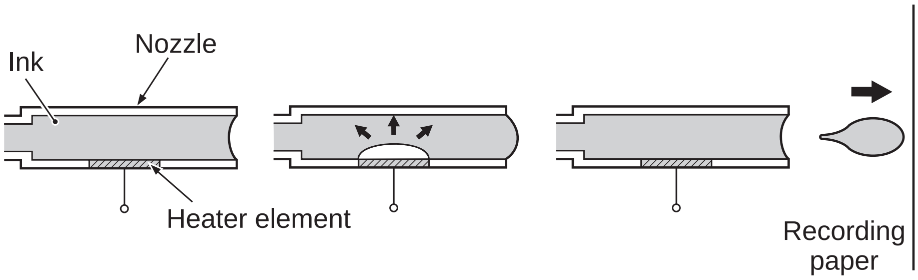

Fig. 2-17 Ink Jet Recording Method

2.2.3 Electrophotographic method

Canon is putting onto the market facsimiles that use a LASER beam printer (LBP) engine.

By this method, the pattern to be recorded is exposed on the surface of a photosensitive drum by a LASER beam, and toner is made to adhere on that pattern. Next, the toner on the photosensitive drum is transferred to the recording paper, and is then fixed on the paper by heat and pressure. This series of operations is called the “print process.”

This recording method has the same advantages as the ink jet recording method as it uses plain paper as the recording paper. It also has an extra feature in that it records at high speed. However, as its structure is relatively elaborate and expensive, it is widely used in medium- and high-class facsimiles.

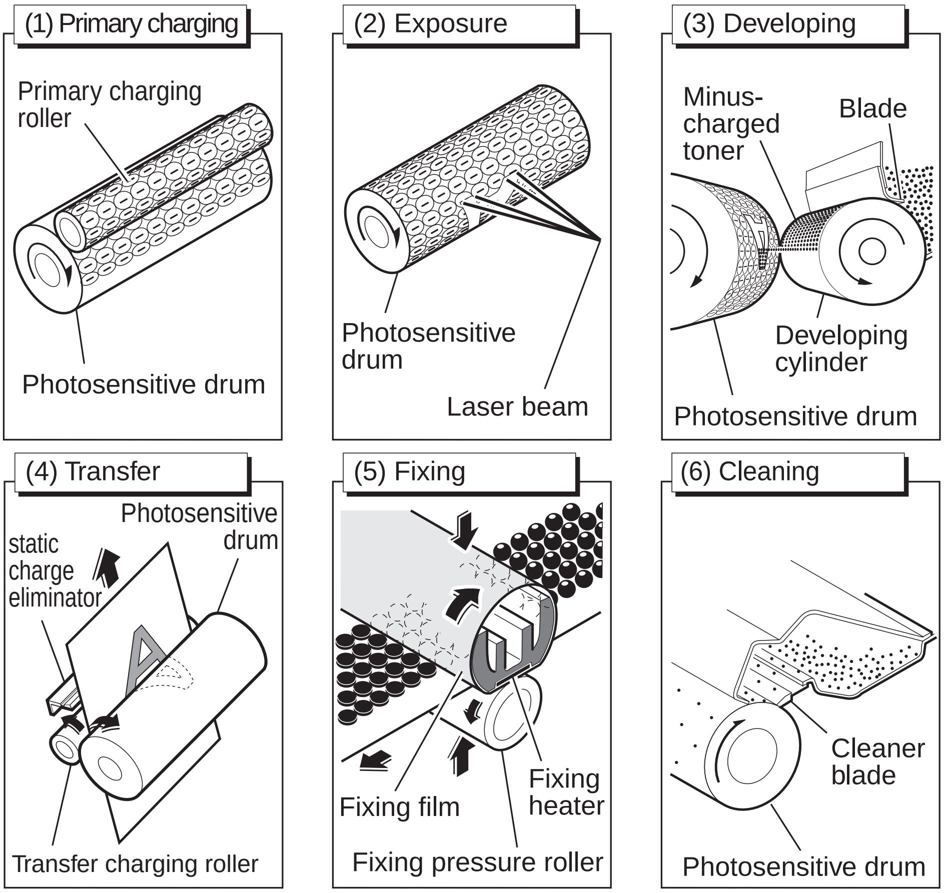

Fig. 2-18 Electrophotographic System

2.3 MODEM

Facsimiles must transmit image signals (digital signals) of scanned documents to other parties via telephone lines (analog lines). For this reason, the transmitting facsimile must convert these digital signals to analog signals and transmit them out onto the telephone line. This conversion is called “modulation.” Alternatively, the receiving facsimile must convert the analog signals (modulated signals) that arrive over the telephone line to digital signals. This conversion is called “demodulation” due to the fact that “modulated signals are restored to their original state.” A device that modulates signals is called a “modulator,” and a device that demodulates signals is called a “demodulator.” A device that can perform both modulation and demodulation is called a “MODEM” (MOdulator and DEModulator). As the frequency bandwidth of a telephone line is between 300 to 3,400 Hz, the modulation methods indicated below recommended by ITU-T are used as the G3 facsimile modem to transmit image signals efficiently and at high speed to the other party within that frequency bandwidth.

- PSK: Phase Shift Keying
- QAM: Quadrature Amplitude Modulation

FSK (Frequency Shift Keying) is used as a modulation method for procedure signals required for transmitting image signals.

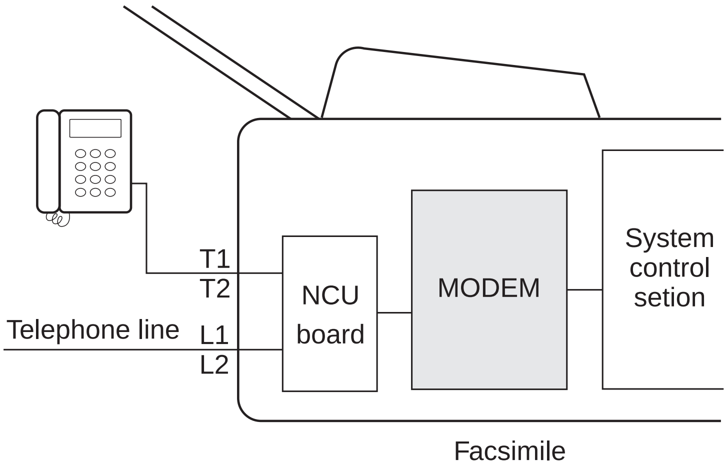

Fig. 2-19 Modem Location

2.4 NCU board (Network Control Unit board)

The NCU board is a kind of relay board for interfacing the telephone line to facsimile equipment. This unit detects the calling identification signal (for ringing the bell on the called party's telephone) that arrives from the telephone line to perform control of connection to the telephone or the modem.

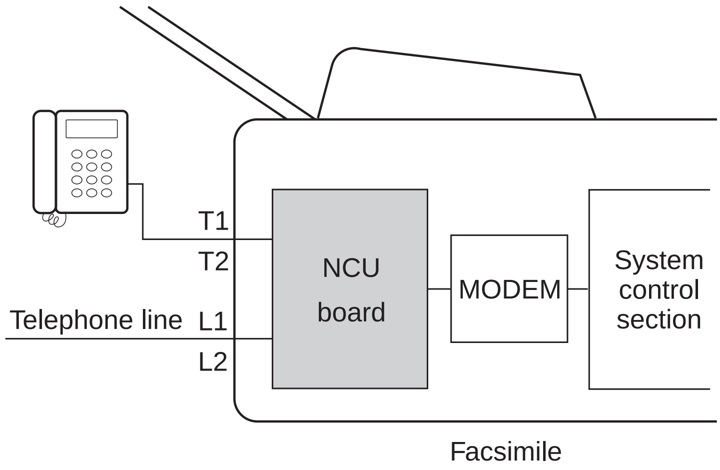

Fig. 2-20 NCU board Location

2.5 System Control Section

The role of this control section includes the control of all facsimile devices (mainly the CPU, program ROM and memory), data processing and saving of data.

Generally, the system control section corresponds to the electrical circuit boards called the SCNT board or IP board mounted on Canon facsimiles.

3. THE FUTURE OF FACSIMILES

The facsimiles we have discussed so far only transmit and receive black-and-white images over telephone lines. How will facsimiles look in the future?

This section describes color facsimiles, LAN-networked facsimiles and Internet facsimiles whose use is expected to expand in the future.

3.1 Color Facsimiles

Color facsimile products that use proprietary image data compression methods and proprietary communications protocol are already on the market. As only low-resolution image can be tarnsmitted, and only proprietary methods are used, communications is possible only between models of facsimiles made by the same manufacturer.

In the future, color facsimile communications using image data compression methods and communications protocol that conform to ITU-T recommendations will become standard due to the appearance of color facsimiles capable of tarnsmitting high-resolution color images to facsimiles made by other manufacturers.

3.2 LAN-networked Facsimiles

LANs (Local Area Networks) in offices are spreading at a rapid rate. As a result, various trends are beginning to emerge. These include the remote control of facsimile functions. For example, a possible application could be to call up a letter drafted on a networked personal computer, then call up a facsimile networked on the same LAN (let’s call this facsimile a “LAN-FAX”), and then transmit that letter directly to a specific party from your personal computer. This will allow people to transmit documents to other parties directly without having to go to the lengths of printing out the letter on paper. The same method could be applied to receiving documents. First of all, the document to receive (image data) that is transmitted to the LAN-FAX is temporarily stored on the LAN-FAX itself or on a LAN-networked server. The content of these received document pages can also be checked on the personal computer’s screen, and only the required pages of the document can be printed out on paper.

An application different from a general facsimile application is also possible. Facsimiles originally are machines that have both a printer and an image scanner. These functions could also be used effectively on the LAN;

you could use the facsimile from a personal computer as a network printer or as an image scanner. Such facsimiles have already started appearing on the market.

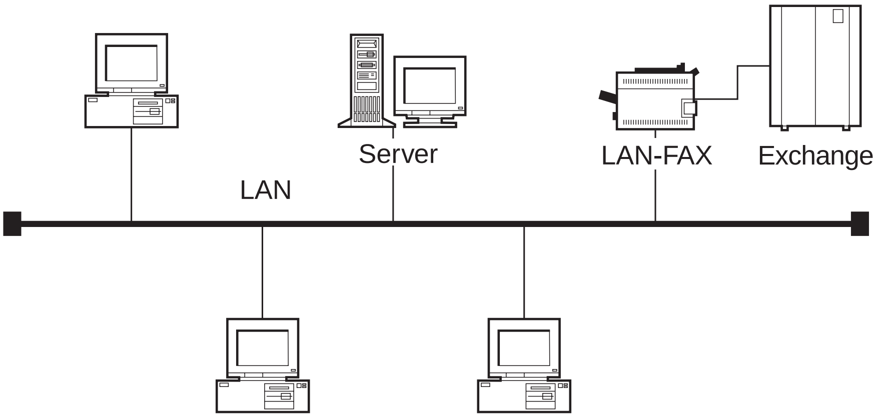

Fig. 2-21 LAN-networked Facsimiles

3.3 Internet Facsimiles

The mere mention of the Internet makes people think of e-mail and home pages. The Internet is in the process of becoming an indispensable item just like the telephone in society today. Facsimiles too are being required to be connected to the Internet in addition to telephone lines. If we consider that “What is important for a facsimile is to deliver image information (messages) to the other party,” then we will see that the Internet has similar kinds of services. The message exchange service on the Internet is e-mail. That is, if we successfully integrate e-mail and facsimiles, then the facsimile will come to be usable on the Internet.

The specifications of an Internet facsimile have been under review since 1996 by the IETF on the premise that e-mail services will be incorporated. Standards centering around RFC 2305 were determined in March of 1998, and these were turned into recommendation T.37 (simple mode) in July 1998 with the cooperation of the ITU-T. These specifications define services for specifying mail addresses from facsimile machines connected to the network for delivering information to other parties or alternatively delivering e-mail to facsimiles by. If Internet facsimiles are used, we can use facsimiles to transmit urgent business as e-mail. Also, mobile users will also be able to receive all facsimiles addressed to themselves as e-mail, so facsimiles will come to be transmitted and received anywhere.

Full-mode specifications and real-time type T.38 recommendations have also been added.

Either way, we believe that facsimiles will be transformed from being standalone facsimile machines, and will enter the market as facsimiles to be connected to LANs and the Internet, as facsimiles for connection to network systems. For this reason, conventional knowledge of telephone lines and facsimiles will not be sufficient for handling these products. Improving and acquiring knowledge of LAN technology, Internet technology and LAN-related networks will prove to be all the more important from now on.

Notes

CHAPTER **3**

READING SECTION

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1. INTRODUCTION

This chapter describes the reading section of the facsimile.
At the reading section, a document comprising two or more sheets is fed one sheet at a time to the image sensor (e.g. contact sensor) where it is read, and the resulting image data undergoes image processing.

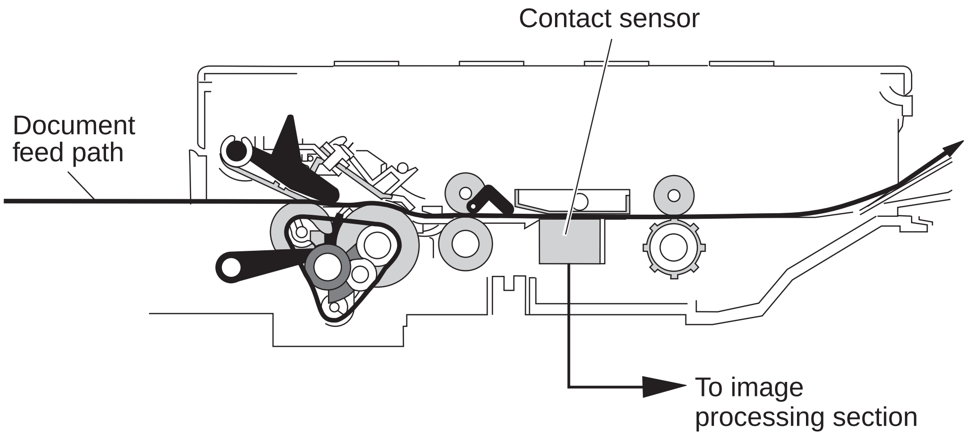

Fig. 3-1 Reading Section

2. READING METHODS

There are two types of reading methods, sheet reading method and book reading method. There are a further two types of reading methods for the sheet reading method, flat-bed type and drop-in type.

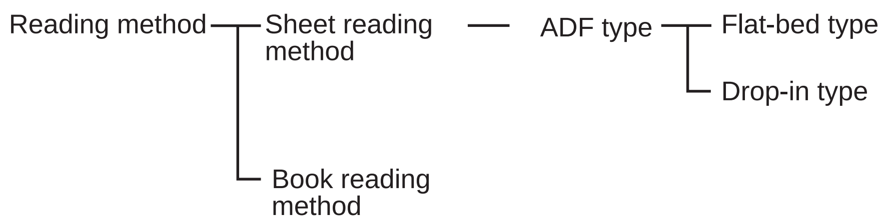

Fig. 3-2 Types of Reading Methods

2.1 Sheet Reading Method

The general operation of sheet reading is as follows.

The document is fed up to the separation roller and separation guide by the forwarding roller.

Next, the separation roller and separation guide separate the document one sheet at a time from the bottommost sheet. After the document sheets are separated, they are fed to the contact sensor by the feed roller. After the document is read by the contact sensor, it is output by the eject roller.

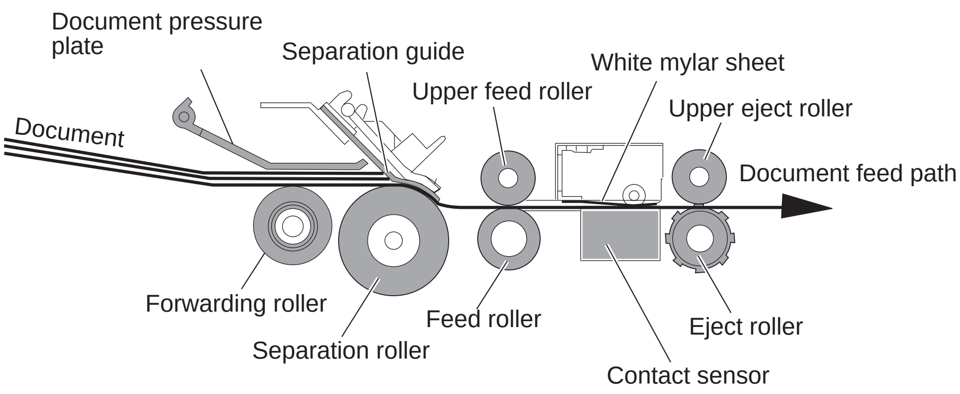

Fig. 3-3 Sheet Reading

2.2 Book Reading Method

Book reading is a method where the document (thick document) is placed on the copyboard glass and is read by the contact sensor. This sensor is moved backwards and forwards in the vertical scanning direction along the guide shaft by motor drive transmitted to the belt via gears.

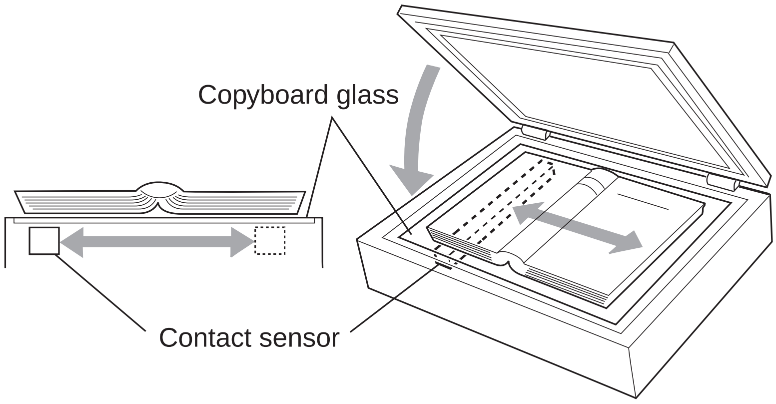

Fig. 3-4 Book Reading Method

2.3 ADF Type

One of the sheet reading methods is the ADF (Auto Document Feeder) separation method. There are two main ADF types, flat-bed type and drop-in type.

2.3.1 Flat-bed type

A feature of this ADF type is consistent performance during loading of documents, which makes it suitable for loading a document comprising many sheets.

On the other hand, however, it costs more as a forwarding roller is required in the mechanism and more installation space is required. Double feeding sometimes occurs due to over-insertion of document sheets when the document is loaded, or, alternatively, sheets being non-fed due to an insufficient amount of sheets being loaded.

- Explanation of flat-bed type operation

By this type of ADF mechanism, drive from the document feed motor is transmitted to the rollers required for document forwarding, separation, feed, and eject via gears and belts.

To control ADF operation, the CPU counts the number of step pulses of the document feed motor, and two photointerrupter type sensors, document sensor (DS) and document edge sensor (DES), installed on the actuator arm detect the feed state of the document.

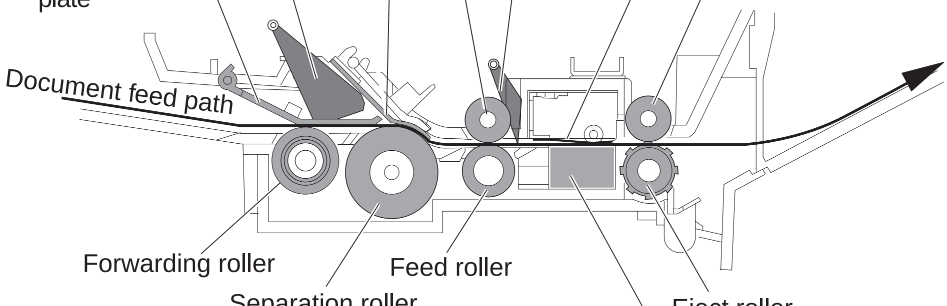

Fig. 3-5 Flat-bed type ADF

Now, let's take a look at which operations are performed.

(1) Document forwarding operation

When the document is inserted in the ADF section and pushes up the actuator on the document sensor, the forwarding roller picks up the document as far as the separation roller and separation guide.

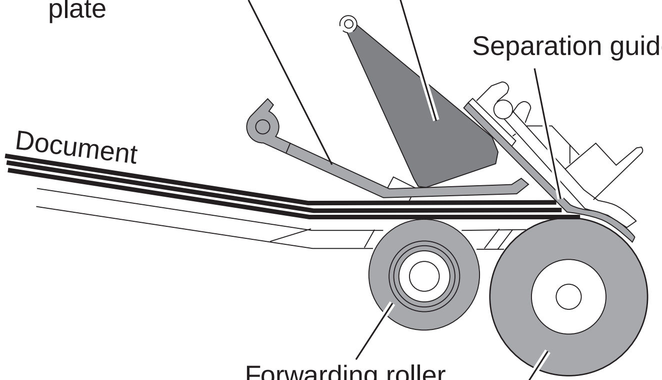

Fig. 3-6 Document Pickup

(2) Document separation operation

After document forwarding, the document is fed out into the document feed section one sheet at a time from the bottommost sheet by the separation roller and separation guide.

Entry of the remaining document sheets into the document feed section is prevented by the separation guide.

The relationship shown by the following equation is used for separated document sheets.

If the friction coefficient between the document and separation roller is taken to be μ1, the friction coefficient between the separation guide and the document to be μ2, and the friction coefficient between two sheets of the same document to be μ3, then the following relationship between these three friction coefficients must be satisfied:

$\mu1 > \mu2 > \mu3$

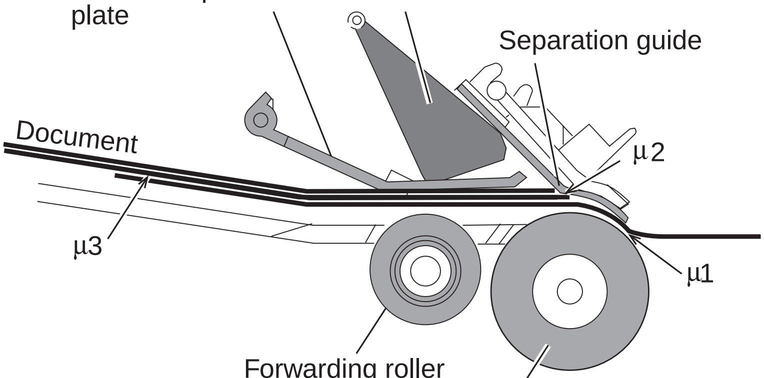

Fig. 3-7 Document Separation

(3) Document feed operation

After the document is separated, the document sheets are fed to the contact sensor by the feed roller. When the leading edge of the document pushes up the actuator of the document edge sensor located at the feed roller section, monitoring of the document length begins.

To prevent slack in document feed, the document feed roller is driven at a speed faster than that of the document separation roller. In this state, however, the document is pulled out from the separation roller. As a result, the spring clutch inside the separation roller pulls back both the separation roller and forwarding roller simultaneously to equalize the feed speed of the rollers in the entire document feed section.

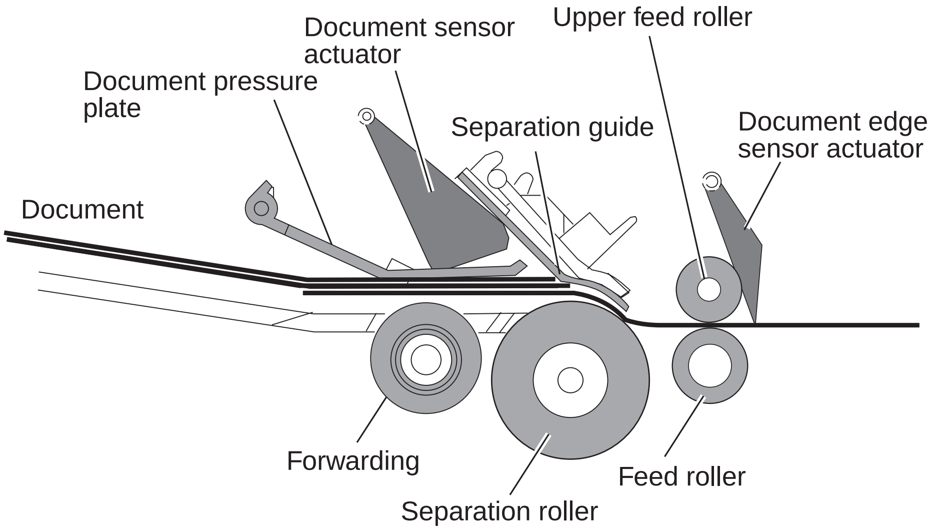

Fig. 3-8 Document Feed

(4) Document reading operation

The document is held down from above by the white mylar sheet (white reference sheet).

After the contact sensor has detected the white level from the white mylar sheet, the document is passed over the contact sensor to be read.

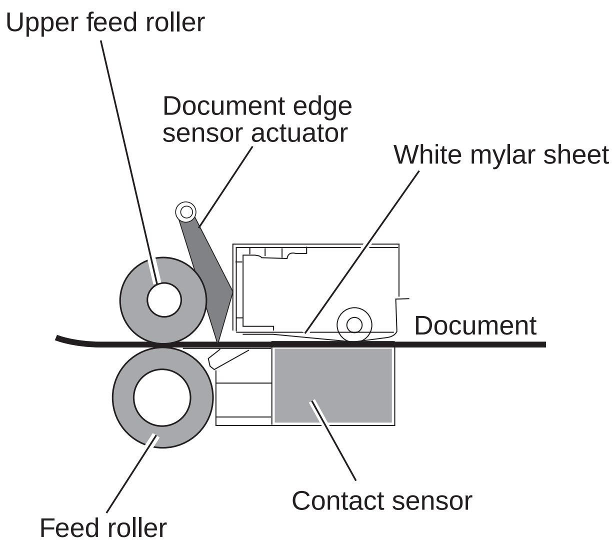

Fig. 3-9 Document Reading

(5) Document eject operation

When the trailing edge of the document has passed out of the separation roller, pulling back by the spring clutch inside the separation roller stops, and the separation roller enters the separation process for the second document sheet. When the trailing edge of the document passes the feed roller, the actuator on the document edge sensor drops to end monitoring of the document length.

The document is then output onto the document tray by the eject rollers.

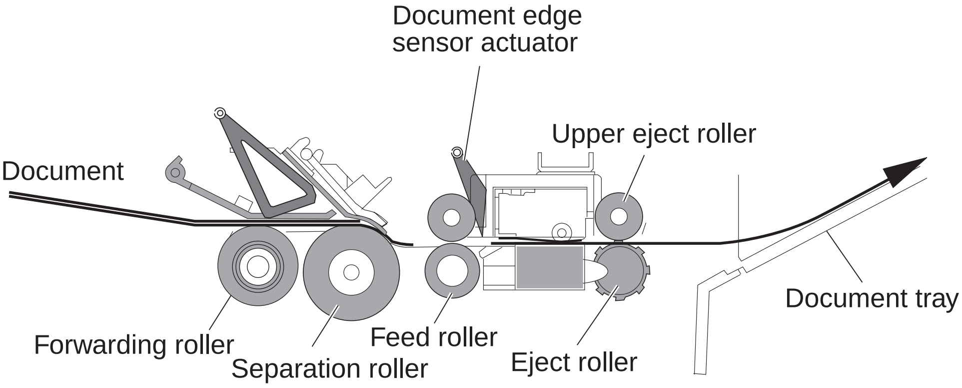

Fig. 3-10 Document Output

NOTE

Flat-bed types recently are designed to be equipped with a document stopper to reduce feed problems caused by over-insertion of the document or insufficient insertion.
Some types are also designed with separation rollers provided above and below in place of the separation guide and with an inversion roller to improve separation performance.

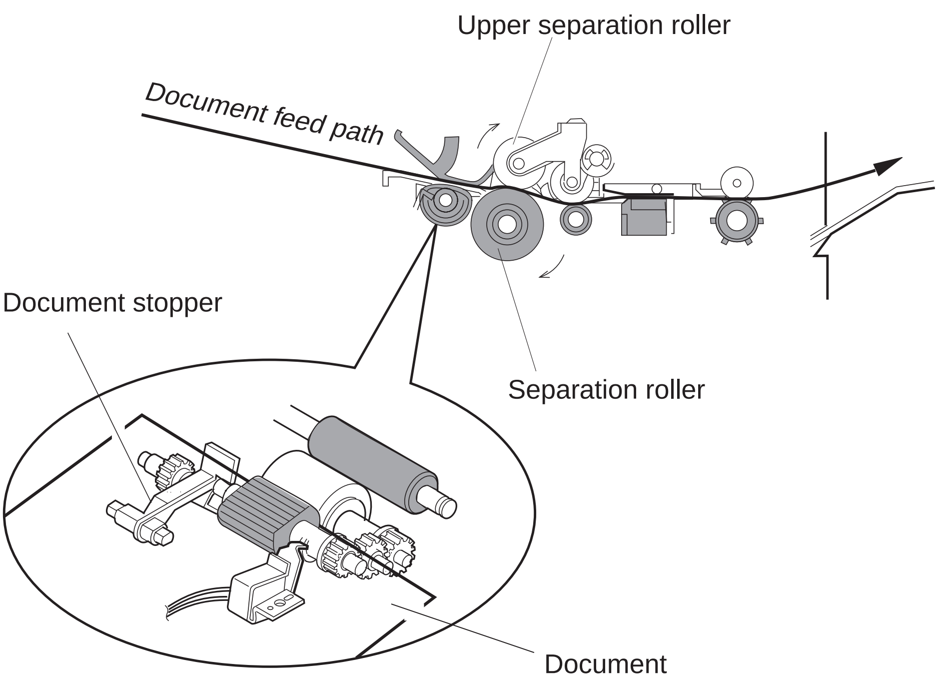

Fig. 3-11 Document Stopper

2.3.2 Drop-in type

With this ADF type, performance when loading documents is inconsistent due to its inclined document feed path. This sometimes results in the non-feeding of sheets when a document comprising many sheets is loaded. Also, as the document output direction is downwards, output documents tend to stack poorly. On the other hand, however, it costs less as a forwarding roller is not required, and less installation space is required as the document feed path is inclined.

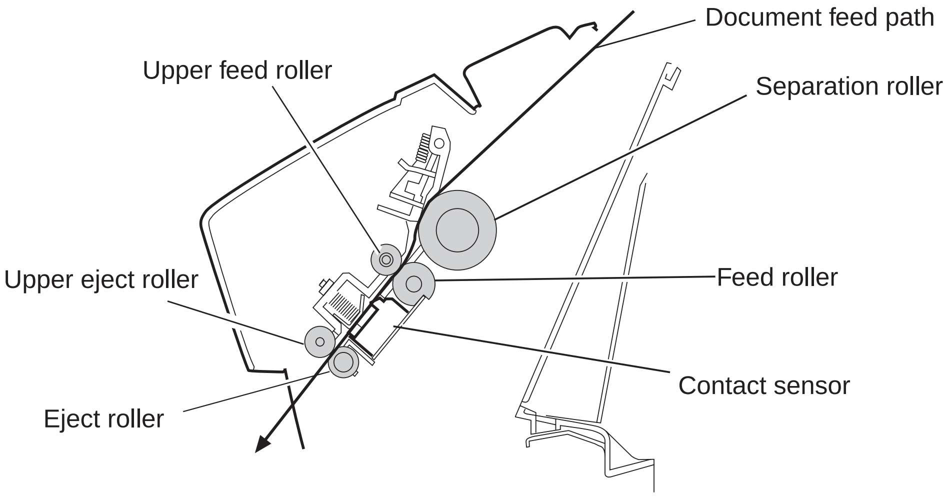

Fig. 3-12 Drop-in Type ADF

- Explanation of drop-in type operation

The same operations as for a flat-bed type ADF are performed for drop-in type ADFs except that there is no document forwarding operation.

3. CONTACT SENSOR

3.1 Structure of Contact Sensor

The structure of the contact sensor is designed to prevent dirt and dust from collecting on the sensor surface or entering the inside. The inside of the contact sensor comprises an LED array, contact glass, rod lens array and photo-transistor array. The LED array emits the light for reading the document, the contact glass refracts the light emitted from the LED array to irradiate the document, the rod lens array picks up and channels the light reflected from the document, and the photo-transistor array receives the reflected light. (See Fig. 3-13)

3.2 Features of Contact Sensor

There are two types of contact sensor, the multi-chip type and the α-Si (Amorphous Silicon) type.
The following describes the strengths and weakness of each type.

(1) Multi-chip type

- Unevenness of the sensor chip is less than that of the α-Si type.
- Image quality is good as the gamma characteristics are proportional.
- Documents can be read even if they rise off the glass surface slightly. (This is dependent, though, on the performance of the rod lens array.)
- The document need not be held down by rollers. So, photographs need not be pasted onto a sheet for reading.
- The density level differs among the sensor chips. So, a density difference may occur between sensor chips which may affect the image if the density is not compensated.

(2) α-Si (amorphous silicon) type

- Costs can be reduced as a rod lens array is not required in the structure of the contact sensor.
- The contact sensor can be designed to be thinner as the rod lens array is not required.
- Light irradiated from the read surface of the copyboard glass is reflected internally on the contact sensor to enter the photo-transistor array. So, there is the possibility that even black originals will be reproduced as gray.

- When the document rises up even slightly from the glass surface, that section is read as black. So, the document must be held down by a roller.
- As the document is pressed against the glass surface, there is the possibility that documents that tend to stick such as photographs cannot be fed.
- As the roller is held in contact with the glass surface, it is difficult to clean the contact sensor.

3.2.1 Multi-chip type

The radiated light emitted from the LED array is reflected by the document, and passes through the rod lens array to be received by the phototransistor array.

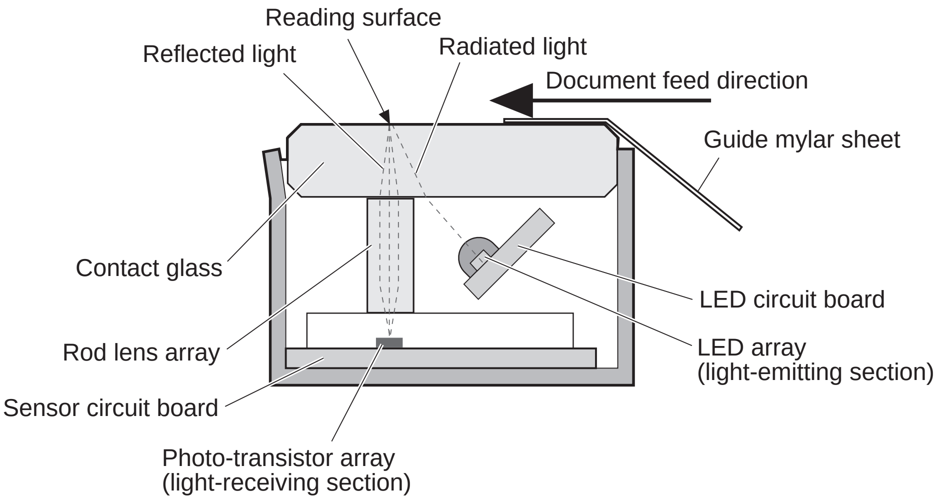

Fig. 3-13 Multi-chip Type (cross-section view)

The sensor circuit board has a built-in driver circuit for amplifying the output of the received light, and the output of that driver circuit is converted to serial data to be transmitted to the system controller.

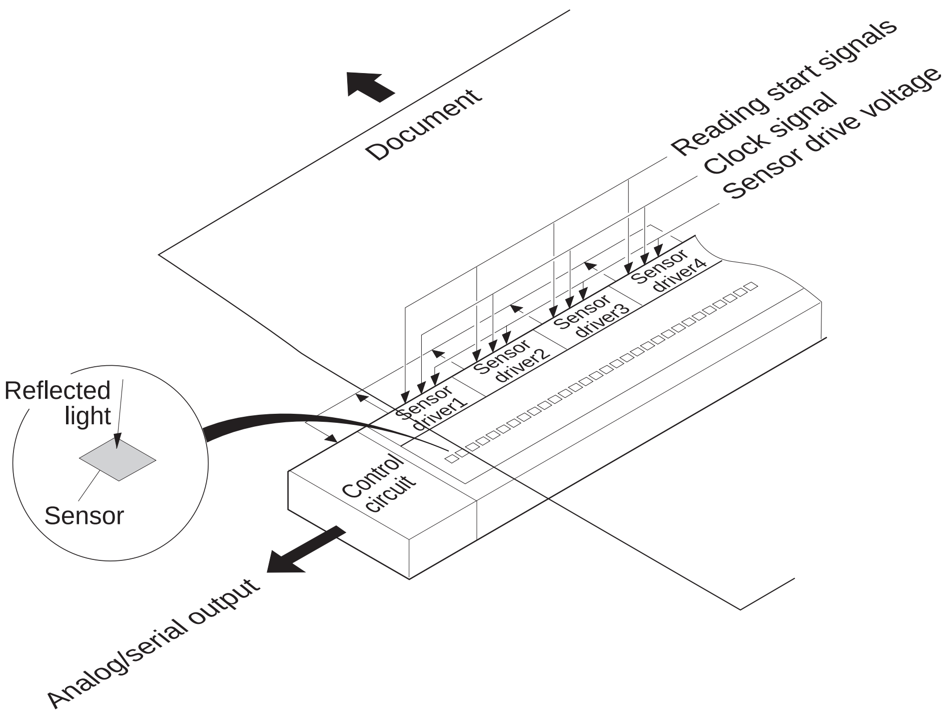

Fig. 3-14 Multi-chip Type

3.2.2 α-Si type

The irradiated light emitted from the LED array is reflected by the document, and is received by the photo-transistor array.

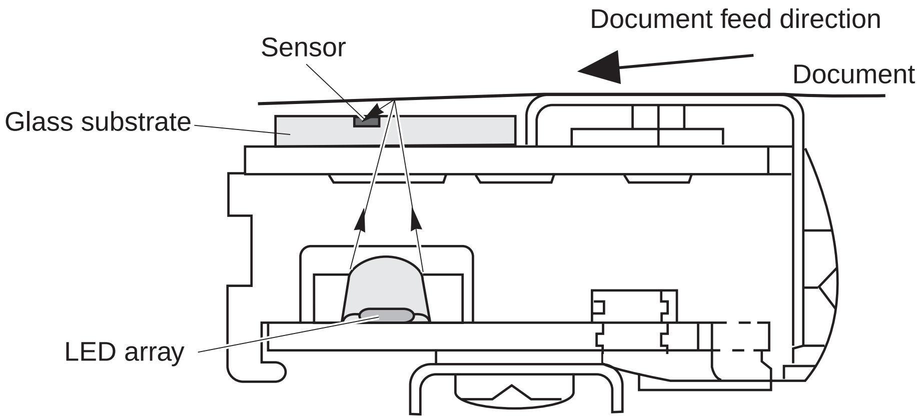

Fig. 3-15 α-Si Type (cross-section view)

The glass substrate has a built-in driver circuit for amplifying the output of the received light, and the output of that driver circuit is converted to serial data to be transmitted to the system controller.

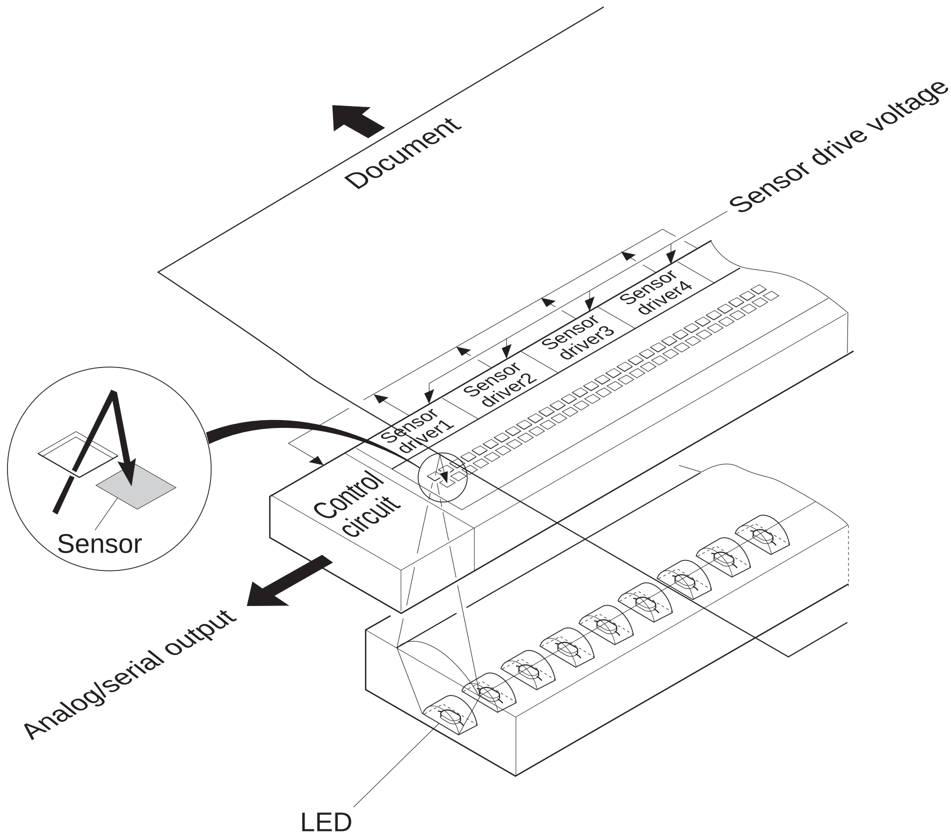

Fig. 3-16 α-Si Type

4. IMAGE DATA PROCESSOR

After the document is read by the contact sensor, the resulting image data undergoes various image data processing at the system controller.
The following shows a block diagram outlining the content of image processing.

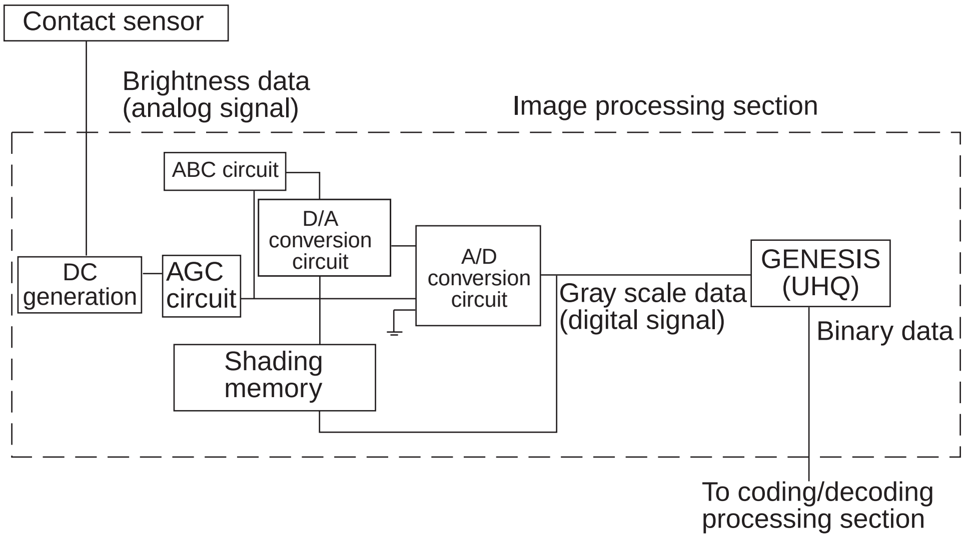

Fig. 3-17 Block Diagram

4.1 Various Image Data Processing

After the image data has been read, it undergoes various data processing before it is sent. The following describes these processing types.

- Pre-scan

  By the pre-scan, the base color of the white mylar sheet attached to the document feed section on the contact sensor is read for one line at the start of document reading so that the unevenness compensation values for the output contact sensor are stored to shading memory.

- DC generation

  DC generation matches the black side reference voltage of the A/D conversion circuit with that of the contact sensor.

- AGC circuit

  AGC (Auto Gain Control) adjusts for unevenness in the reading system (LED, white mylar sheet and contact sensor) to prevent the maximum value exceeding the maximum value of the A/D conversion circuit when the background color of the white mylar sheet is read for one line.

- Shading memory

  A pre-scan is performed at the start of document reading to store the reading brightness data for the base color of the white mylar sheet to shading memory. Then, the data stored to shading memory is compared with the reading brightness data when the document is read to generate uniform image reading brightness data.

- A/D conversion circuit

  This circuit converts the analog signals (voltage signals) that arrive from the contact sensor to digital image signals.

  In the A/D conversion circuit, A/D conversion processing is performed based upon the reference voltage. As adjusting this reference voltage also adjusts the reading density range (difference between minimum and maximum output levels) of each pixel, this influences the signal level after A/D conversion.

- D/A conversion circuit

  This circuit converts digital signals for shading compensation data, for example, into analog signals.

  It also generates the white side reference voltage for the A/D conversion circuit.

- ABC circuit

  The ABC (Auto Background Control) function converts the level of the skin color density in a document so that the reading density of skin color in a color background document is adjusted as white skin color. This function is achieved by varying the white reference voltage of the A/D conversion circuit according to the brightness level of the document to be input.

  As shown in Fig. 3-18, the skin color in a document is eliminated by lowering the density range of a color background document to lower than that of a white background document.

  If there were no ABC circuit, color background documents would be read as black documents.

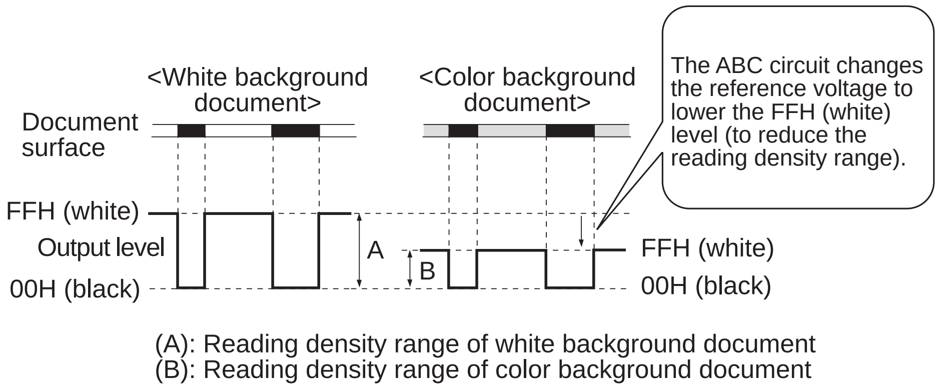

Fig. 3-18 ABC Circuit Functions

3

- GENESIS (UHQ)

  (GEneration of NEw Superior Imaging System (Ultra High Quality))

  GENESIS (UHQ) is an image processing method that achieves high-quality images for text documents by performing edge emphasis and notch processing, and high-quality images for documents containing both text and photos by performing error diffusion processing.

- Edge emphasis

  Normally, the contours of the image read by the contact sensor are blurred or collapsed compared with the contours of the original image. For this reason, the edge emphasis section compensates for blurring or collapsing of the contours so that the read image is reproduced more faithfully to the original image.

- Notch processing

  Notch processing is for processing notches in binary data that is processed by simple binarization. By notch processing, unwanted notches (jagged sections) are automatically compensated for based upon the information relating to the focus pixel and peripheral pixels.

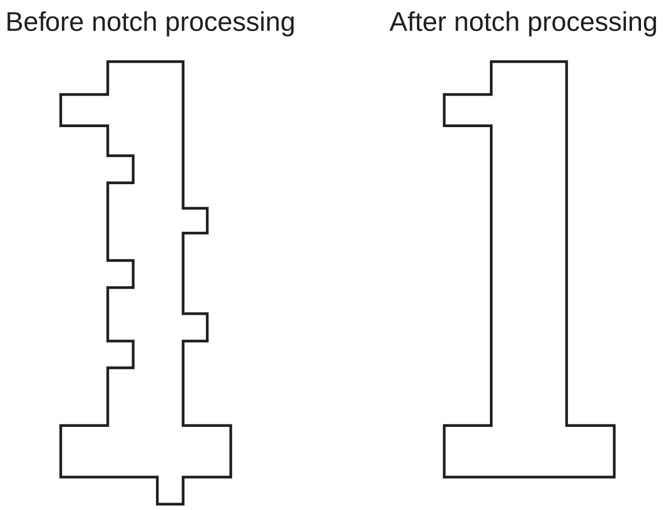

Fig. 3-19 Notch Processing

CHAPTER 4

RECORDING SECTION

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   4.13 BJ Cartridge 4-58

1. INTRODUCTION

This chapter describes the recording section on a facsimile.
At the recording section, the image data is processed to data for printing, and then the recording paper is picked up, printed, and output.
The recording section can be broadly divided into the following three sections:

- Image data processing section
- Paper feed section
- Printing section

This chapter describes each of the components that comprise a recording section referring to an LBP (LASER Beam Printer) and a BJ printer (Bubble Jet Printer) that are currently the main engines for facsimiles.

2. IMAGE DATA PROCESSING SECTION

The purpose of the image data processing is to achieve better-looking prints. After the image data has undergone various image processing by the system control section, it is sent to the printing section. Image data processing is almost the same on both LBP system and BJ system facsimiles.
Fig. 4-1 shows a general flow of image processing.

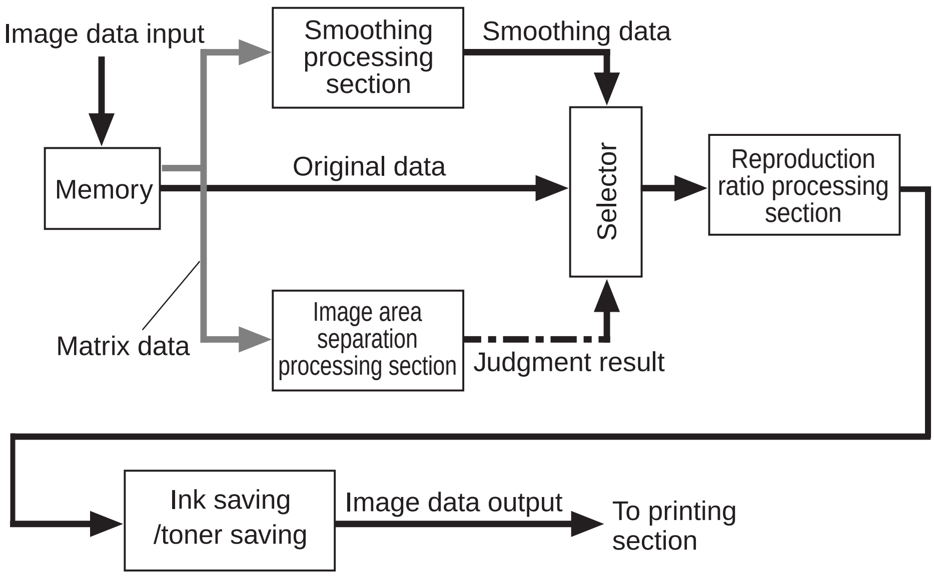

Fig. 4-1 Flow of Image Processing

First of all, part of the image data is stored in memory. Next, the image data undergoes smoothing, the process for printing oblique and curved sections of the image data more smoothly. At the same time, in the image area separation processing, judgment is performed as to whether the image data is binary data or an image containing half-tones such as a photo. The selector selects whether or not the data is the original data or smoothing data based upon the judgment results by the image area separation processing. The image data is then reduced as necessary by the reproduction ratio processing section, and sent to the printing section.
Next, let’s describe of the components in a little more detail.

2.1 Image Area Separation Processing, Smoothing Processing and Selector

2.1.1 Image area separation processing

Image area separation processing section looks at the pixels around the pixel (focus pixel) that is to be smoothed, and judges whether the pixels are part of a binary image or part of an image with half-tones such as a photo. The following describes "number of isolated pixels" and "number of black/white reversions" that are used for judgment, and the judgment criteria.

- Number of isolated pixels

The focus is applied to a certain single pixel, and the total number of isolated pixels in a given matrix centered around that pixel is calculated. For example, if a certain pixel is white, and the adjacent four pixels are black, then that pixel is said to be an "isolated pixel."

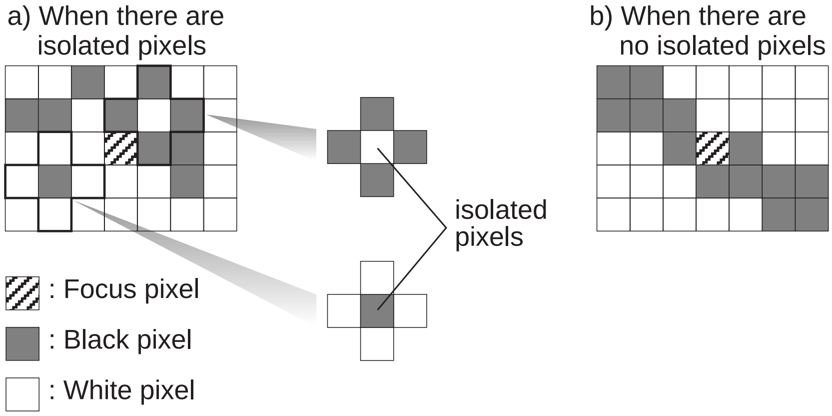

Fig. 4-2 Number of Isolated Pixels

In Fig. 4-2 a), the number of isolated pixels is two, and in b) the number of isolated pixels is zero.

- Number of black/white reversions

The focus is applied to a certain single pixel, and the total number of black/white reversions in a given matrix centered around that pixel is calculated. If the adjacent pixels are black and white, then it is said that black/white reversion is occurring.

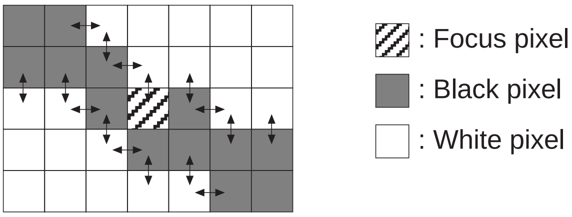

Fig. 4-3 Number of Black/White Reversions

In Fig. 4-3, the number of black/white reversions (number of arrows) is 16 when the focus pixel is black.

- Judgment criteria

The image is judged to be a binary image or an image containing half-tones when the following condition is satisfied.

Binary image: When the number of isolated pixels is the stipulated number or less, and the number of black/white reversions is the stipulated number or less

Image containing half-tones: When the number of isolated pixels is the stipulated number or more, or the number of black/white reversions is the stipulated number or more

2.1.2 Smoothing processing

When image data of a resolution lower than even that of the printer is printed, the oblique or curved sections of the image become jagged. The function for removing these jagged parts to smooth oblique or curved sections is called “smoothing.” Smoothing is performed only on binary images and not on images containing half-tones.
In the following example, let’s describe how smoothing is performed when image data of a standard resolution is printed on a fine-resolution printer.

The focus is applied to a certain single pixel. When smoothing is performed on that pixel, a pixel pattern enclosed by a dashed line is referenced.

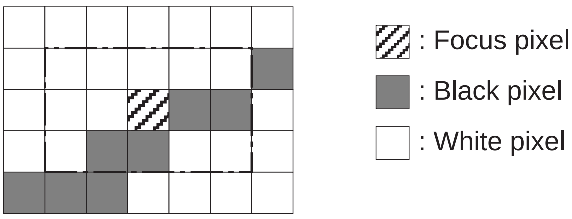

Fig. 4-4 Smoothing (1)

Whether or not the smoothing judgment pattern matches the pixel pattern enclosed by the dashed line is investigated. If it matches, the focus pixel is converted according to the smoothing conversion pattern.

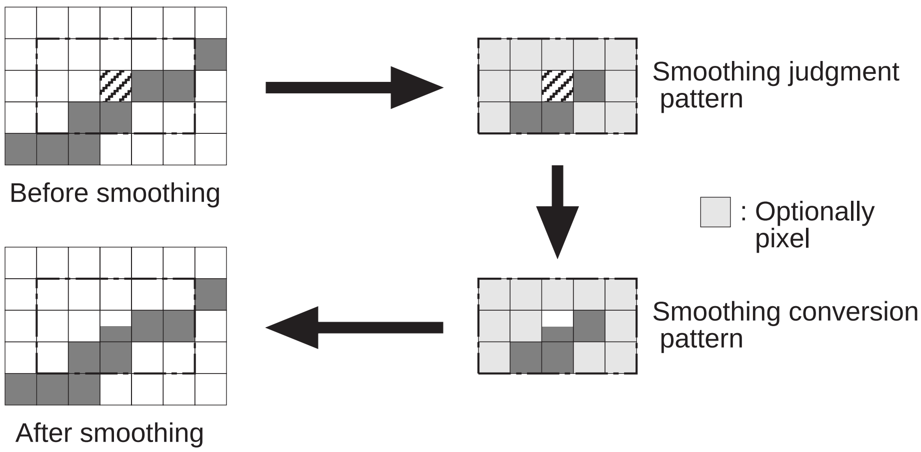

Fig. 4-5 Smoothing (2)

Fig. 4-6 shows the result of smoothing when a certain document is printed in each of the standard, fine, super-fine and ultra-fine modes.

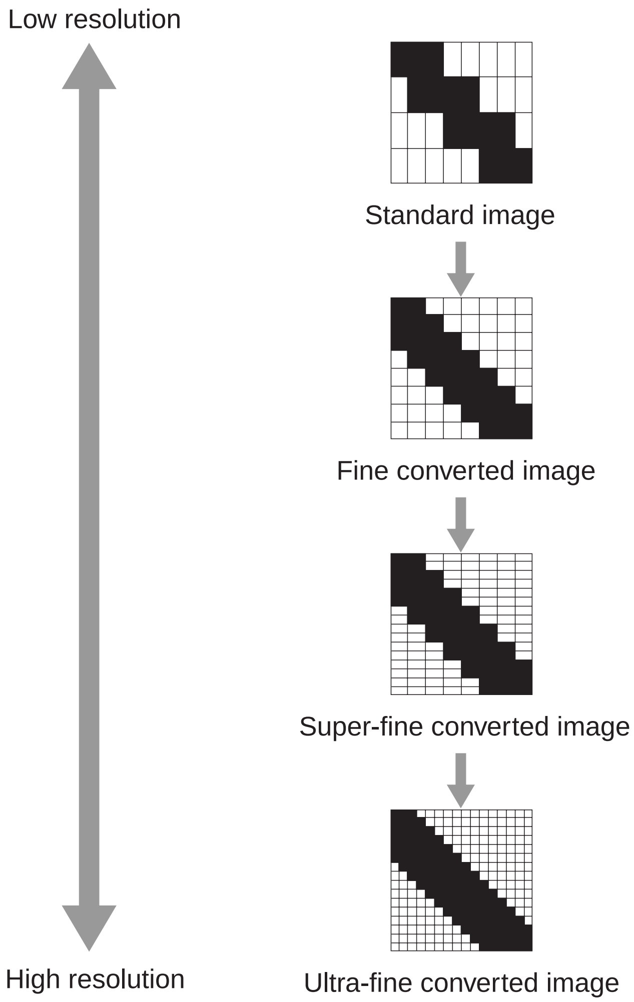

Fig. 4-6 Smoothing (3)

2.1.3 Selector

The selector selects either of the smoothing data or original data based upon the result of judgment performed by the image area separation processing. If the document is judged to be a binary image, the smoothing data is sent to the scaling processor, and if the document is judged to be an image containing half-tones, the original data is sent.

2.2 Reproduction Ratio Processing Section

The image is then reduced by one of the Reproduction ratio shown below. After scaling, the image data is sent to the printing section.

(1) Regular reproduction

Size of Image Data	Size of Recording Paper	Reproduction
A3	A4	The image data is reduced by a ratio of 70%.
A3	B4	The image data is reduced by a ratio of 86%.
B4	A4	The image data is reduced by a ratio of 81%.

(2) Fixed reproduction

The image data is reduced by a reproduction ratio (fixed) that is set on the user registration switches.

(3) Automatic reproduction

The image data is automatically reduced to fit on a single sheet of recording paper even if the image data is longer than the recording paper.

(4) mm/inch conversion

Normally, the resolution of image data that is received in the G3 mode is expressed using the millimeter unit system. The resolution of the printer, however, is expressed using the inch unit system. For this reason, image data of a resolution expressed in the millimeter unit system is converted to resolution expressed in the inch unit system held by the printer. This is called “mm/inch conversion.” mm/inch conversion is performed regardless of whether or not scaling types (1) to (3) described above are performed.

Next, let’s describe an instance where image data of fine resolution is printed on a 360 dpi (dots/inch) printer.

- Horizontal scanning direction

First, the mm system units are converted to inch system units. As one inch is 25.4 mm:

$\rightarrow$ 8 (dots/mm) $\times$ 25.4 (mm/inch) = 203.2 (dots/inch)

Next, the printer calculates how many dots are used to print a single dot of the image data.

$\rightarrow$ 360 (dots/inch) $\div$ 203.2 (dots/inch) = about 1.772

As a result, as the printer prints one dot of the image data using 1.772 dots, this can be converted to the following integer ratio:

→ 1:1.772 = about 9:16

So, the printer knows that nine dots of image data are to be printed using 16 dots.

- Vertical scanning direction

→ 7.7 (dots/mm) × 25.4 (mm/inch) = 195.58 (dots/inch)

→ 360 (dots/inch) ÷ 195.58 (dots/inch) = about 1.847

→ 1:1.847 = about 13:24

Accordingly, the printer prints 13 dots of image data using 24 dots. Fig. 4-7 shows an example of the dot array in mm/inch conversion.

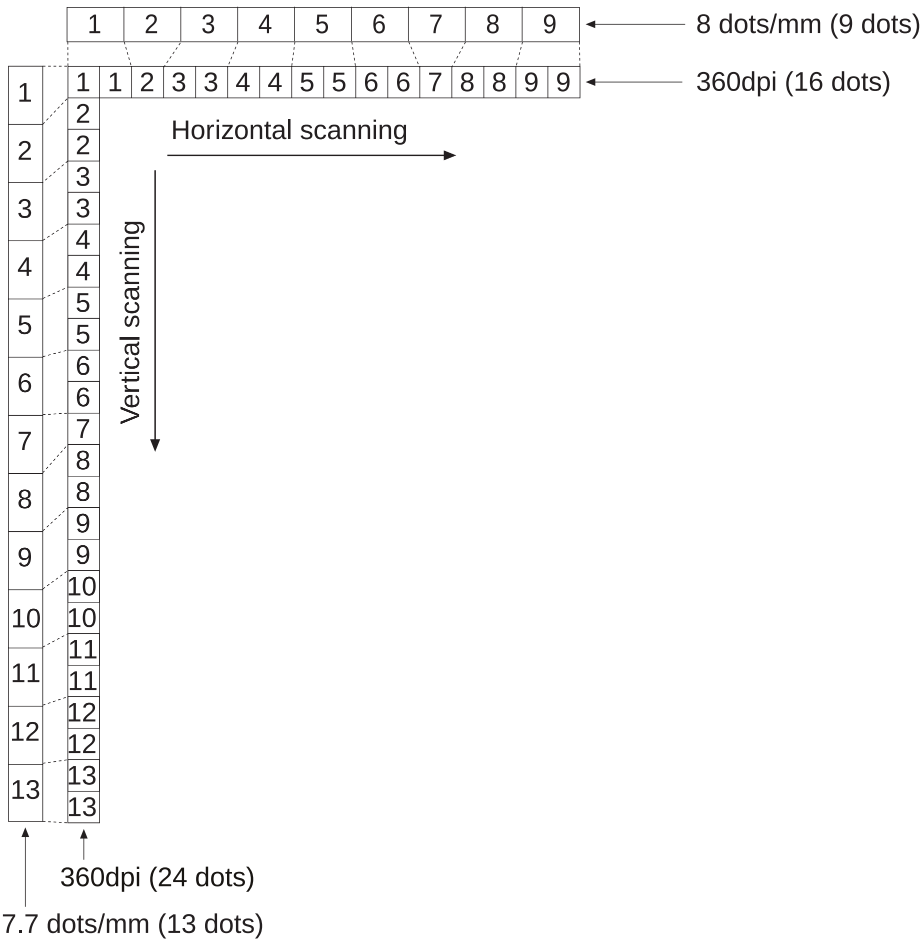

Fig. 4-7 mm/inch Conversion

When printing is actually performed, density conversion of pixels (horizontal scanning direction) is also performed simultaneously with mm/inch conversion. This example describes a case where printing is performed on a BJ printer. The purpose of density conversion is to prevent smudging when ink adheres to the recording paper and to prevent the printed image from collapsing. Black pixels are skipped according to the density conversion pattern. (Black pixels are converted to white pixels.) The following shows an example of this.

There are nine dots of image data of resolution 8 (dots/mm) in the horizontal scanning direction.

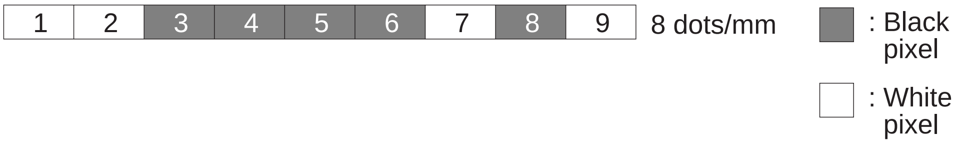

Fig. 4-8 mm/inch Conversion and Density Conversion (1)

Such mechanisms as mm/inch conversion and density conversion are performed simultaneously on this image data.

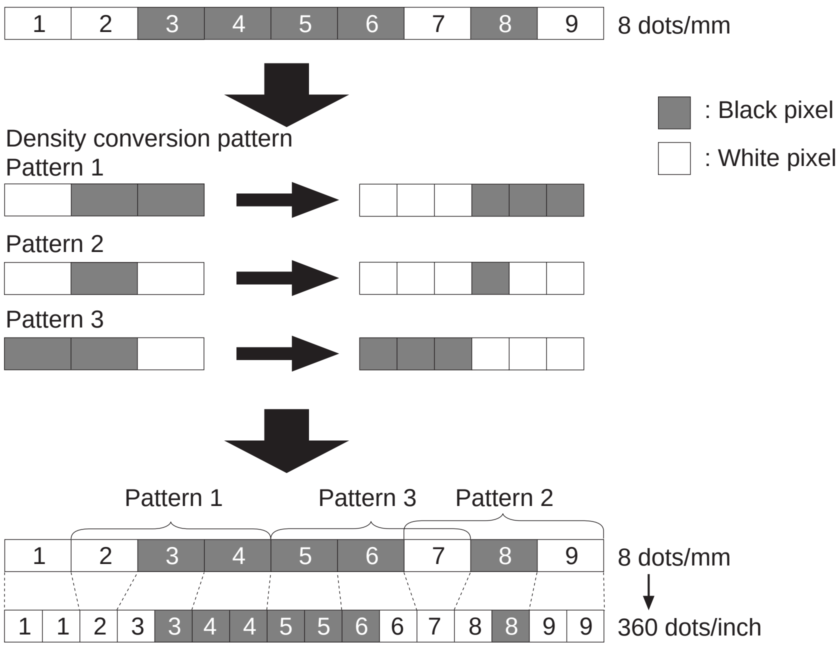

Fig. 4-9 mm/inch Conversion and Density Conversion (2)

2.3 Ink Saving/Toner Saving

This process is performed to save the amount of ink and toner that is consumed during printing. On BJ printers, this is called the “ink saving” function, and on LBP, this is called the “toner saving” function. This function is valid when it is set on user registration switches. This section describes an example of the ink saving function.

- Ink saving function

The amount of ink consumed and the ink drying time are reduced by appropriately converting areas of the image data containing lots of black pixels to white. To be more precise, the focus is applied to a certain single pixel, and the pixels to the left, right, top and bottom of that pixel are investigated. If all of the pixels to the left, right, top and bottom of that pixel are black, the focus pixel is converted to white. The following three patterns are available according to the number of pixels to be targeted.

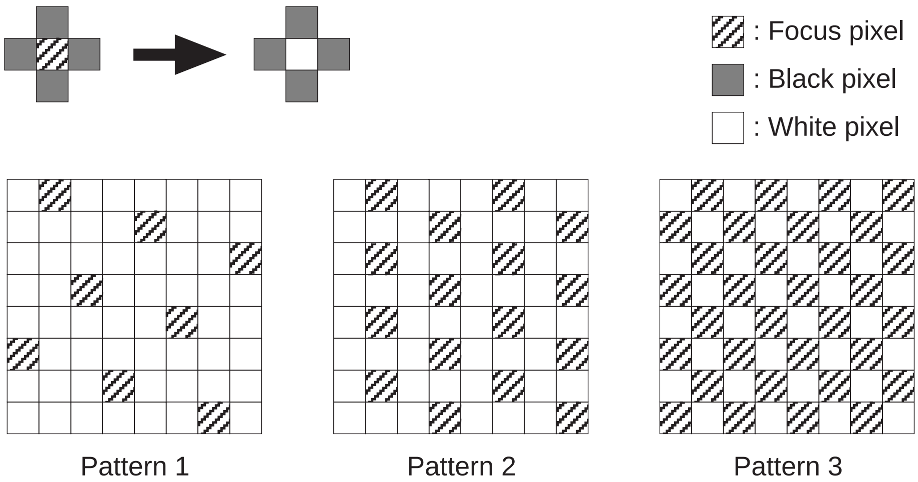

Fig. 4-10 Ink Saving (1)

The following shows an instance where an black/solid image is converted according to pattern 3.

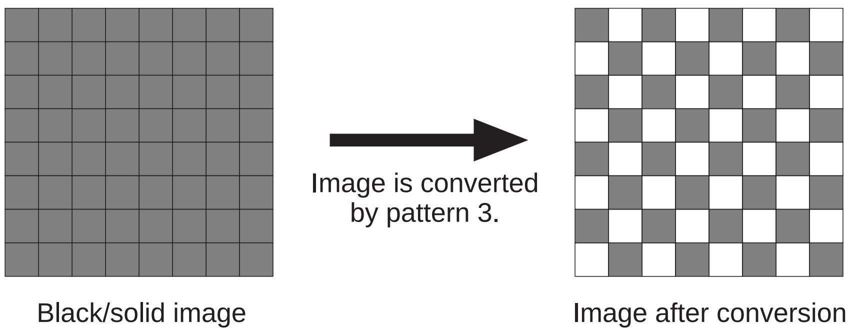

Fig. 4-11 Ink Saving (2)

3. PAPER FEED SECTION

Fig. 4-12 shows the general path of the recording paper.

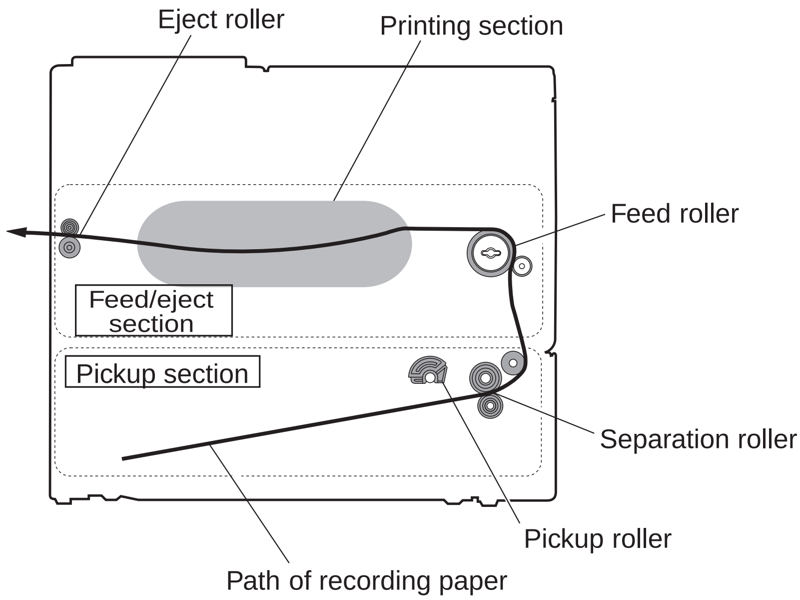

Fig. 4-12 Path of Recording Paper

One sheet of recording paper is picked up at a time by the pickup roller and separation roller, and is sent to the printing section by the feed roller. After printing has ended at the printing section, the recording paper is output to the outside of the machine by the eject roller.
Next, let’s describe the pickup section and feed/eject section.

3.1 Pickup Section

The pickup method is broadly divided into two methods, cassette method and ASF (Auto Sheet Feeder) method. Even in these two pickup methods, the pickup method is further categorized according to the separation method of the recording paper.

3.1.1 Cassette method

With this cassette method, the paper cassette filled with recording paper is attached onto the body of the facsimile. This method allows a relatively large amount of paper to be picked up. There are three paper separation methods for this method: claw method, reverse roller method and friction plate method.

(1) Claw method

The claw at the leading edge angled section of the paper cassette holds down the recording paper. When the recording paper is picked up by the pickup roller, the retention force of the claw holds down the second sheet of recording paper onwards and separates only the first sheet of recording paper.

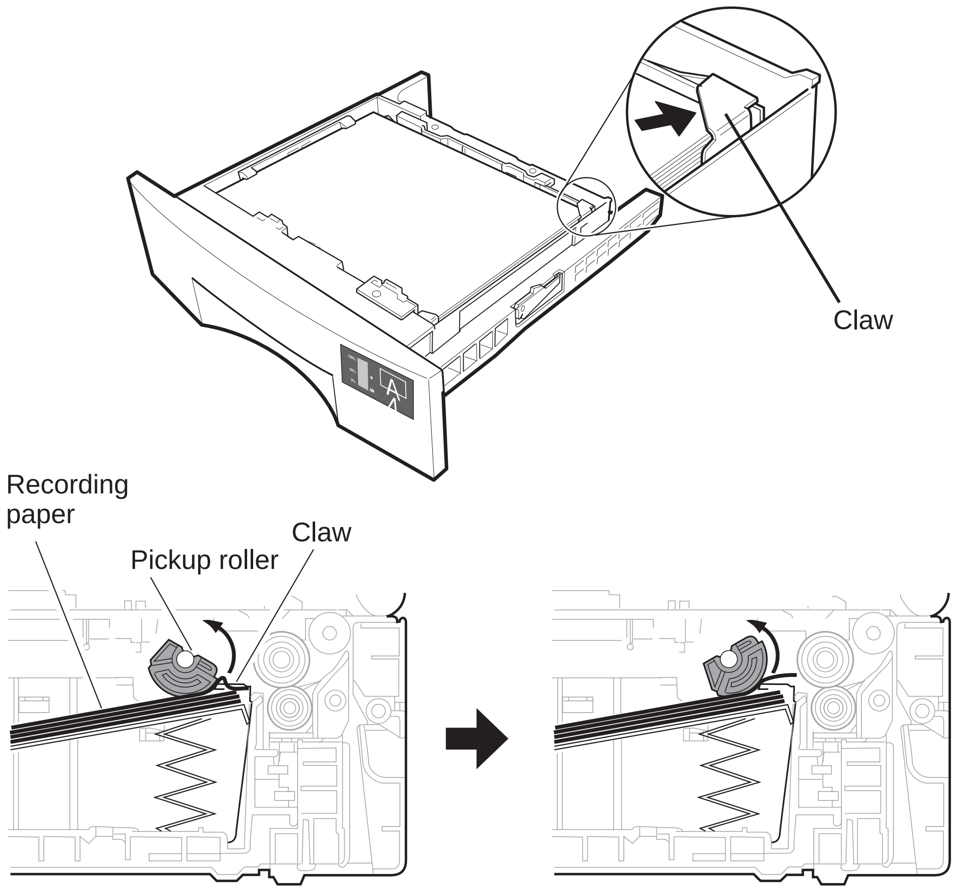

Fig. 4-13   Claw Separation Method

(2) Reverse roller method

The recording paper is separated by applying torque in the counterclockwise direction (opposite to the pickup direction) to the reverse roller.

- Operation before paper pickup

Torque in the counterclockwise direction is applied to the separation roller, or is applied to the reverse roller via a torque limitter. However, as the torque of the reverse roller is smaller than the torque of the separation roller, the reverse roller is pulled back to the separation roller to rotate in the clockwise direction (pickup direction).

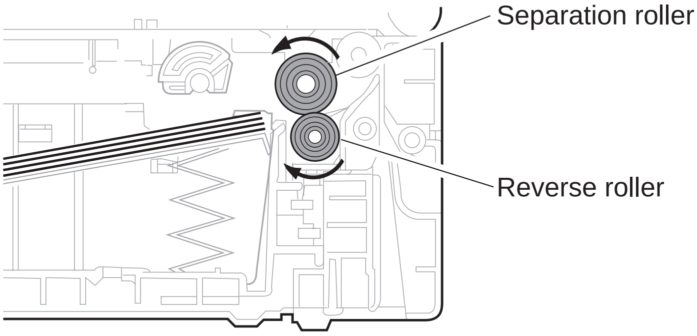

Fig. 4-14 Reverse Roller Method 1

- Operation during normal paper pickup

The reverse roller is pulled back onto the recording paper, and rotates in the clockwise direction (pickup direction).

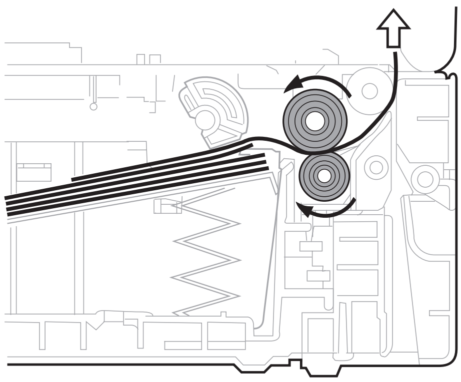

Fig. 4-15 Reverse Roller Method 2

- Operation during double-feeding

  The reverse roller rotates in the counterclockwise direction, and the recording paper (second sheet onwards) on the reverse roller side returns in the counter-pickup direction. Only the recording paper (first sheet) on the separation roller side is fed to the printing section.

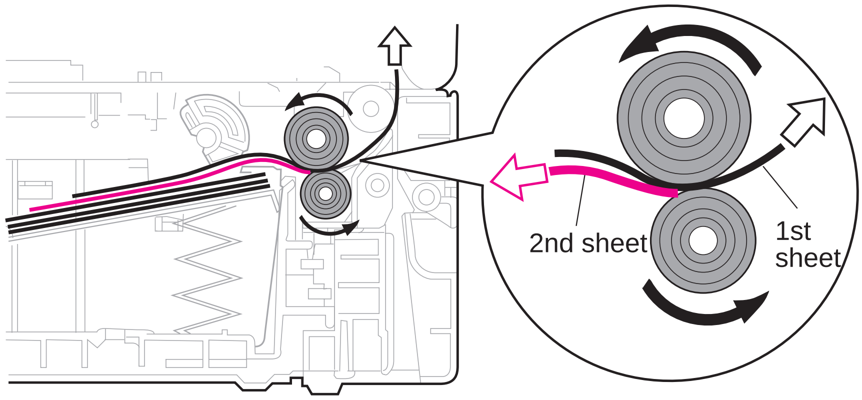

Fig. 4-16 Reverse Roller Method 3

(3) Friction plate method

The friction plate is held against the pickup roller, and the recording paper is separated by the stopping power caused by friction. The principle of operation is the same as the Chapter 3, Document Separation Operation on page 3-6.

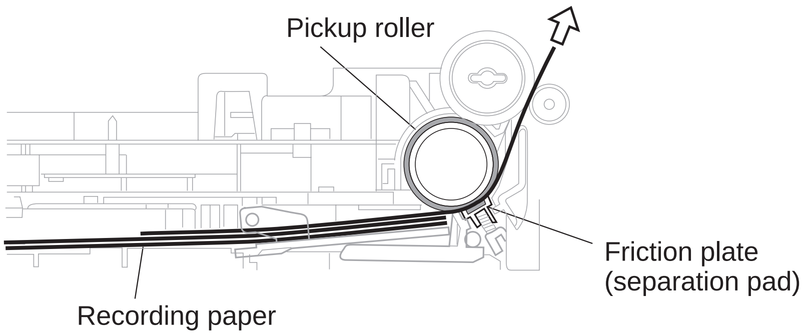

Fig. 4-17 Friction Plate Method

3.1.2 ASF method

With this method, the recording paper is loaded directly in the pickup entrance on the facsimile body. Though the number of paper sheets that can be loaded in one operation is not as much as the cassette method, a feature of this method is that it allows the mechanism to be designed more compactly. The same configuration is also adopted in the sub-pickup methods of units that adopt the cassette method. Claw separation and friction plate separation methods are available as the separation method used in ASF methods. The principle of operation is the same as the separation method in the cassette method.

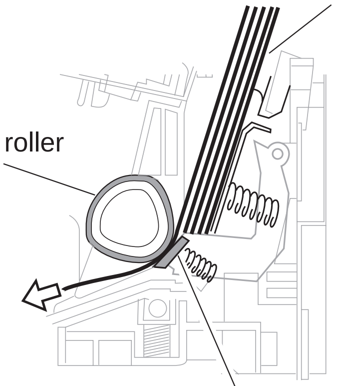

Fig. 4-18 ASF Paper Feed

3.2 Feed/Eject Section

The recording paper that arrives from the pickup section is sent to the printing section by the feed roller, and is output to the recording paper output exit by the eject roller after it has been printed.

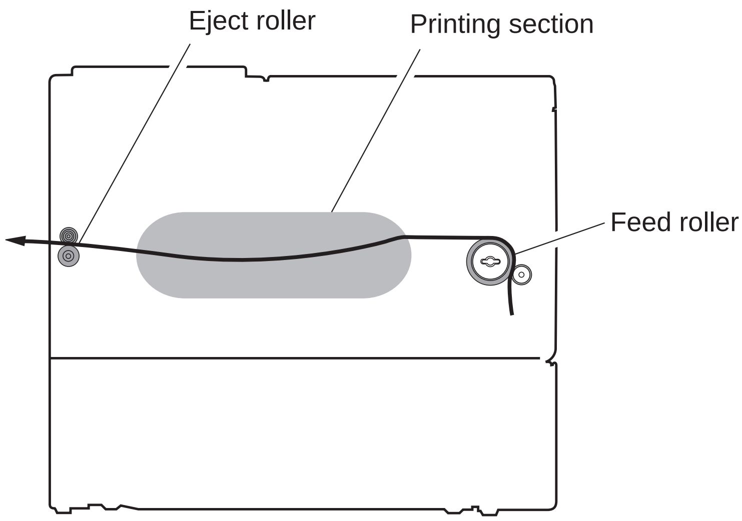

Fig. 4-19 Paper Feed/Eject Section

NOTE

Recording Paper Eject Methods

Normally, paper is eject in order from the first sheet after a facsimile is received. However, on some types of machines, the facsimile is temporarily stored to memory so that it can be output in order from the last page (print in order). Some types of machines allow the user to select whether to output the facsimile printed side face down or face up by switching the paper delivery selector. These types of output are called “face-down paper delivery” and “face-up paper delivery,” respectively.

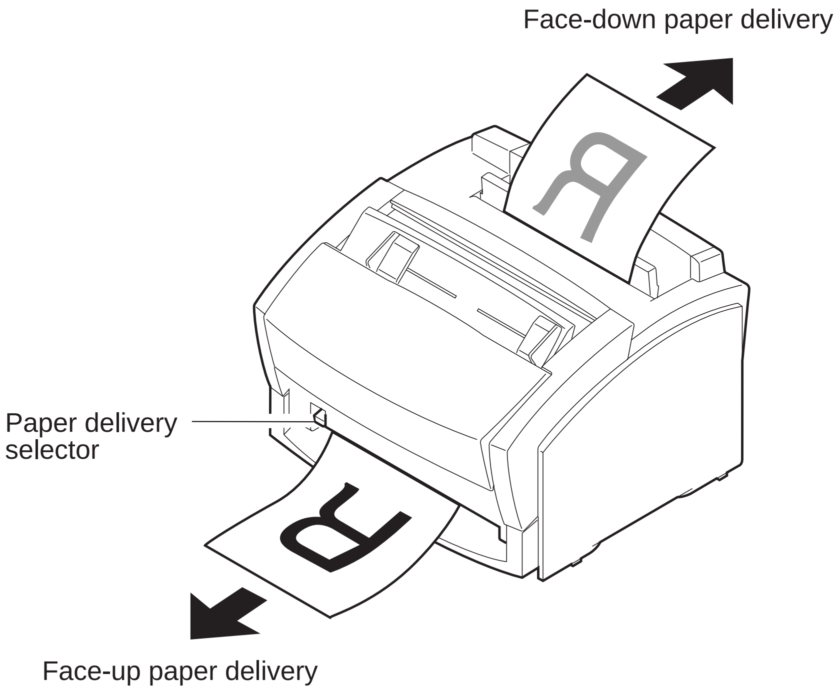

Fig. 4-20 Face-up Paper Delivery and Face-down Paper Delivery

3.3 Detection of Recording Paper Jams

A “recording paper jam” is a state where loaded recording paper has jammed inside the unit without being picked up, fed or ejected. Recording paper jams are detected by the ON/OFF timing of sensors that detect the presence of recording paper. Generally, light-transmitting type photo-interrupters which are a kind of optical sensor are used for detecting the presence of recording paper. When the light that is irradiated from the light-emitting section of the photo-interrupter is detected by the light-receiving section, the sensor turns “ON.” Alternately, when light is blocked by the actuator and cannot be detected by the light-receiving section, the sensor turns “OFF.” Changing of the ON/OFF state of the sensor in this way is used for detecting the presence of recording paper.

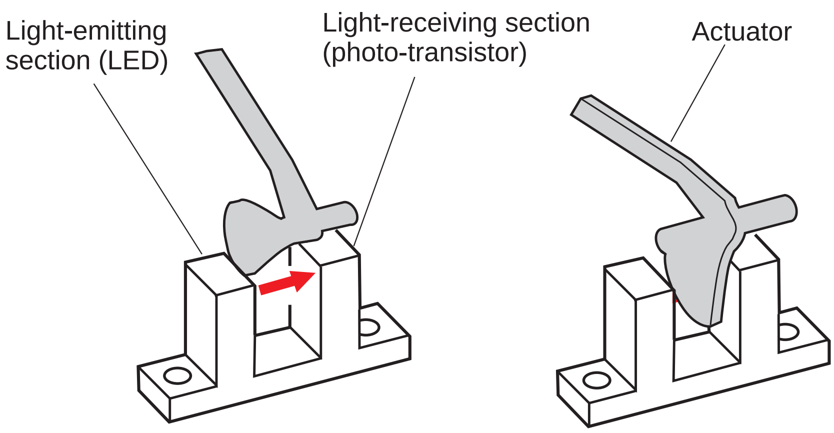

Fig. 4-21 Photo-interrupter

Generally, the following four types of recording paper jams occur:

- Pickup jam
- Feed jam
- Fixing unit wrap-around jam (only in case of LBP)
- Eject jam

- Pickup jam

  This jam occurs in the following two instances:

  - when the pickup sensor cannot detect the leading edge of the recording paper within a specified period of time after the pickup operation has started
  - when the sensor cannot detect the trailing edge of the recording paper within a specified period of time after the sensor has detected the leading edge of the recording paper

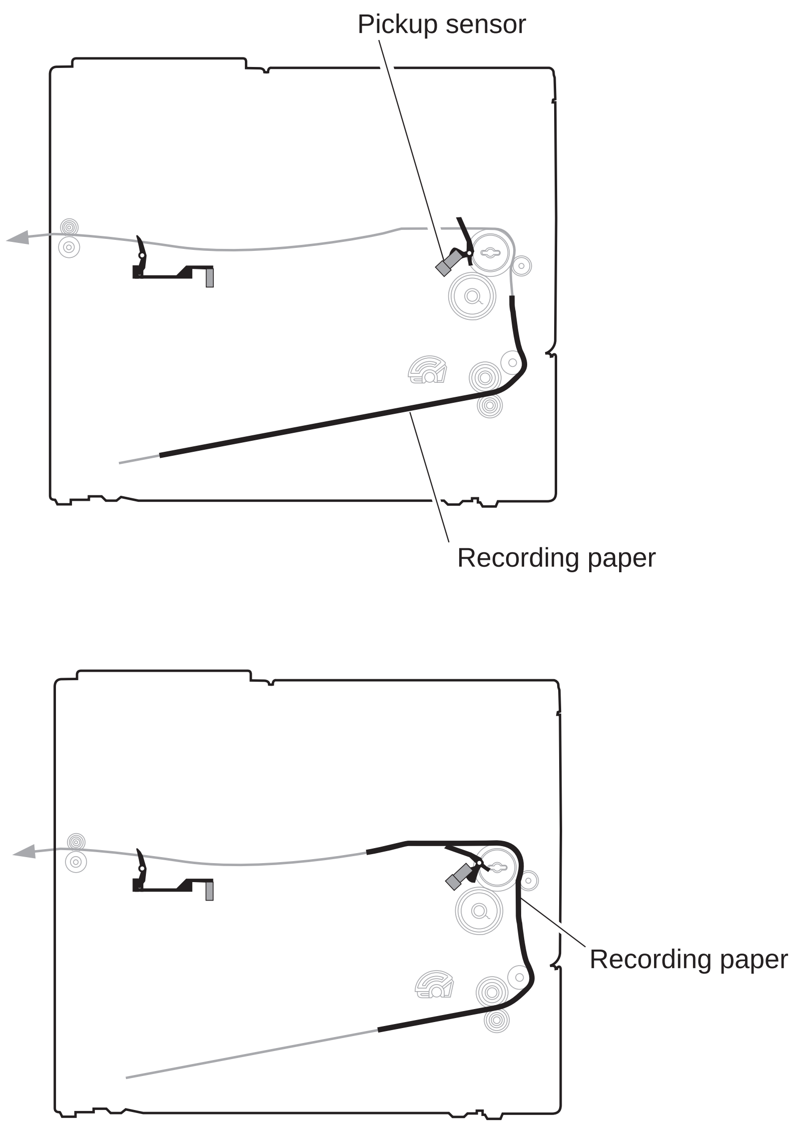

Fig. 4-22 Pickup Jam

- Feed jam

  This jam occurs when the eject sensor cannot detect the leading edge of the recording paper within a specified period of time after the pickup sensor has detected the trailing edge of the recording paper.

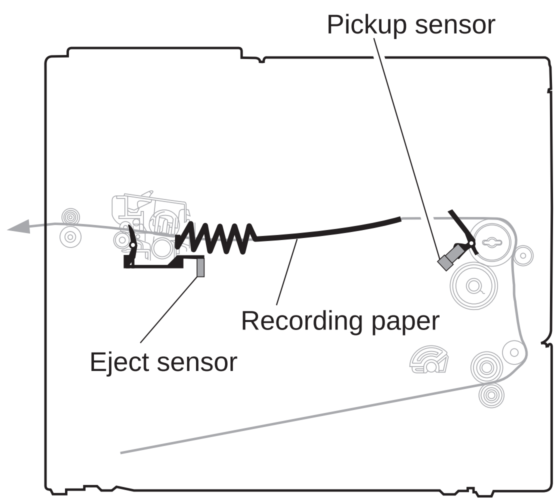

Fig. 4-23 Feed Jam

- Fixing unit wrap-around jam (only in case of LBP)

  This jam occurs when the eject sensor has detected a “no recording paper” state within a specified period of time after the eject sensor has detected the leading edge of the recording paper.

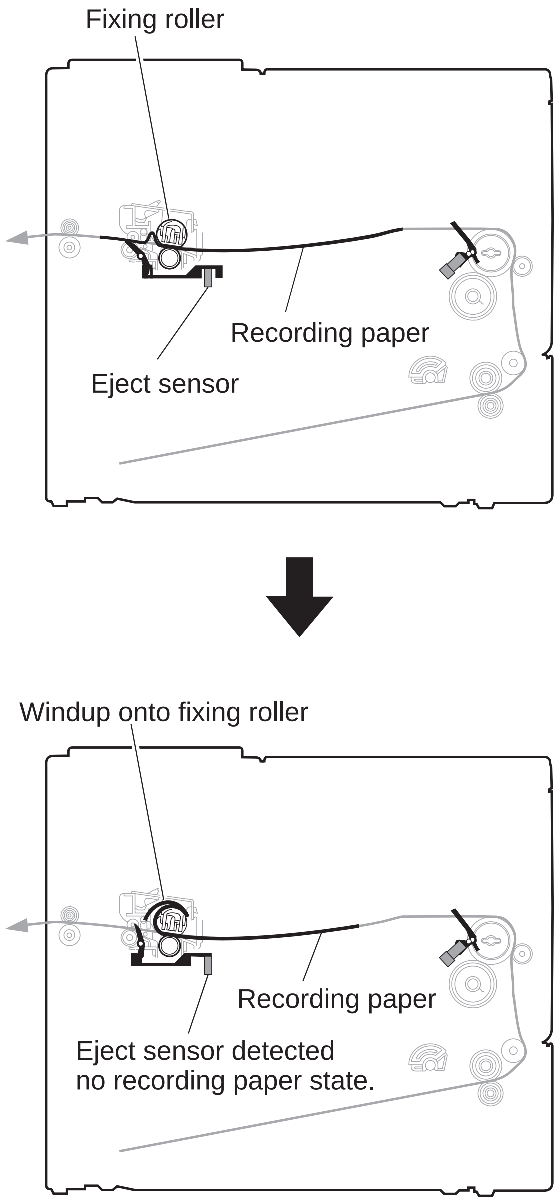

Fig. 4-24 Fixing Unit Wrap-around Jam

- Eject jam

  This jam occurs when the eject sensor cannot detect the trailing edge of the recording paper within a specified period of time after the eject sensor has detected the leading edge of the recording paper.

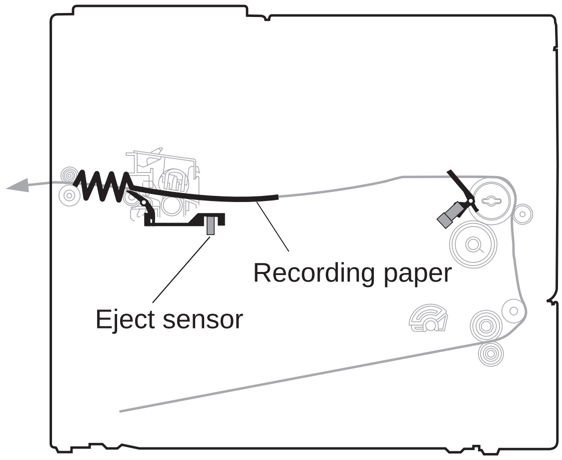

Fig. 4-25 Eject Jam

4. PRINTING SECTION

Image data is printed on recording paper that arrives from the pickup section. This section describes the printing sections of an LBP and a BJ printer.

4.1 LBP (LASER Beam Printer)

As its name implies, an LBP prints images using a LASER beam. This printer is quiet during printing as it does not generate the kind of impact noise that is generated on a typewriter. Another feature of this printer is its fast printing speed as it is a type of page printer and prints images in single pages at a time.

4.2 Printing by LASER

Image data is divided into pixel (dot) units. Each of these pixels is made to correspond to a LASER spot, and images are printed by turning LASER spots ON and OFF.

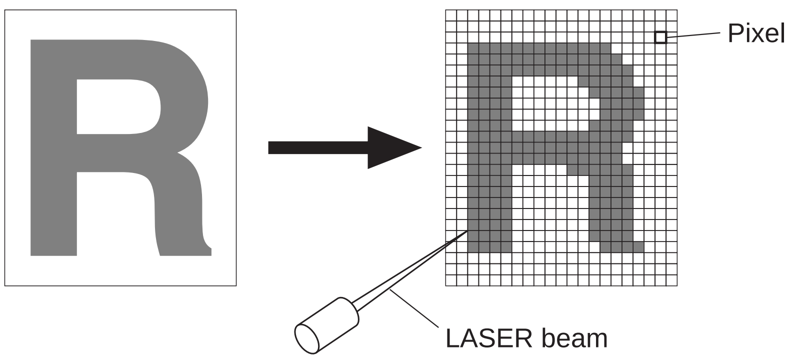

Fig. 4-26 LASER Printing 1

As the LASER beam itself only advances straight, the LASER beam is reflected on a rotating scanning mirror to scan in the horizontal scanning direction. Scanning for one line's worth of the image is performed on one of the planes of the scanning mirror. To draw the next line, the location to be scanned itself advances by one line.

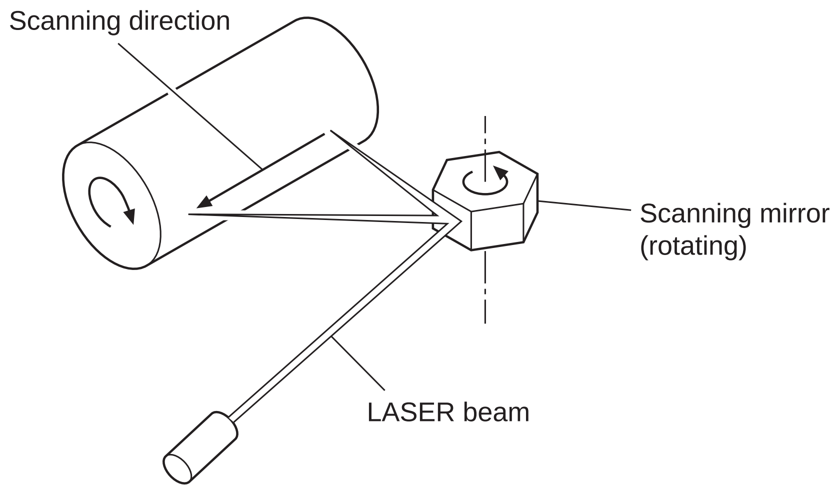

Fig. 4-27 LASER Printing 2

4.3 Flow of Printing

Fig. 4-28 shows the general flow of printing.

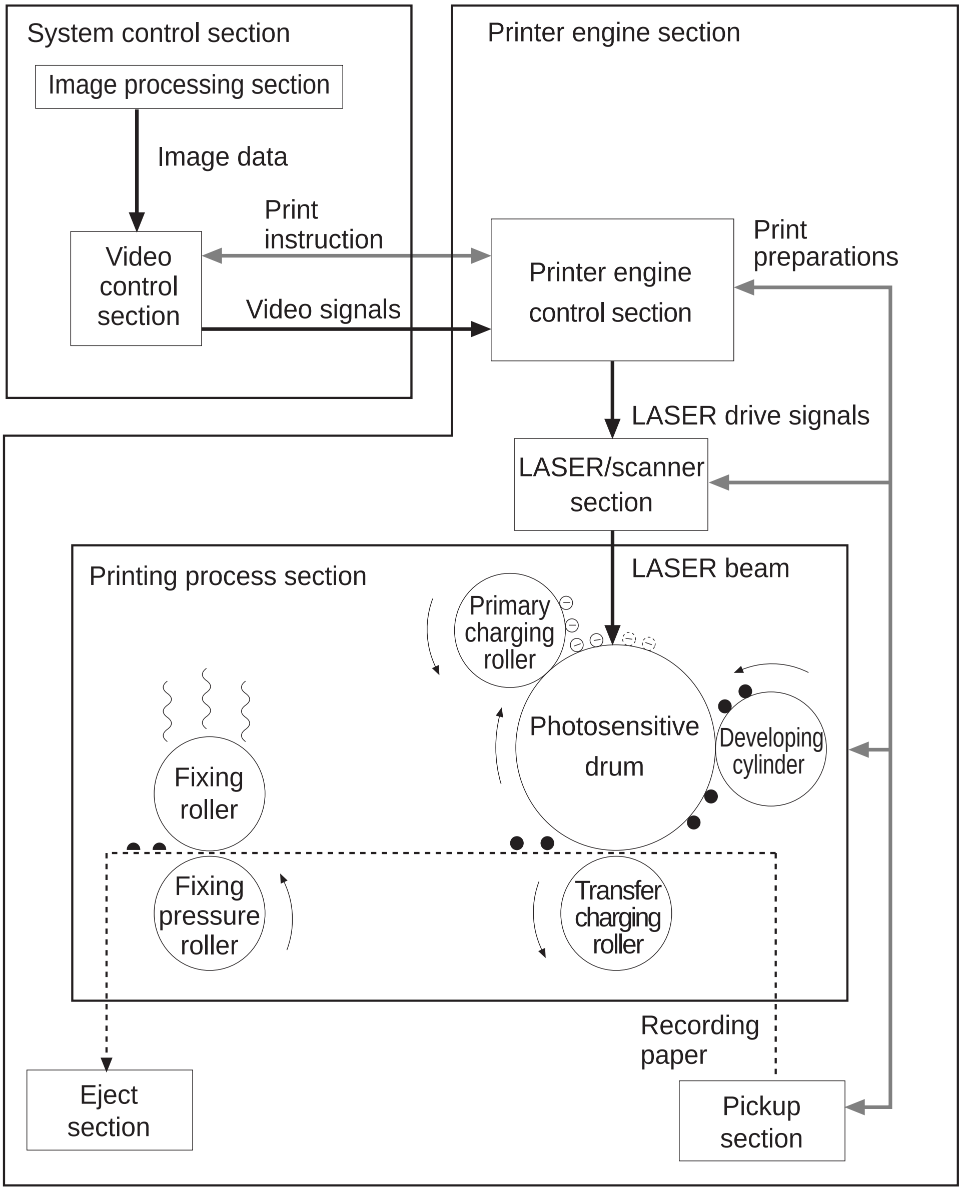

Fig. 4-28 Printing Sequence

First of all, the video control section outputs the print instruction to the printer engine control section which starts to prepare for printing (picking up recording paper, etc.). Next, when the printer is ready for printing, the video control section sends the video signals (image data) to the printer engine control section. The printer engine control section generates the signals (LASER drive signals) for turning the LASER ON and OFF based upon the video signals, and sends these signals to the LASER/scanner section.

At the LASER/scanner section, the image is drawn on the photosensitive drum by the LASER beam. The image at this stage is not yet visible to the human eye. In the printing process section, toner is attached to this invisible image on the photosensitive drum to change it to a visible image, and the toner is transferred to and fixed on the recording paper, which is then eject.

Next, let's describe each of these components in a little more detail.

4.4 Video Control Section/Printer Engine Control Section

At the video control section, the image data that has undergone image processing is converted to video signals. The video control section then checks the state of the printer engine by handling the signals with the printer engine control section, and then instructs printing, after which it sends the video signals.

The printer engine control section generates the LASER drive signals based upon the received video signals, and sends the LASER drive signals to the LASER/scanner section. These signals that are handled between the video control section and printer engine control section are called "video interface signals."

4.4.1 Main video interface signals

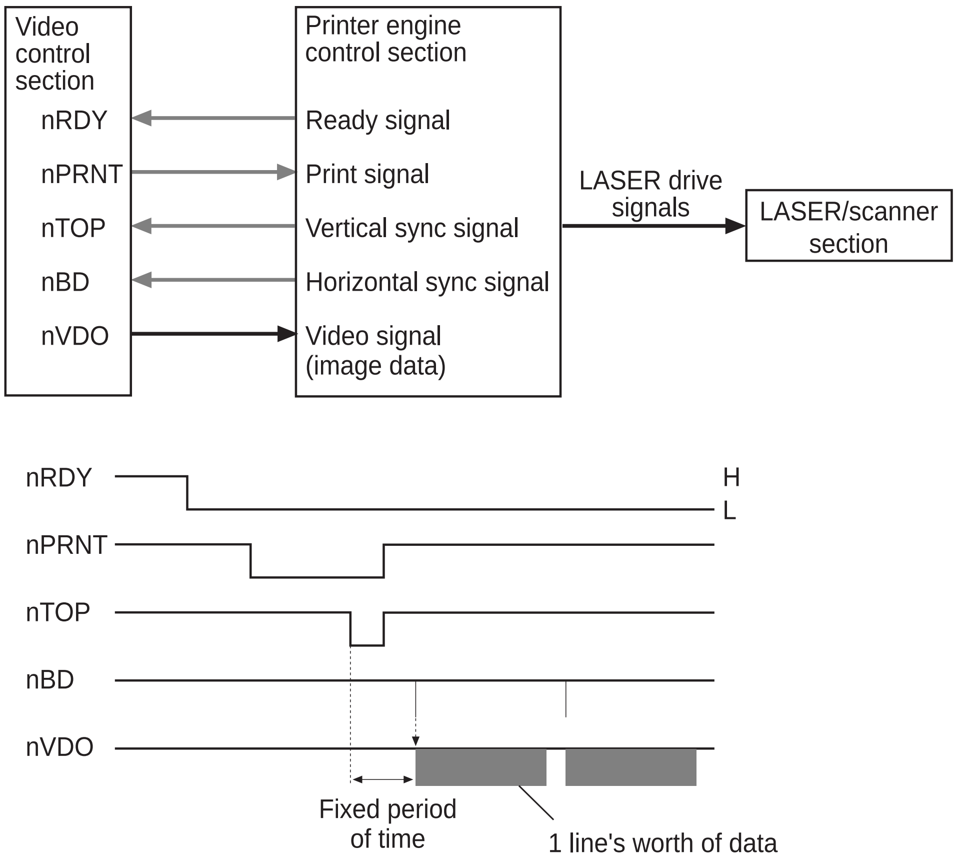

Fig. 4-29 Video Interface Signals

- nRDY signal (Ready)

  This signal is issued by the printer engine control section to the video control section to show that it can start or continue printing.

- nPRNT signal (Print)

  This signal is issued by the video control section to the printer engine control section to instruct start or continuation of printing. The video control section sends this signal when one full page worth of data is present and the nRDY signal state is "Low." When the printer engine control section receives this signal, it prepares the printer for printing by rotating the photosensitive drum and picking up the recording paper, for example.

- nTOP signal (Top Of Page)

  This is the vertical scanning (vertical direction) sync signal for the LASER beam, and is used for printing the start of the image (first line) at an appropriate position on the recording paper.

- nBD signal (Beam Detect)

  This is the horizontal scanning (horizontal direction) sync signal for the LASER beam, and is used for ensuring that the image printing position in the horizontal scanning direction is constant.

- nVDO signal (Video)

  As its name implies, this is the image signal. The video control section sends the nVDO signal synchronized with the nBD signal after a fixed period of time after it has detected that the state of the nTOP signal has changed to "Low." nVDO signals are sent successively from the 1st line of the image. The LASER is turned ON when nVDO is "Low" and OFF when "High."

- LASER drive signals

  The LASER drive signal is an nVDO signal to which the LASER ON signal has been added. LASER ON signals are required for generating the nBD signal.

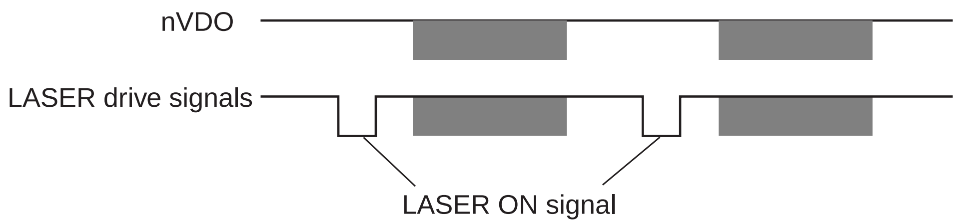

Fig. 4-30 LASER Drive Signals

NOTE

About the nBD and nTOP Signals

As described above, the nVDO signals are sent synchronized with the nBD signals and nTOP signals. What is the purpose of this? There are two reasons:

- To draw images correctly on the photosensitive drum
- To transfer the image correctly onto the recording paper

The LASER beam scans one line of the image at a time to form the image on the photosensitive drum. If the scanning start position in the Horizontal scanning direction is different for each line of the image during scanning, then the image will not be able to be drawn correctly on the photosensitive drum.

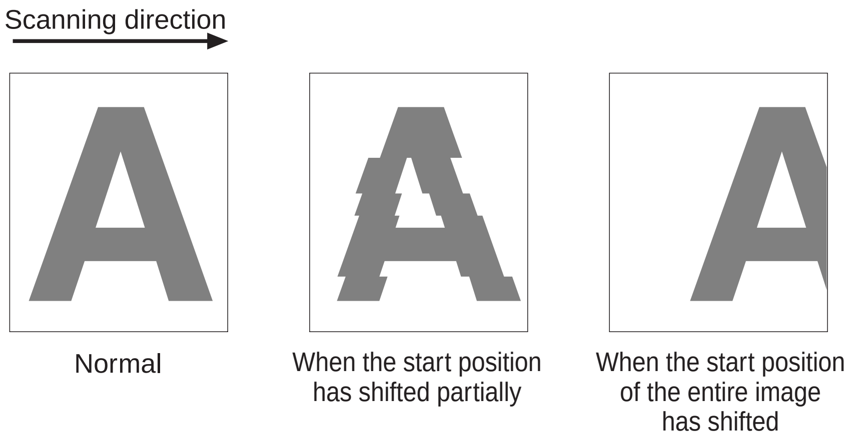

Fig. 4-31 Scanning Start Position

For this reason, the nBD signal is required for making the scanning start position in the Horizontal scanning direction the same for each line of the image.

The nBD signal is the signal generated by irradiating the LASER beam on a small mirror (BD mirror) at the end of the photosensitive drum and detecting it.

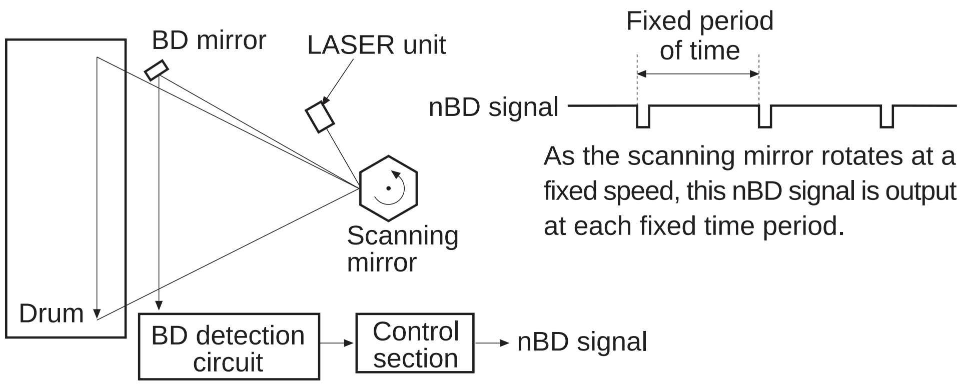

Fig. 4-32 nBD Signal

The nVDO signal is sent after a fixed period after this nBD signal has been sent. Accordingly, the image can be drawn correctly on the photosensitive drum as scanning always starts from the same position for each line.

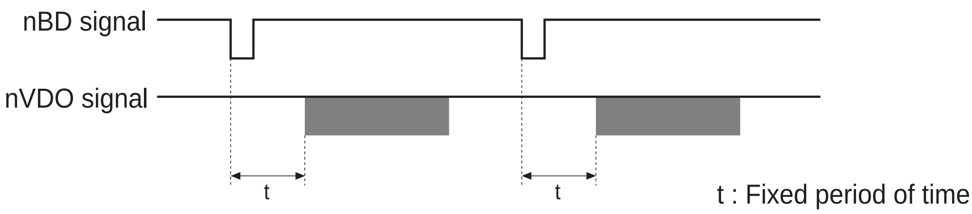

Fig. 4-33 nBD and nVDO Signals

- Correct transfer of images to the recording paper

The image on the photosensitive drum must be transferred to the recording paper. During this transfer, the leading edge of the image on the photosensitive drum must be made to match the leading edge of the recording paper. For this reason, the nTOP signal is required for controlling the start of the image, that is, the scanning start position of the first line of the image. The first line of the image is sent after a fixed period of time from this nTOP signal.

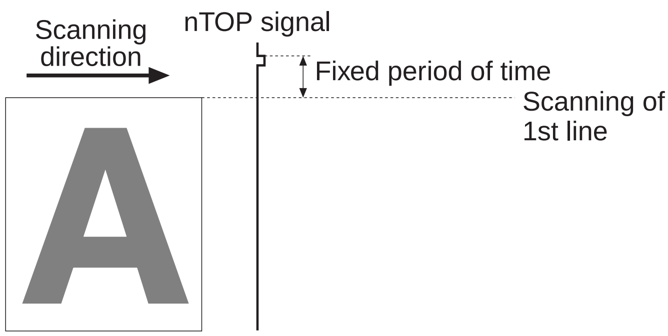

Fig. 4-34 nTOP Signal

4.5 LASER/Scanner Section

Fig. 4-35 shows the basic configuration of the LASER/scanner section.

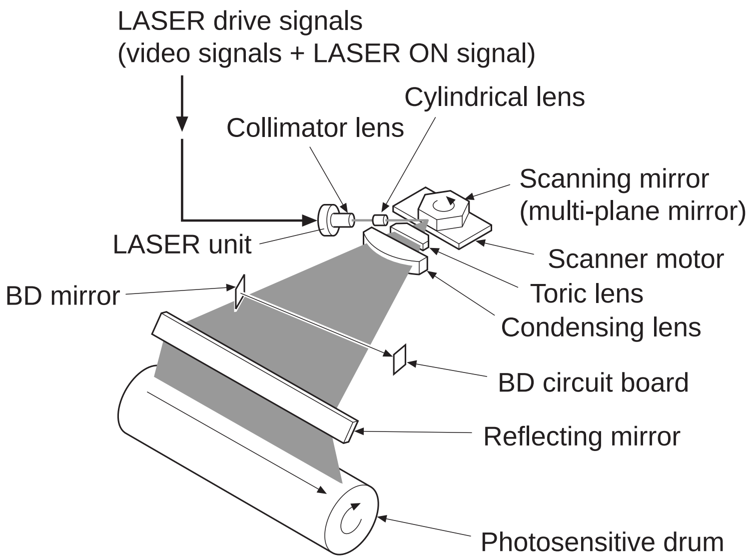

Fig. 4-35 Configuration of LASER/Scanner Section

The LASER unit turns the LASER beam ON and OFF according to the LASER drive signal. This LASER beam passes through the collimator lens and cylindrical lens to be irradiated on the scanning mirror that is rotating at a fixed speed. After being irradiated on the scanning mirror, the LASER beam passes through the toric lens and condensing lens to be scanned on the photosensitive drum. This series of operations is repeated for each line of the image at a time. The photosensitive drum also rotates at a fixed speed to prevent lines of the image overlapping each other.

Next, let’s describe the functions of each component.

(1) Collimator lens

The LASER beam emitted from the semiconductor LASER is diffused. This lens corrects the LASER beam so that it becomes parallel.

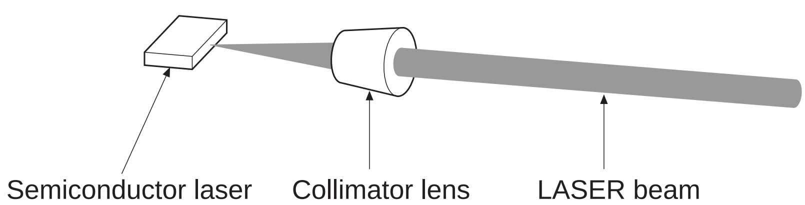

Fig. 4-36 Collimator Lens

(2) Cylindrical lens

This lens focuses the LASER beam on the planes of the scanning mirror.

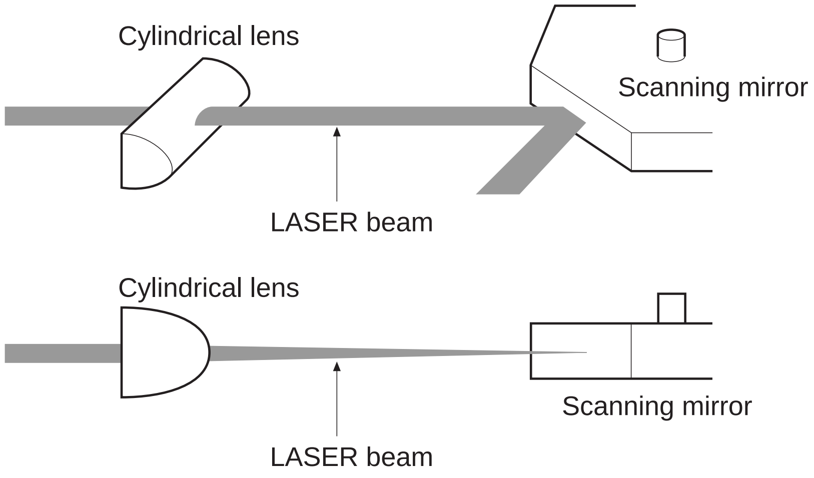

Fig. 4-37 Cylindrical Lens

(3) Toric lens

This lens corrects the LASER beam again so that it becomes parallel.

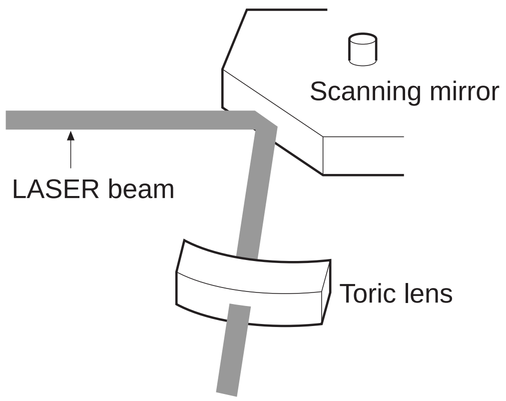

Fig. 4-38 Toric Lens

4

(4) Condensing lens

This lens focuses the LASER beam on the photosensitive drum. Note, however, that the scanning speed at points A and B is different by simply focusing the LASER beam as can be seen in Fig. 4-39. Accordingly, a lens that has the characteristic of ensuring that the scanning speed is uniform at any point on the photosensitive drum is used as the condensing lens.

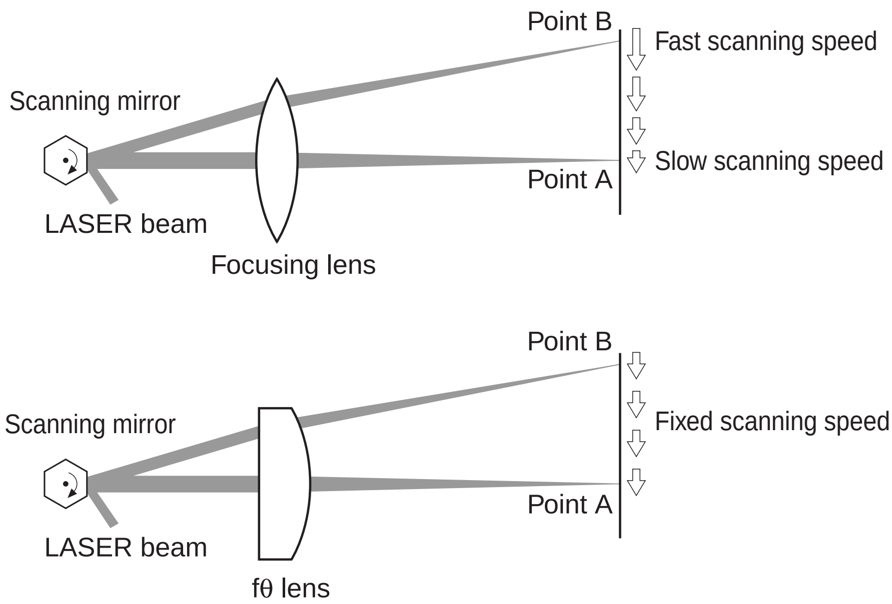

Fig. 4-39 Condensing Lens

4.6 Printing Process

The printing process comprises the six steps shown below.

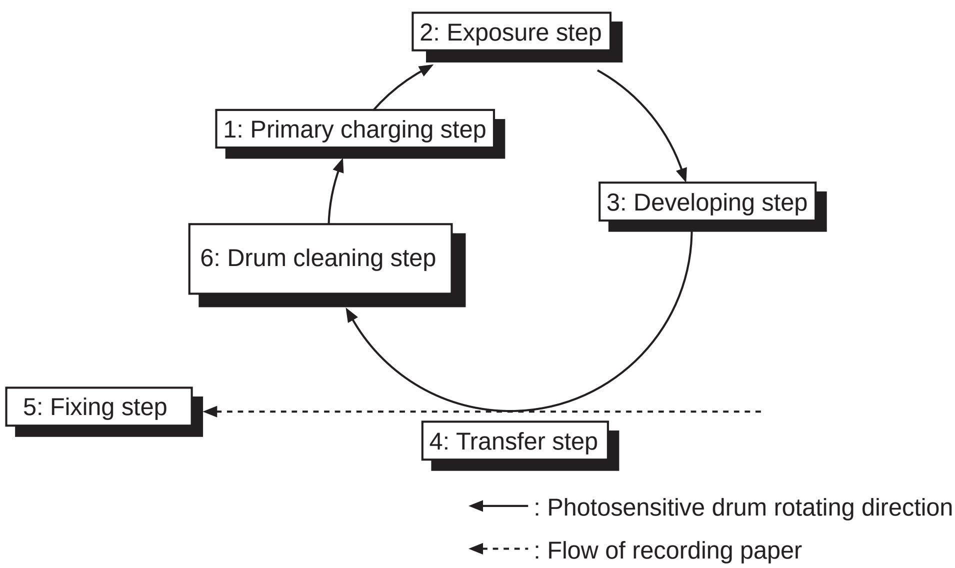

Fig. 4-40 Printing Process

(1) Primary charging step

In this step, the surface of the photosensitive drum is charged with a negative electrical charge by a roller charging system.

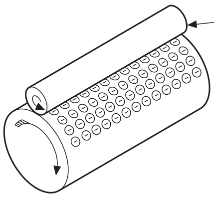

Fig. 4-41 Primary Charging Step

(2) Exposure step

In this step, the LASER beam draws the image (area where the charge has disappeared) on the photosensitive drum.

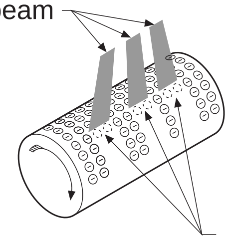

Fig. 4-42 Exposure Step

(3) Developing step

In this step, toner is attached to this invisible image on the photosensitive drum to change it to a visible image.

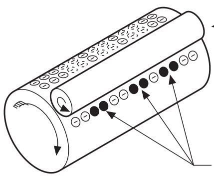

Fig. 4-43 Developing Step

(4) Transfer step

In this step, the toner (image) on the photosensitive drum is transferred onto the recording paper.

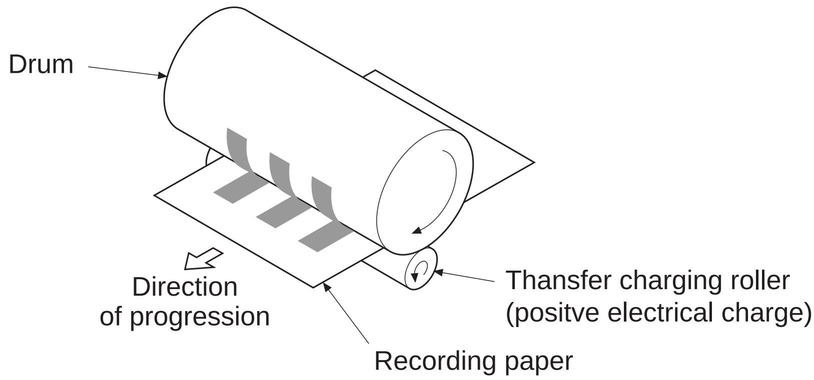

Fig. 4-44 Transfer Step

(5) Fixing step

In this step, the toner transferred onto the recording paper is fused on the recording paper to form a permanent image.

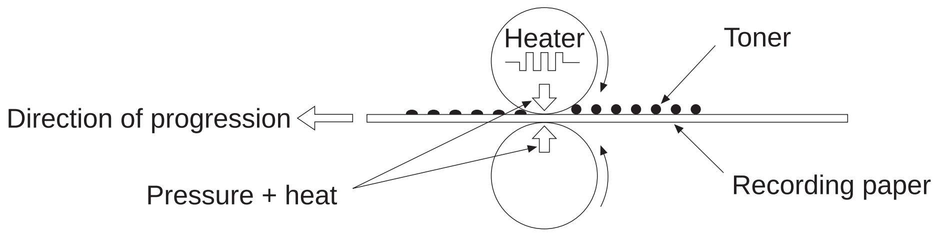

Fig. 4-45 Fixing Step

(6) Drum cleaning step

In this step, the remaining toner is removed from the photosensitive drum

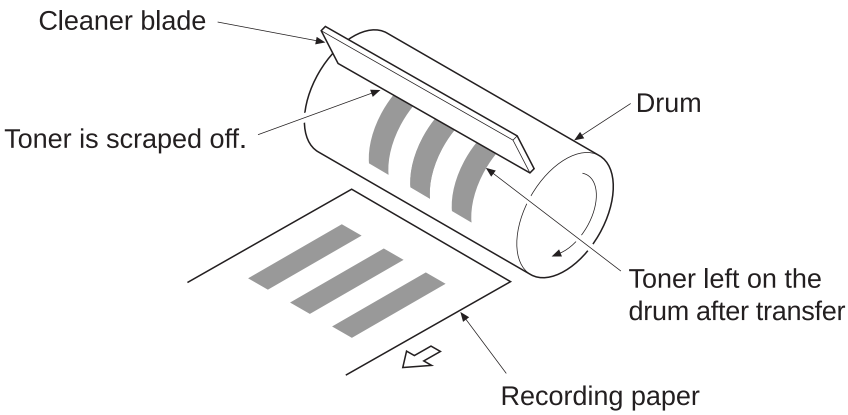

Fig. 4-46 Drum Cleaning Step

Next, let's explain each step in a little more detail.

- Primary charging step

DC bias and AC bias of several thousand volts is applied to the primary charging roller. As the electrical potential of the photosensitive drum is higher than that of the primary charging roller, the negative electrical charge that was generated on the primary charging roller moves to the photosensitive drum.

This charging method is called "roller charging" because of the fact that the photosensitive drum is charged by the primary charging roller. The AC bias functions to maintain the electrical potential of the negative electrical charge on the photosensitive drum at an uniform value. The DC bias changes proportionately to the DC bias applied to the developing cylinder.

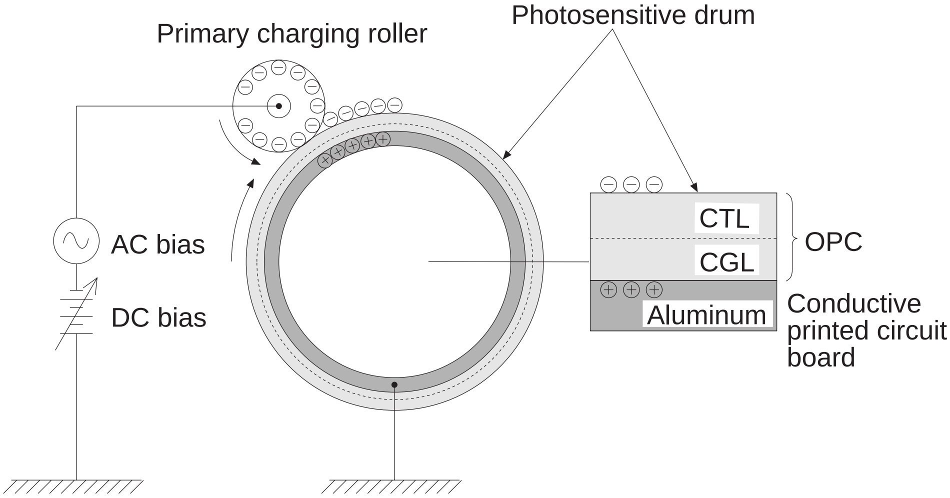

Fig. 4-47 Primary Charging

NOTE

Photosensitive drum

The photosensitive drum is an important component in forming images, and comprises a photosensitive layer and an aluminum substrate. Generally, an OPC (Organic Photo Conductor) is used as the photosensitive layer. This OPC comprises a CTL (Carrier Transport Layer) and a CGL (Carrier Generation Layer). When light strikes the photosensitive drum, positive and negative electrical charges are generated in the CTL, and the CGL carries only the positive electrical charge to the surface of the photosensitive drum.

- Exposure step

A uniform negative electrical charge is on the photosensitive drum. When the LASER beam is irradiated on the photosensitive drum in this state, the negative electrical charge of the areas irradiated by the LASER beam changes state in the neutralization direction (positive direction). Accordingly, an electrical potential difference occurs between the areas irradiated by the LASER beam and areas not irradiated to form an image on the photosensitive drum. Of course, this image cannot be seen by the human eye.

This invisible image is called an “electrostatic latent image,” the area on the photosensitive drum irradiated by the LASER beam a “light area” and the area not irradiated a “dark area.”

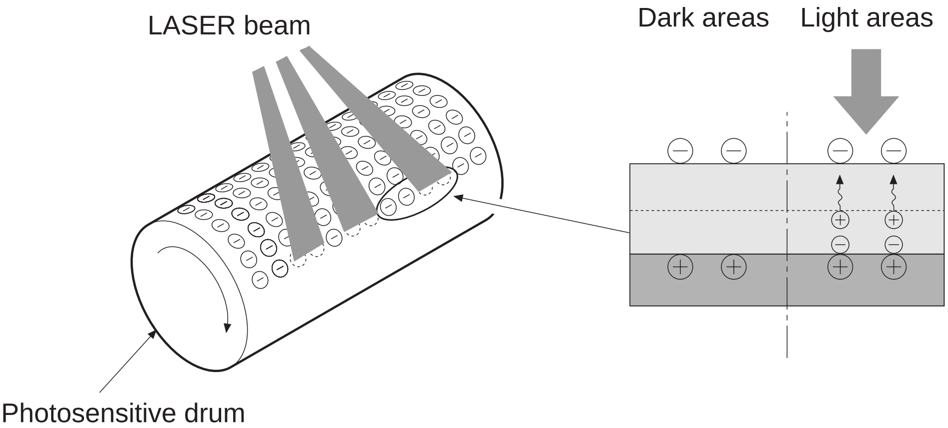

Fig. 4-48 Exposure

NOTE

In actual fact, the negative electrical charge of the area irradiated by the LASER beam is not completely neutralized to become “0”. This means that the negative electrical charge becomes higher than that of the area not irradiated by the LASER beam.

- Developing step

The developing cylinder comprises a magnet and sleeve. First, the toner is charged to have a negative electrical charge by the friction between with the rotating developing cylinder. The toner is then attracted by the magnet to be held in contact on the sleeve. The toner on the sleeve is regulated by the blade to form a uniform layer of toner on the surface of the sleeve. The potential of the AC bias previously applied to the developing cylinder changes, and toner jumps to the electrostatic latent image section on the surface of the photosensitive drum when the electromagnetic field between the surface of the developing cylinder and the electrostatic latent image section on the surface of the photosensitive drum becomes stronger than the force of the magnetic that is attracting the toner. This development is called the “toner projection development.”

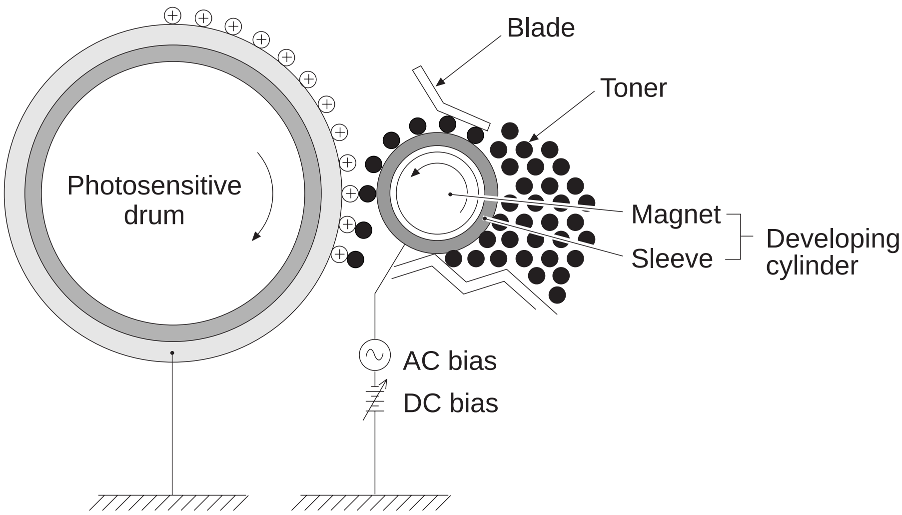

Fig. 4-49 Development

DC bias is also applied to the developing cylinder in addition to the AC bias. This DC bias is the center of the amplitude of the AC bias voltage. Accordingly, the peak of the AC bias voltage changes by varying the DC bias. The AC and DC biases adjust the amount that the toner jumps and works to improve the contrast of the image.

Next, let’s explain the function of toner during development.

- Light areas on the photosensitive drum ("black" image areas)

(1) Here, toner is made to cling on the light areas on the surface of the photosensitive drum. There also exists a difference between the electrical potential of light areas and the electrical potential of the developing cylinder. This difference is in a mutual relationship where the electrical potential of light areas is greater than the electrical potential of the developing cylinder. Accordingly the light areas on the photosensitive drum try to attract toner. The toner frees itself from the magnet to jump to light areas.

(2) Here, excess toner cling to light areas on the surface of the photosensitive drum is removed to improve contract. There also exists a difference between the electrical potential of light areas and the electrical potential of the developing cylinder. This difference is in a mutual relationship where the electrical potential of light areas is smaller than the electrical potential of the developing cylinder. Accordingly, as the developing cylinder tries to attract toner, the toner returns to the developing cylinder. Note, however, that as the difference between the electrical potential of light areas and the electrical potential of the developing cylinder is slight, this does not mean that all toner cling to light areas returns.

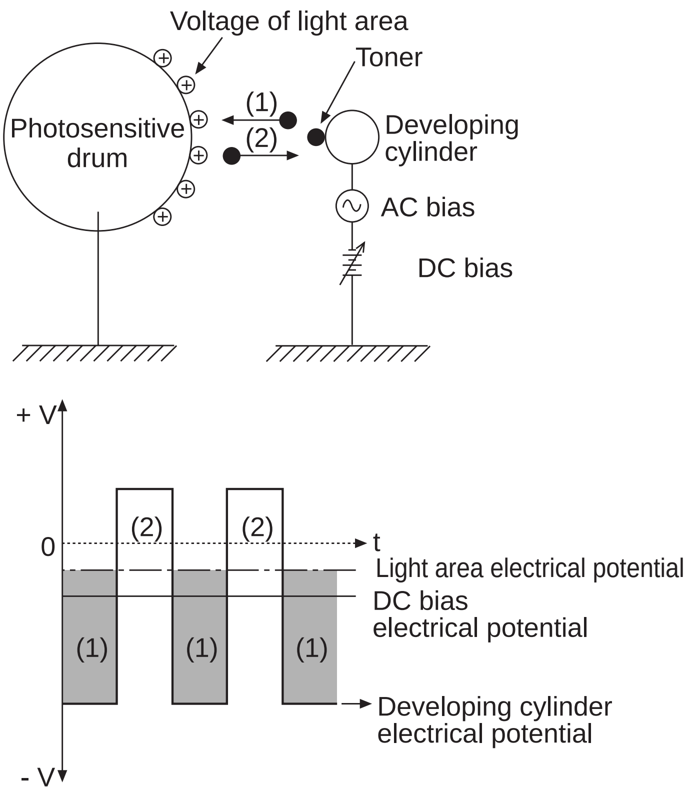

Fig. 4-50 Function of Toner (light areas)

- Dark areas on the photosensitive drum (“white” image areas)

(3) Here, toner cling to dark areas though in small amounts. There also exists a difference between the electrical potential of dark areas and the electrical potential of the developing cylinder. This difference is in a mutual relationship where the electrical potential of dark areas is greater than the electrical potential of the developing cylinder. Accordingly the dark areas on the photosensitive drum try to attract toner. The toner frees itself from the magnet to jump to dark areas though in small amounts.

(4) Here, excess toner cling to dark areas on the surface of the photosensitive drum is removed to prevent “fogging.” There also exists a difference between the potential of dark areas and the potential of the developing cylinder. This difference is in a mutual relationship where the potential of dark areas is smaller than the potential of the developing cylinder. As the mutual difference between electrical potentials is large, toner returns to the developing cylinder as the developing cylinder tries to attract the toner.

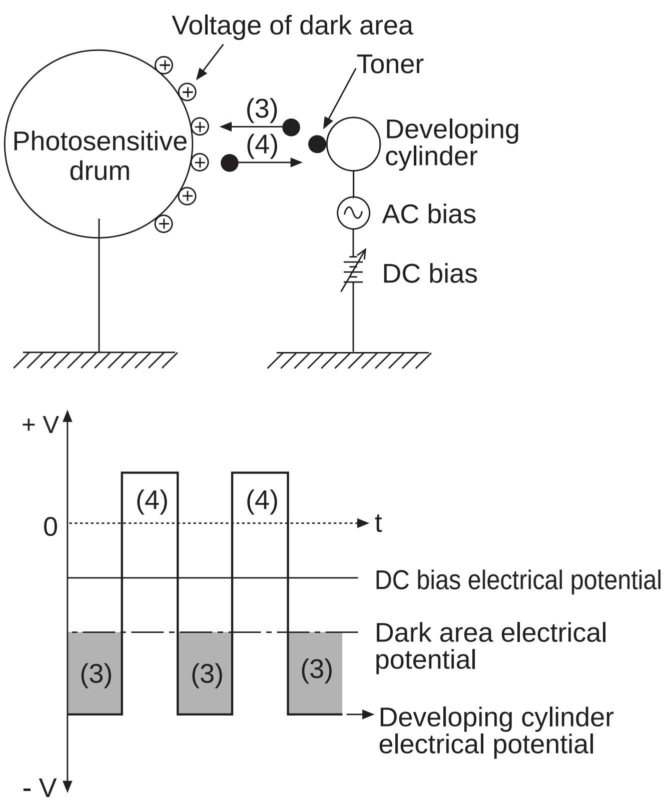

Fig. 4-51 Function of Toner (dark areas)

NOTE

About Toner

There are two types of toner, single-component toner and double-component toner. Single-component toner is used on Canon facsimiles, and comprises mainly resin and magnetic substance.

Print Density Adjustment

To adjust the density of the image to be printed, change the DC bias applied to the developing cylinder. To lighten the density, heighten the DC bias, and to darken the density, lower the DC bias. The print density can be adjusted using the density adjustment dial or user registration switches.

- Transfer step

When the recording paper is charged with the positive electrical charge from the rear surface via the transfer charging roller, the positive electrical charge moves to the surface of the transfer roller. As the toner has a negative electrical charge, the toner is transferred onto the recording paper. This method is called the “roller transfer method.” After the toner is transferred, the charge remaining on the recording paper is removed by the static charge eliminator, and the recording paper is separated from the photosensitive drum by the curvature separation method.

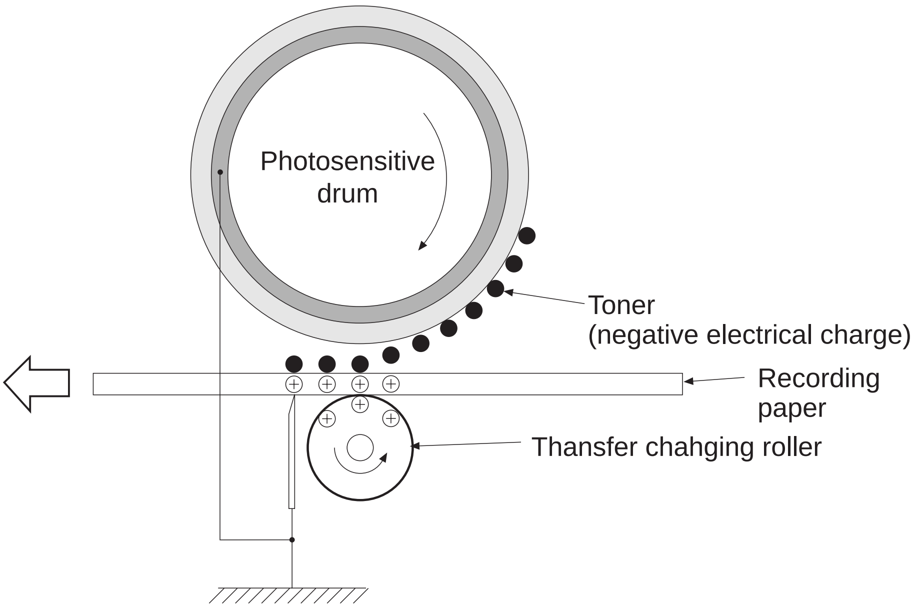

Fig. 4-52 Transfer

NOTE

Curvature Separation and Static Charge Eliminator

As shown in Fig. 4-52, recording paper tends to be wound onto the photosensitive drum more easily after toner has been transferred. For this reason, the recording paper separates naturally from the photosensitive drum due to the strength of the recording paper itself as a result of the outside diameter of the photosensitive drum being reduced. This is called “curvature separation.”

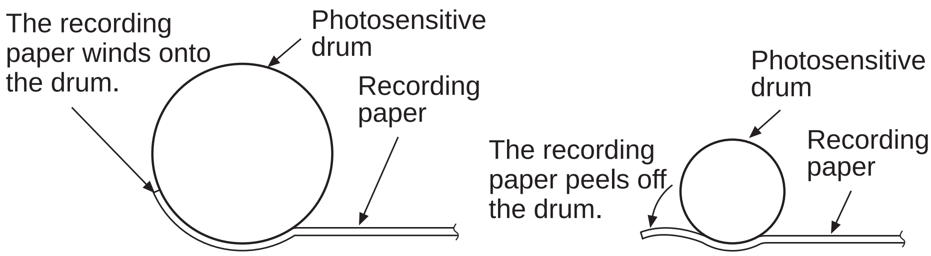

Fig. 4-53 Curvature Separation

As even light-stock recording paper tends to wind onto the photosensitive drum, the electrical charge remaining on the recording paper is removed by the static charge eliminator.

• Fixing step

The toner that is transferred to the recording paper is turned into a permanent image by applying heat and pressure. This fixing method is called the “heat fixing method.” This item describes the SURF fixing method (sometimes referred to as “on-demand fixing method”) that is the mainstream heat fixing method today. The fixing roller has a built-in heater which heats the roller surface to a temperature of about 160 to 200°C during printing. When the recording paper on which toner is cling passes between the fixing film and the fixing press roller, the toner melts as a result of the heat, and is fixed to the recording paper by pressure.

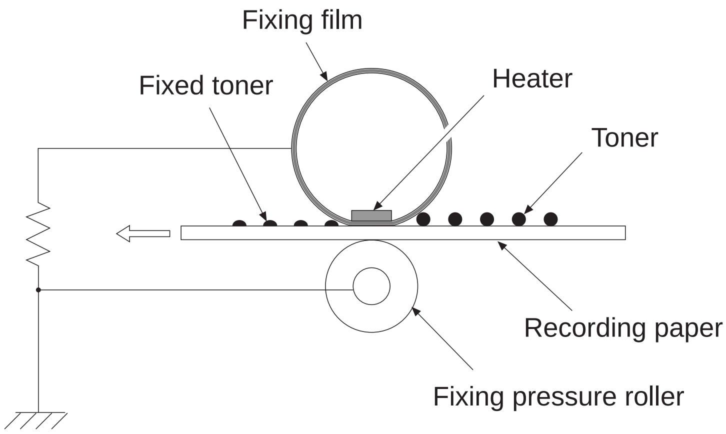

Fig. 4-54 Fixing

Generally, fluorine-coated polyimide film is used as the fixing film. The reason why the film is coated with fluorine is to prevent the adhesion of toner onto the fixing film. Silicon rubber is used on the fixing pressure roller.

NOTE

SURF Fixing

As the fixing film is thin and has little heat capacity, the temperature of the fixing film instantaneously rises to a fixable temperature when it is heated by the heater. Accordingly, the heater is turned OFF in a standby state, and the heater is turned ON only when printing is performed. This fixing method is called the “SURF fixing method” or the “on-demand fixing method.”

Nip Width

The fixing pressure roller presses the fixing roller by coil springs on the left and right. The area where the fixing press roller presses the fixing roller is called the "nip," and the width of this nip section is called the "nip width." The nip width is stipulated, and sometimes is the cause of faulty fixing or skewing of the recording paper when it is outside the stipulated range.

- Drum cleaning step

After toner transfer, an extremely slight amount of toner remains on the photosensitive drum without being transferred to the recording paper. For this reason, the toner remaining on the photosensitive drum is removed, in this step. This step involves rotating the photosensitive drum, and scraping off the remaining toner from the photosensitive drum to clean the surface of the drum. After being scraped off the photosensitive drum, the toner is collected in the waste toner container inside the cartridge.

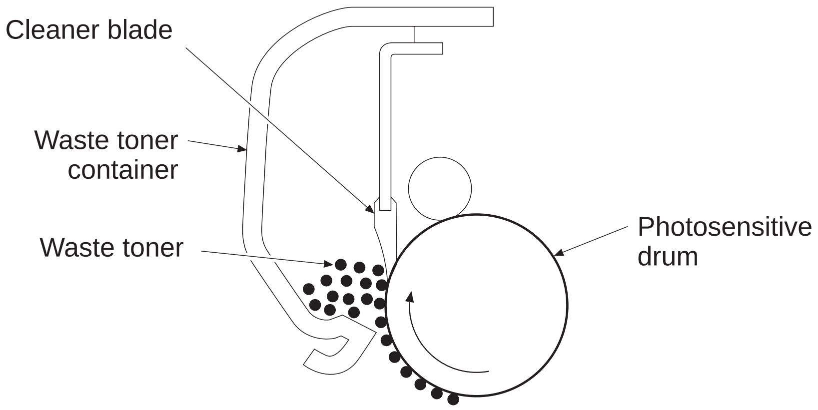

Fig. 4-55 Drum Cleaning

4.7 Toner Cartridge

Fig. 4-56 shows the structure of the toner cartridge. This toner cartridge contains the primary charging roller, photosensitive drum and developing cylinder.

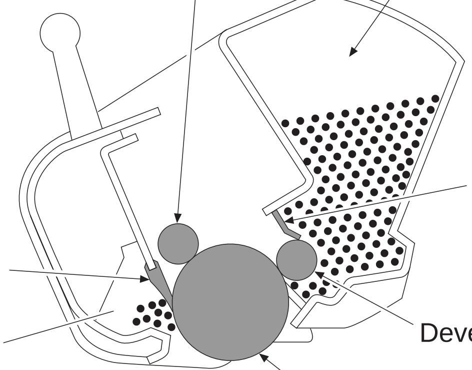

Fig. 4-56 Structure of Toner Cartridge

Next, let's describe the types of toner cartridges and toner detection methods used in facsimile products.

Cartridge Type	Toner Detection Method
FX-V/FX-VII	Antenna sensor method
FX-1/FX-2	LED method
FX-3/FX-4	Magnetic sensor method

- Antenna sensor method

The developing cylinder and antenna sensor are electrostatically joined. When a voltage is applied to the developing cylinder, a voltage is also generated to the antenna sensor. The voltage generated to the antenna sensor changes according to the amount of toner. Toner is judged to be absent when the amount of toner falls and the output voltage of the antenna sensor falls below a certain stipulated value.

- LED method

Light is irradiated on a photo-transistor on the outside of the cartridge from the LED under the cartridge. Toner is judged to be absent when the output voltage of the photo-transistor falls below a certain stipulated value.

- Magnetic sensor method

  A magnetic sensor is pressed against the side of the toner container in the cartridge to detect the amount of toner in the toner container. The magnetic field generated by the toner, which is a liquid, generates a voltage on the coil inside the magnetic sensor. Toner is judged to be absent when the output voltage applied to this coil falls below a certain stipulated value.

NOTE

When There is No Toner Detection Method

The toner detection function may not necessarily be needed if the facsimile is used only as a printer. The reason for this is that a new toner cartridge should be loaded and printing should be executed again if the print image is faint or printed as blank. What should we do for a facsimile? If the print image is faint after the image has been received, we must contact the other party and ask them to send again. Alternately, if a received print image is blank, it is impossible to know where the image was transmitted from. Accordingly, facsimile products have a toner detection function. When the toner cartridge runs out of toner, received messages are stored to memory, and are printed when a new toner cartridge is loaded.

4.8 BJ (Bubble Jet) Printer

With a BJ printer, the ink is made to bubble to change the state of the ink and cause ink drops to be ejected to print the image by suddenly changing the state of the ink by heat generated from the heater.

4.9 Printing by Bubbles

The following figure shows the operating principle of BJ printing.

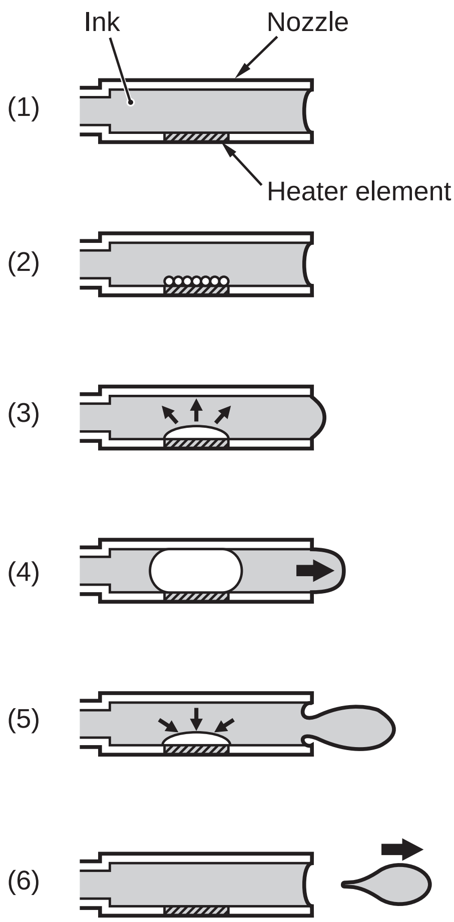

Fig. 4-57 Principle of Operation of BJ Printing

(1) The nozzle is charged with ink.

(2) The ink on the heater surface is suddenly heated to form small bubbles when the heater is turned ON in an extremely short period.

(3) The ink suddenly vaporizes for form bubbles.

(4) The bubbles expand to maximum size, and an ink drop is pressed outside the nozzle.

(5) The heater temperature drops and the bubble suddenly shrinks. This causes the ink that was pressed outside to form into liquid.

(6) When the heater temperature drops further, the ink drop flies out of the nozzle. The ink that flies out of the nozzle is charged in the nozzle from the ink tank by capillary phenomenon.

4.10 Printing Section

The printing section is broadly divided into the following three parts:

- Carriage section
- Purge unit
- BJ cartridge

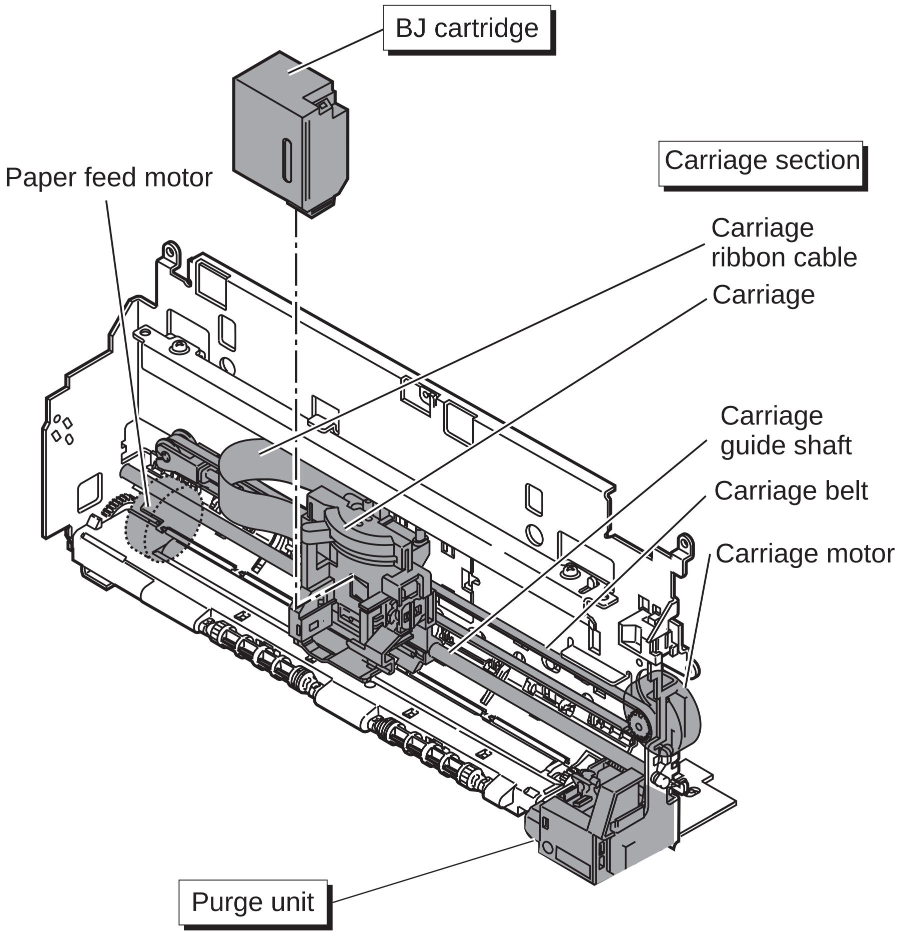

Fig. 4-58 Printing Section

4.11 Carriage Section

The carriage section comprises the following five mechanisms:

- BJ cartridge loading mechanism
- Carriage drive mechanism
- Print deviation compensation mechanism
- Paper feed motor drive switching mechanism
- Pumping operation state detection mechanism

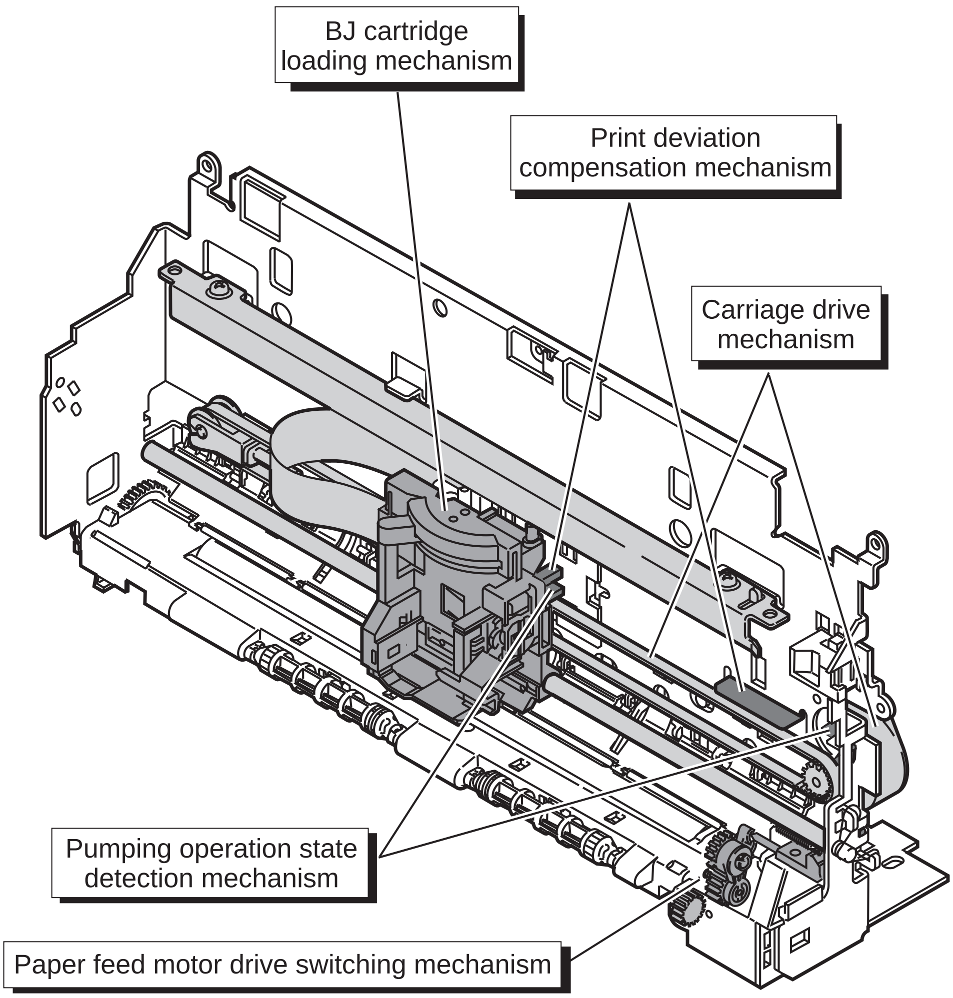

Fig. 4-59 Carriage Section

- BJ cartridge loading mechanism

The BJ cartridge is fixed mechanically onto the cartridge holder. At the same time that it is fixed onto this holder, the BJ cartridge pressure contacts the signal contact pad of the carriage ribbon cable to form an electrical connection. By this connection, signals such as print signals are sent to the BJ print head. The printer control section monitors the mounted state of the BJ cartridge at all times, and judges that there is no cartridge if the BJ cartridge head is not electrically connected with the signal contact pad of the carriage ribbon cable for a certain period or more.

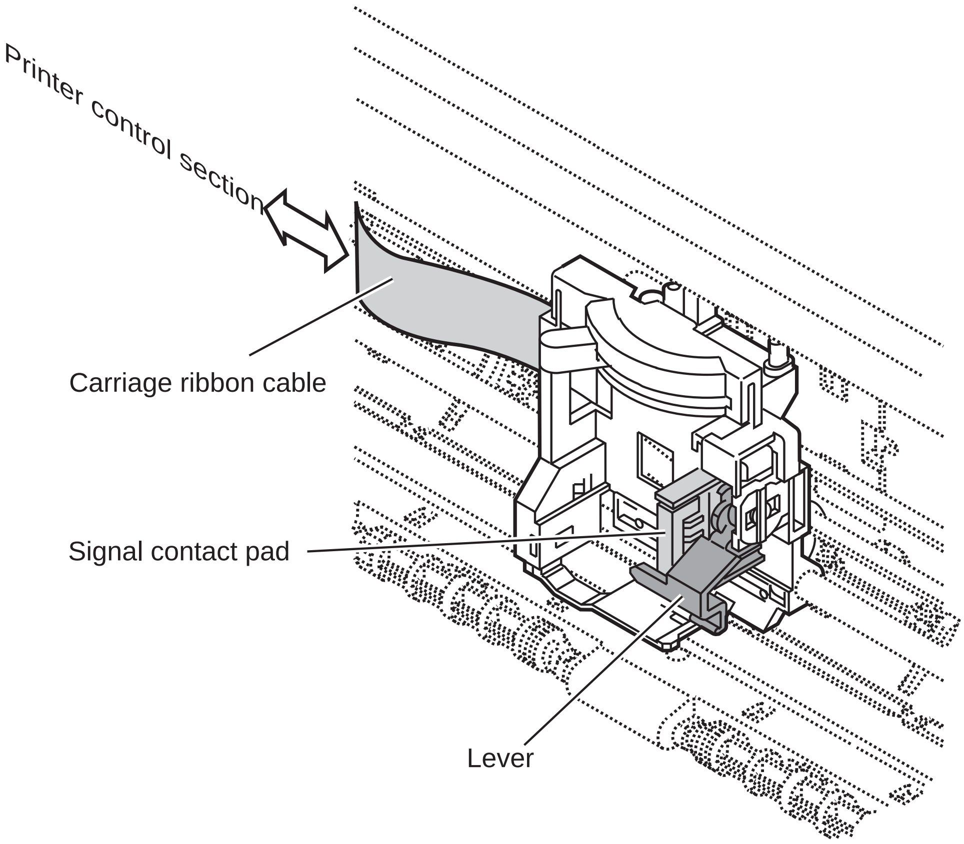

Fig. 4-60 BJ Cartridge Loading Mechanism

- Carriage drive mechanism

The carriage is installed on the carriage belt, carriage guide shaft and carriage guide rail, and moves reciprocally in the horizontal direction by power from the carriage motor. The carriage position is detected by the home position (photo-interrupter) sensor installed at the rear side of the carriage. When printing is started, the home position (carriage reference position) is detected by the home position sensor passing the light-shading plate of the printer frame. During printing, the carriage position is judged by the printer controller counting the number of motor drive pulses.

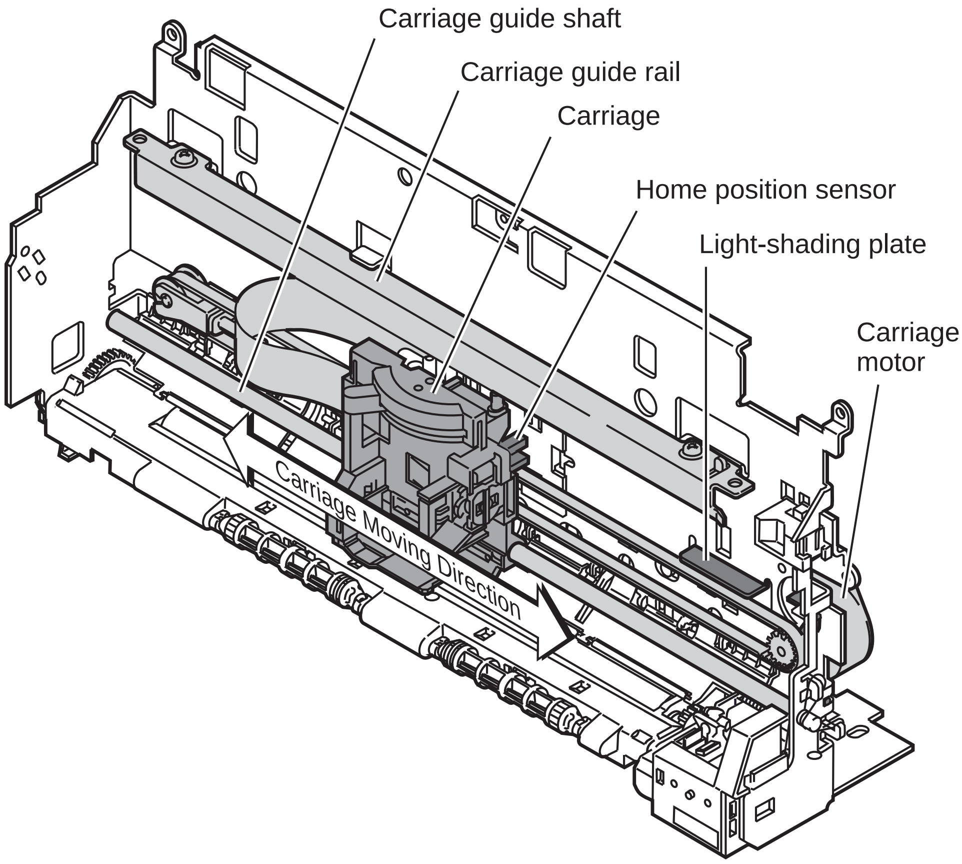

Fig. 4-61 Carriage Drive Mechanism

- Print deviation compensation mechanism

The carriage motor load is adjusted and the carriage position is compensated to prevent print deviation caused by changes in the BJ cartridge weight and error during bi-directional printing. During detection of the home position at the start of printing, the error between the reference value and the measured value in the home position detection timing is detected so that the printer controller can compensate the carriage position.

- Paper feed motor drive switching mechanism

  The recording paper is fed and cleaning performed by switching the power of he paper feed motor.

  (1) During recording paper feed

  The power in the forward direction of the paper feed motor is transmitted to the paper feed roller to feed the recording paper. At this time, the carriage is at the home position, and the pendulum gear is fixed by the control pin inside the purge unit.

  (2) During pumping operation

  The pendulum gear is released by the carriage moving to the home position and pressing the control pin, and the purge drive gear is coupled with the pendulum gear. Power in the reverse direction of the paper feed motor is transmitted to the purge drive gear inside the purge unit via the feed roller and pendulum gear to perform pumping.

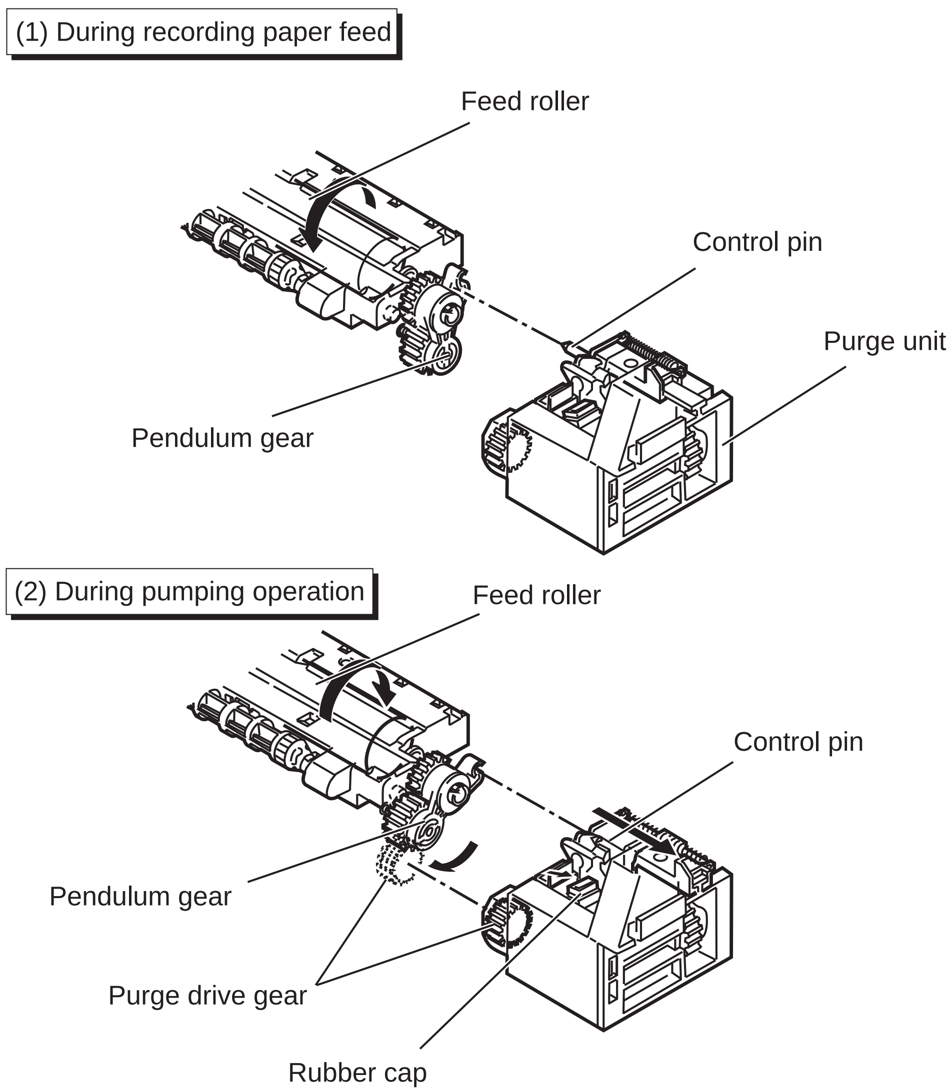

Fig. 4-62 Paper Feed Motor Drive Switching Mechanism

NOTE

Home Position Sensor

The maintenance jet absorber on the purge unit is the home position (carriage reference position) of the carriage. When the carriage is not at the home position (carriage reference position), a home position error occurs. Even if image data is received during a home position error, printing is not performed, and the received image data is stored to memory. When the error is canceled, the received image data in memory is printed.

- Pumping operation state detection mechanism

When the carriage moves to the home position, the home position sensor switches to the sensor for detecting the pumping operation state. The home position sensor detects the pumping operation state by the movement of the actuator arm that is interlocked with the pumping operation control cam inside the purge unit.

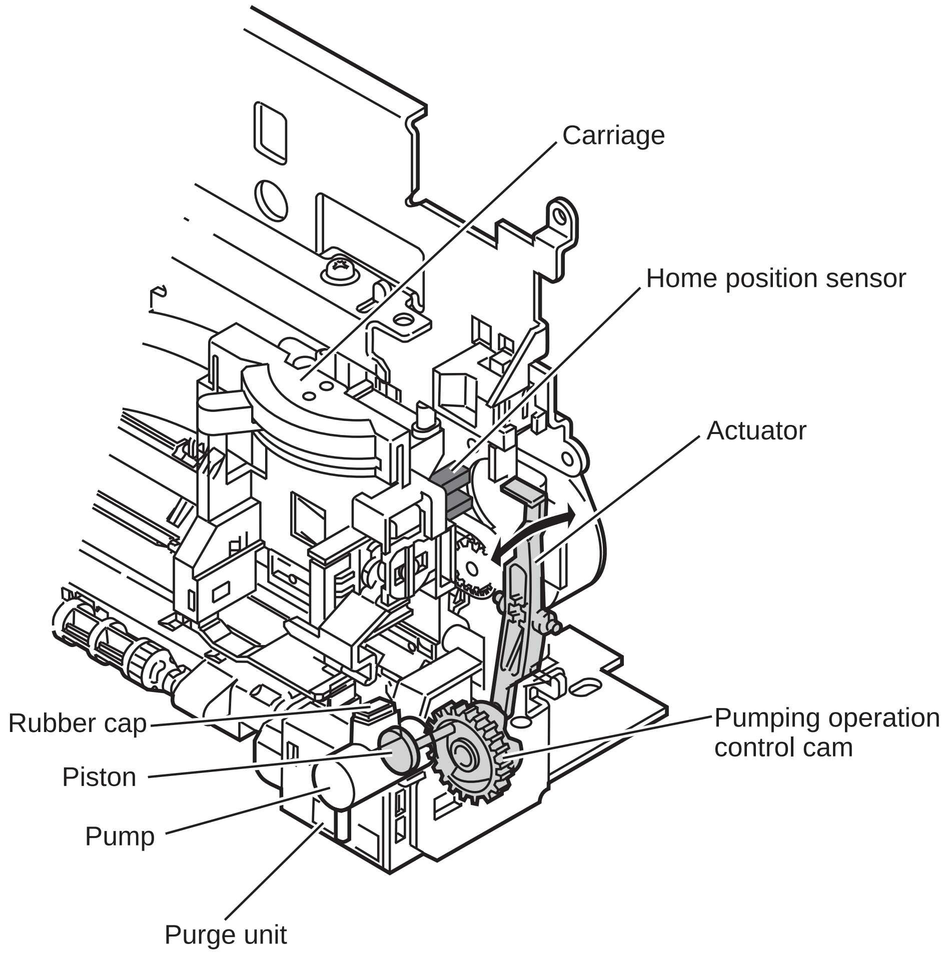

Fig. 4-63 Pumping Operation State Detection Mechanism

4.12 Purge Unit

The purge unit performs cleaning operation.

The purpose of cleaning is to eliminate defective printing caused by faulty ejection discharge of ink from the BJ cartridge. Cleaning involves the following four operations:

- Capping operation
- Pumping operation
- Wiping operation
- Maintenance jet operation

Cleaning is performed automatically at the following times:

- When the BJ cartridge is replaced
- When a fixed amount of time has elapsed since the previous cleaning before the power is turned ON and before printing
- When the ink discharge count has reached the preset count during printing

Manual cleaning initiated by the user is also possible.

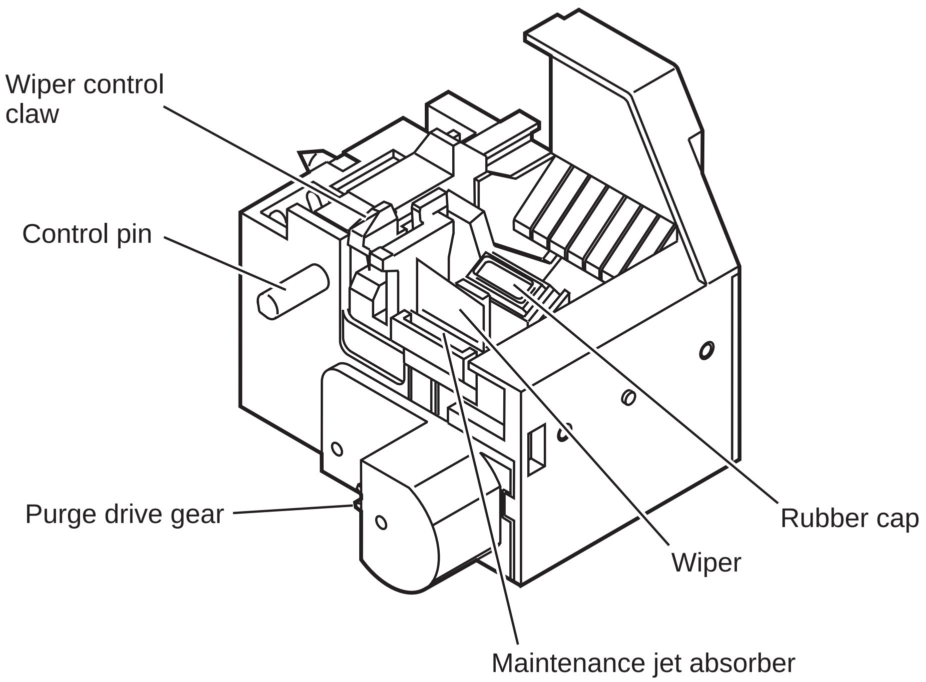

Fig. 4-64 Purge Unit

- Capping operation

  This operation functions to prevent the drying of ink, ink leakage and the adhesion of dust on the BJ print head. The rubber cap on the pump rotates several tens of times by the carriage pressing the control pin when it moves to the home position, and covers the nozzle outlets on the BJ cartridge. After a fixed period of time has elapsed after image data has stopped arriving, capping operation is automatically performed.

- Pumping operation

  When capping is canceled, and the BJ print head is released from the cap, the pump sucks out ink via the rubber cap and the ink is blown out to the waste ink sheet. The inside of the nozzles on the BJ print head are then filled with fresh ink. This operation is called “pumping.” Pumping removes unwanted air bubbles and impurities together with ink from inside the nozzles.

- Wiping operation

  The surface of the nozzles is wiped by a wiper. This operation is called “wiping.” Wiping removes unwanted ink droplets and paper fiber from the surface of the nozzles.

- Maintenance jet operation

  After wiping, ink is blown out of the nozzles in the direction of the maintenance jet absorber. The purpose of this is two-fold, to prevent the nozzles on the BJ print head from clogging, and to correct the ink surface shape on nozzle outlets.

4.13 BJ Cartridge

4.13.1 Structure of bj cartridge

Fig. 4-65 shows the structure of the BJ cartridge.

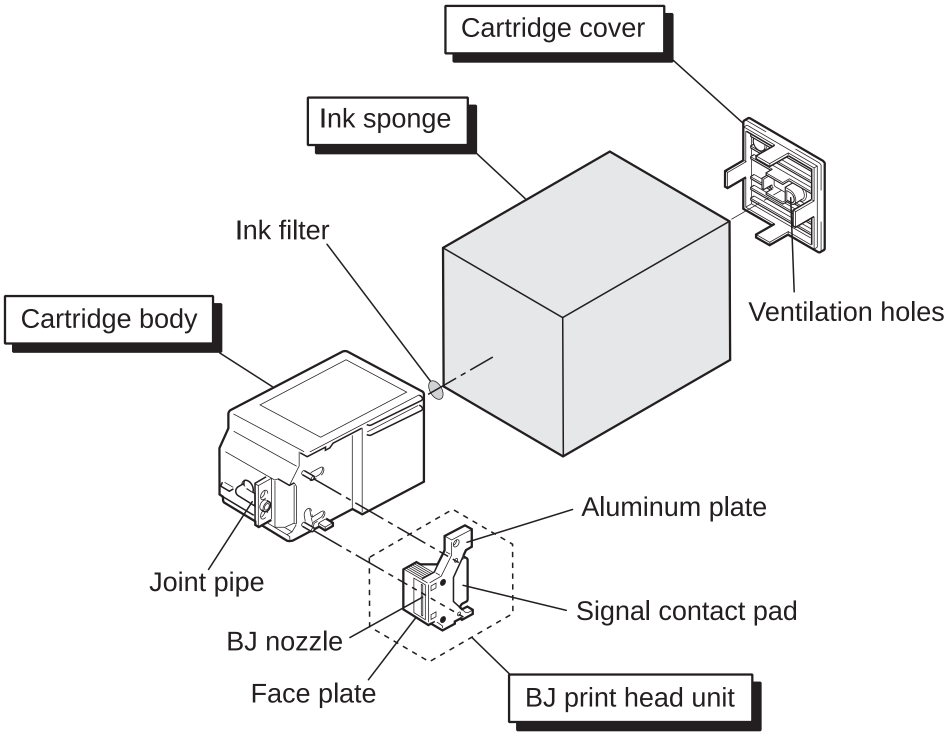

Fig. 4-65 Structure of BJ Cartridge

- Cartridge cover

  This plastic cover is bonded to the cartridge body to prevent ink leakage from inside the cartridge. As ink is consumed, the pressure inside the cartridge body falls below atmospheric pressure, and supply of ink to the head is prevented. The ventilation holes on the cartridge cover maintain the inside of the cartridge body at a fixed pressure to prevent this phenomenon.

- Ink sponge

  This sponge is soaked with ink, and is contained inside the cartridge body in a compressed state.

- Cartridge body

  This plastic case couples the BJ print head unit to the ink sponge.

- BJ print head unit

The ink that is supplied from the ink sponge is sent to the BJ nozzles according to print signals that arrive from the signal contact pad.

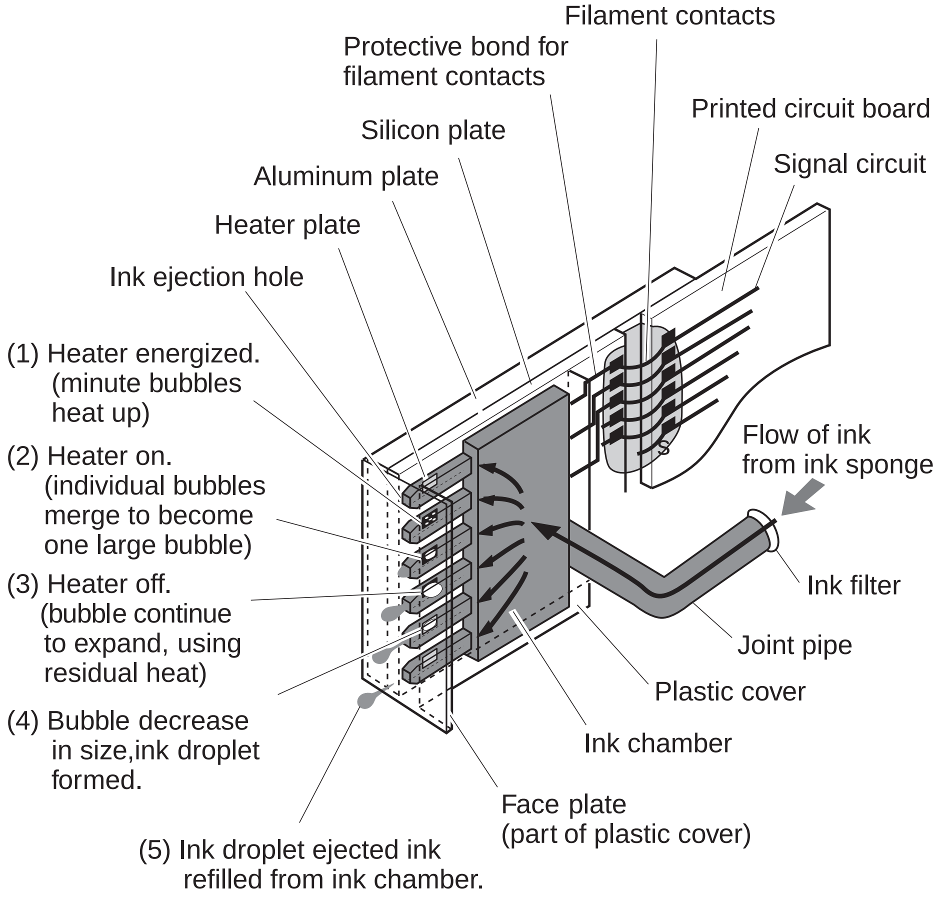

Fig. 4-66 BJ Print Head

The ink in the ink sponge is filtered by the ink filter to remove any dust, and is sent to the BJ nozzles via the joint pipe. When head drive current flows to the heater plate inside the nozzles, the ink boils to be formed into numerous bubbles. Eventually, these bubbles become a single boiling bubble. Though the head drive current is stopped before the ink droplets leave the nozzles, bubbling by remaining heat from the heater continues to discharge ink droplets from the nozzle tips. After ink droplets are ejected from the nozzles, the nozzles are charged with ink again from the ink sponge.

NOTE

There are two types of BJ cartridge: ink cartridge integrated type and ink cartridge separate type. When the latter type of BJ cartridge has run out ink, replacement of only the ink cartridge is possible. Generally, the ink cartridge is called the “ink tank.”

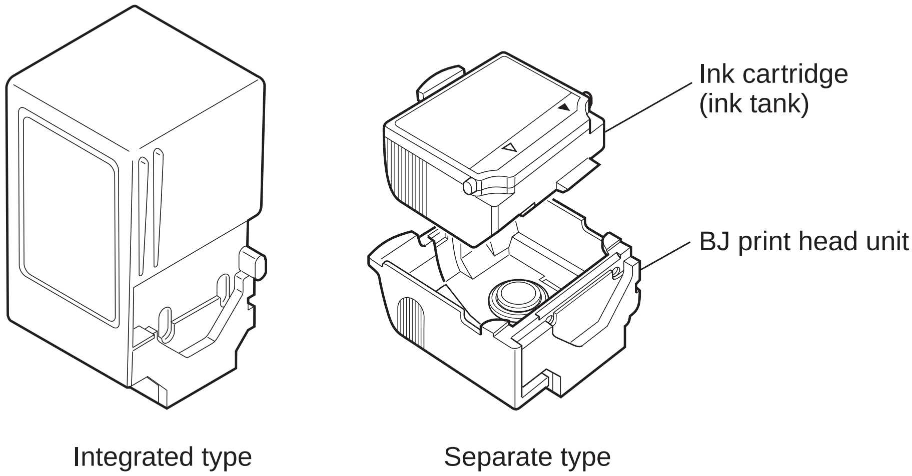

Fig. 4-67   BJ Cartridges (integrated type and separate type)

4.13.2 Types of bj cartridges

The following table shows the types of BJ cartridges used on facsimile products.

Type	Ink Retention State	BJ Print Head/ Ink Tank	Target Ink Tank
BC-01 black	Ink sponge	Integrated type	—
BX-2 black	Ink sponge	Integrated type	—
BX-3 black	Ink sponge and liquid	Integrated type	—
BC-10 black	Ink sponge	Separate type	BCI-10 black BCI-17 black
BC-11e color	Ink sponge	Separate type	BCI-11 black BCI-11 color
BX-20 black	Ink sponge	Integrated type	—
BC-20 black	Ink sponge	Integrated type	—
BC-21e color	Ink sponge	Separate type	BCI-21 black BCI-21 color
BC-22e photo	Ink sponge	Integrated type	—
BC-29F fluorescent	Ink sponge	Integrated type	—

4

4.13.3 Ink detection method

There are two types of ink detection methods: a light-transmitting type photo-interrupter method that uses an optical sensor and a reflecting-type photo-interrupter method. A dot count method that uses software to count the number of ink ejects (dot count) is incorporated in some products.

- Light-transmitting type photo-interrupter method

When the power is turned ON or at the end of printing, ink is ejected to the optical axis between the LED (light-emitting section) and the photo-transistor (light-receiving section. The presence of ink is detected by the change in photo-transistor output at this time. For the duration that ink is present, the amount of light reaching the photo-transistor decreases by the ejected ink. When there is no more ink, the amount of light reaching the photo-transistor does not change.

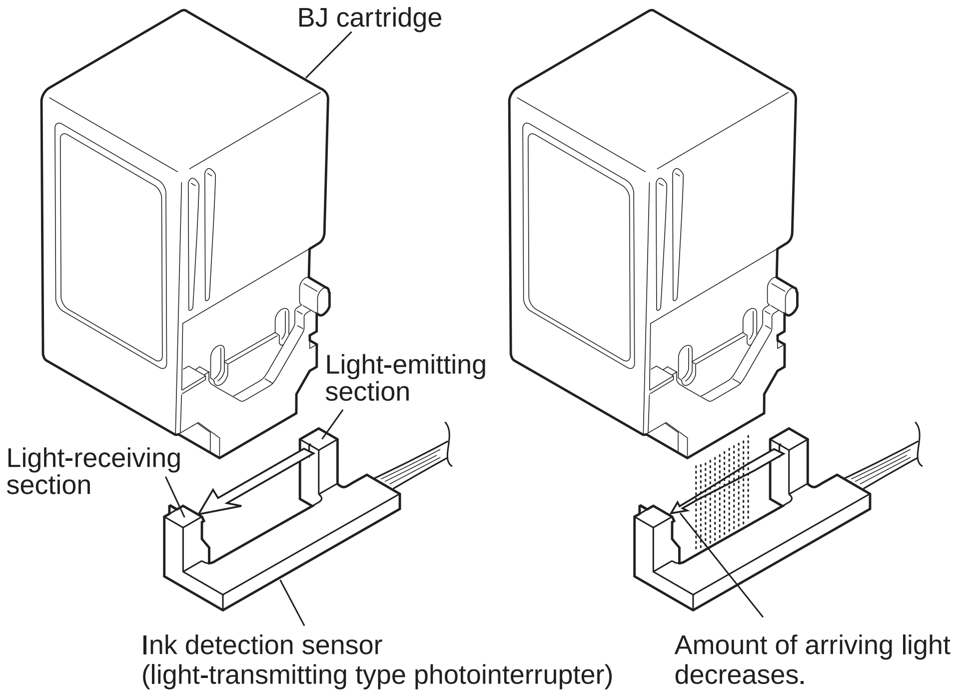

Fig. 4-68 Light-transmitting Type Photo-interrupter Method

- Reflecting-type photo-interrupter method

  At the end of printing, light is emitted from the LED (light-emitting section) in the direction of the footer mark (black) printed on the trailing edge of the recording paper, and the reflected light is detected by a photo-transistor (light-receiving section). The presence of ink is detected from the output of the photo-transistor at this time. For the duration that ink is present, the light is absorbed by the footer mark and does not reach the photo-transistor. When there is no more ink, the footer mark is not printed, and so light is reflected on the recording paper (white) and reaches the photo-transistor.

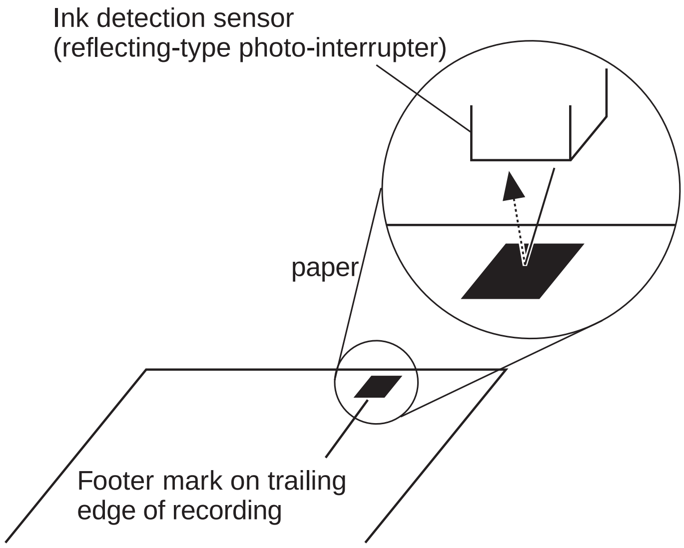

Fig. 4-69 Reflecting-type Photo-interrupter Method

- Reflecting-type photo-interrupter method + dot count method

  When the power is turned ON or at the end of printing, light is emitted from the LED (light-emitting section) in the direction of the ink tank filled with liquid ink (black), and the reflected light is detected by the photo-transistor (light-receiving section). The presence of liquid ink is detected by the photo-transistor output at this time.

  For the duration that there is liquid ink, light is absorbed by the ink, and does not reach the photo-transistor. When there is no more liquid ink, light is reflected onto the reflector plate (white) provided inside the ink tank, and reaches the photo-transistor. Note, however, at the point where the ink tank runs out of liquid ink, ink still remains absorbed by the ink sponge and the ink tank has not completely run out of ink. Counting of the number of ink ejects is started after the no liquid ink state has been detected, and it is judged that there is completely no more ink when the ink eject count reaches a specified number.

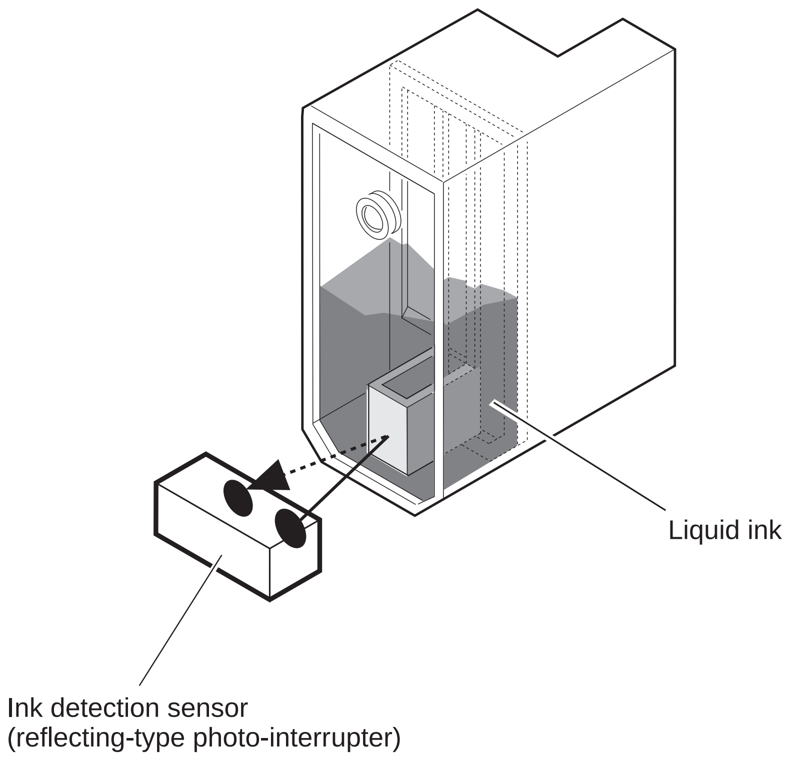

Fig. 4-70 Reflecting-type Photo-interrupter Method

CHAPTER **5**

G3 FACSIMILE COMMUNICATIONS

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1. INTRODUCTION

This chapter describes the fundamental technology and transmission control procedures relating to G3 facsimile communications.

2. WHAT IS A “G3 FACSIMILE?”

“G3 facsimile” is the general term for facsimiles made in compliance with ITU-T recommendations on an analog telephone line.
In the past, G1 facsimiles and G2 facsimiles were also used. However, G3 facsimiles have become the mainstream because of their good transmission speed and image quality. G3 facsimiles have the following features:
Features

- Image data is handled as groups of black and white dots.
- Coding and high-speed modulation are adopted.
- Various and diverse functions can be used as binary signals are adopted for control procedural systems.

NOTE

When G3 facsimiles first appeared on the market, they transmitted a A4-size standard document in about one minute. However, the document transmission time was drastically reduced by improvements made in MODEMs and coding schemes.
Standard A4 document transmission time: approx. 3 sec
(transmission in standard mode: V.34 MODEM installed facsimiles excluding control procedures.)

3. G3 FACSIMILE IMAGE TRANSMISSION

The following shows a block diagram of G3 facsimile image transmission.

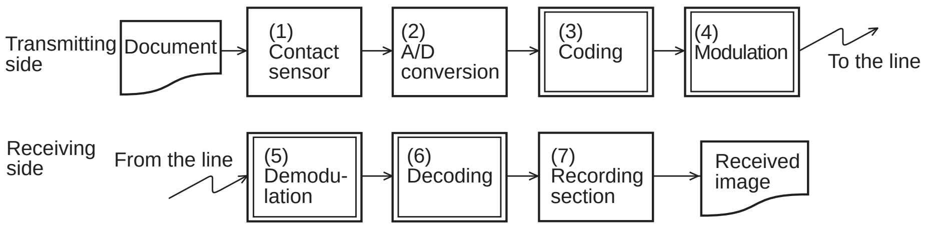


Fig. 5-1 Image Transmission by G3 Facsimile

Description of each block

(1) The document is converted to electrical signals by the contact sensor.

(2) After the document is converted, the electrical signals undergo A/D conversion to be converted to digital binary image data.

(3) The binary image data is compressed by coding to reduce the size of the data to be sent as much as possible. The resulting data is coded data.

(4) The coded data is converted to analog signals modulated by the MODEM, and is transmitted via the telephone line.

(5) The modulated analog signals are demodulated by the MODEM on the receiving side. The resulting data is digital coded data.

(6) The coded data is converted to binary image data by decoding.

(7) The binary image data is sent to the recording section to be printed.

5

This chapter describes (3) through (6).
(1) and (2) are described in Chapter 3, Reading Section, and (7) is described in Chapter 4, Recording Section.

3.1 Structure of Image Signals

Reading of the image is performed in each scanline in the horizontal scanning direction. The horizontal scanning line density is 8 dots/mm or 16 dots/mm. After one line is read, the next line is read at the pitch of the vertical scanning line density. There are three vertical scanning line densities: 3.85 lines/mm (standard mode), 7.7 lines/mm (fine mode) and 15.4 lines/mm (super-fine mode). Reading is also possible at 16 dots/mm × 15.4

lines/mm (ultra-fine mode) depending on the product. After the image is read, coding is performed successively in the horizontal scanning direction one scanline at a time.

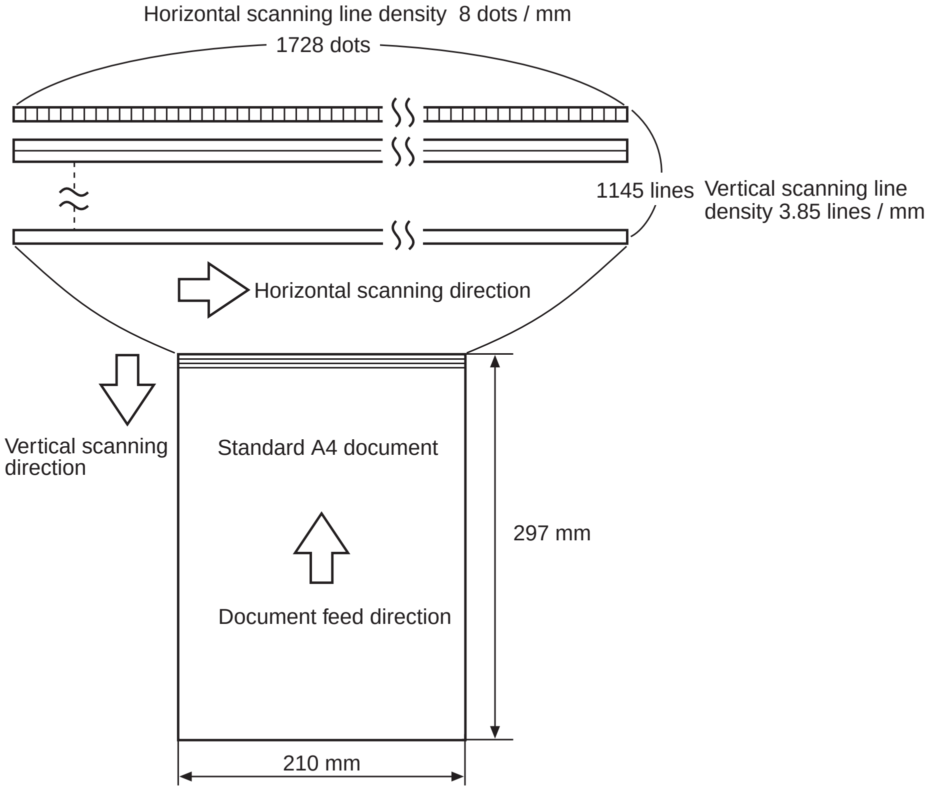


Fig. 5-2 Horizontal Scanning and Vertical Scanning (example of standard resolution)

Image signals on a G3 facsimile comprise one line's worth of read coded data, EOL, RTC and fills. The following describes the components of an image signal.

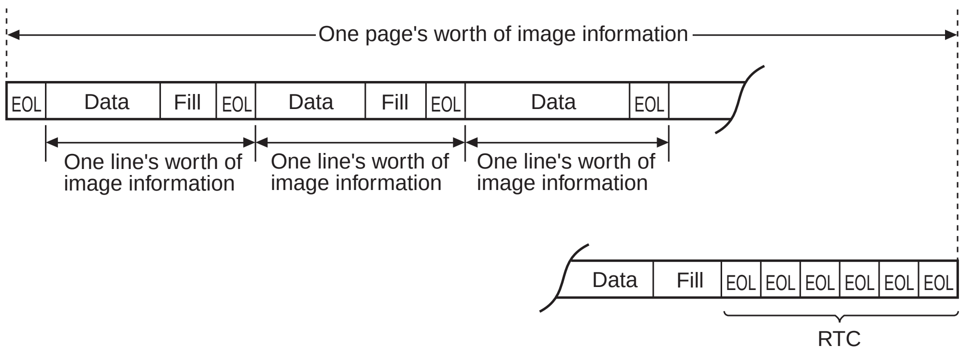


Fig. 5-3 Structure of Image Signals

- EOL (End Of Line)

A coded scanline in the horizontal scanning direction is transmitted consecutively from the 1st line. The end of each scanline is appended with a special signal called an "EOL" for distinguishing the delimiter of each line. The start of the 1st line is also prefixed with an EOL. For this reason, each coded line is enclosed by EOLs in each scanline in the horizontal scanning direction. EOL is a bit pattern of 12 bits 000000000001 (expressed as 001 in Hex).

- RTC (Return To Control)

  This special signal is appended onto the coded data of the final line to show the end of a single page in the document. RTC comprises six consecutive EOLs.

- Data

  This is the image data of one coded line. The data length of a line before it is coded is determined by the size of the document, and all of the lines of the document are the same length. However, as the data obtained by coding those lines is uneven depending on the image of each line, the length of the data is not fixed.

- Fill

  This signal is for adjusting the time to be inserted to prevent the transmission time of a single line from being shorter than the minimum transmission time) described later when the time obtained by combining the data and EOL is shorter than the minimum transmission time. Fills are a string of 0 bits, and their length is not fixed. These signals are removed from the image signal at reception.

5

3.2 Transmission Time

"Transmission time" is the time required to transmit image signals.

To determine the transmission time, the following three factors must be considered:

- Transmission speed (determined by modulation system)
- Image data compression method (determined by coding scheme)
- Minimum transmission time (determined by product specifications)

These three factors are inter-related so the transmission time cannot be determined by any single factor. Even if one is improved, it does not mean that the transmission time will be shortened.

3.2.1 Transmission speed

The transmission speed of a MODEM is determined by the currently adopted modulation system, and is expressed as bps (bits per second), in other words, by how many bits that can be sent in a second. When the same size of data is transmitted, the faster this transmission speed, the shorter the transmission time becomes. Normally, multiple transmission speeds are mounted on a MODEM, and communications is performed using the fastest transmission speed held by the two MODEMs on the transmitting side and the receiving side.

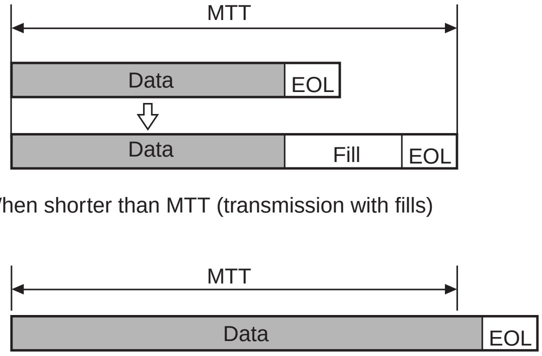
3.2.2 Image data compression methods

The image compression method is also called the “coding scheme.” When image data of the same size is compressed, the size of the data after compression changes depending on the coding scheme that is applied. In other words, the transmission time changes as the size of the data to be actually transmitted changes depending on which compression method was used to compress the data. The transmission time can be reduced by using a highly efficient compression method to reduce the size of the data.

3.2.3 Minimum transmission time

Time is required for executing processing in reading of documents and printing of received images. This time differs according to the machine type as it is determined according to mutual mechanical and electrical performance. On G3 facsimiles, the minimum time required to process each single line at transmission and reception is defined as the “minimum transmission time” (MTT) for expressing the processing capability of that machine.

If the transmitting side transmits without taking into consideration the processing capability of the receiving side, recording on the receiving side will not be able to keep up with reception, and communications will not be possible if, for example, the receiving side machine has a low processing capability. In other words, to ensure successful communications between facsimiles, the faster side must perform processing in keeping with the machine on the slower side. For this reason, during communications, both the transmitting and receiving side G3 facsimiles inform each of other of the MTT to prevent data shorter than the MTT of the slower of the two machines from being sent to prevent this kind of trouble. When a receiving side machine having an MTT of 20 ms communicates with a transmitting side machine having an MTT of 10 ms, the transmitting side inserts a fill after the data to adjust the length to 20 ms or more when the transmission time of a single line including the EOL is less than 20 ms, that is the MTT of the receiving side.



When shorter than MTT (transmission with fills)

When equal to or longer than MTT (transmission without fills)

Fig. 5-4 When Minimum Transmission Times Differ

By ITU-T recommendations, the standard minimum transmission time is set to 20 ms. Optional available times are 0 ms, 5 ms, 10 ms and 40 ms. A “0 ms MTT” means that the unit can receive without the need to insert any fills. For example, on a machine that allows one page’s worth of image data to be received to memory for image reception, the image can be received without any fills as there is no need to worry about the delay in print processing at reception.

Table 5-1 Types of Minimum Transmission Times

Minimum transmission time (ms)		
Reception		Transmission
Standard	Fine	
20	20	20
40	40	40
10	10	10
5	5	5
10	5	—
20	10	—
40	20	—
0	0	0

4. CODING SCHEMES

4.1 Why is Coding Necessary?

One of the features of a G3 facsimile is that image data is coded before it is transmit and received. The reason for coding is to reduce the size of the data to be actually transmitted to reduce the transmission time.

The following example shows by how much the transmission time can be reduced through coding.

Here, let's consider an example where an A4 document is transmitted at standard resolution.

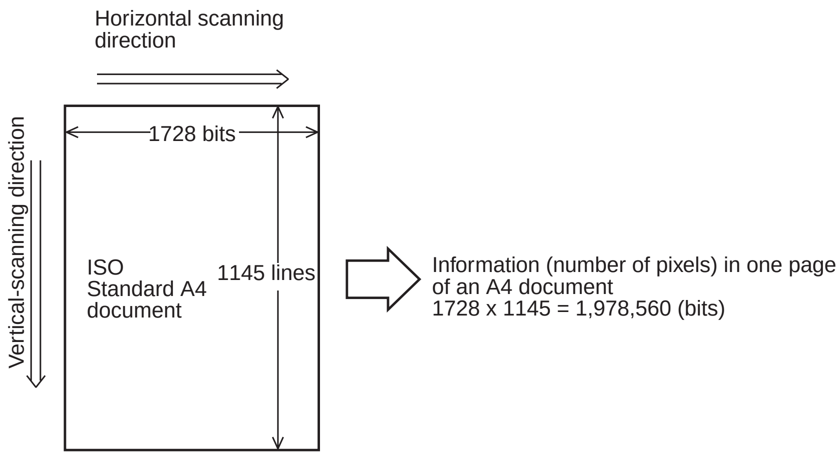
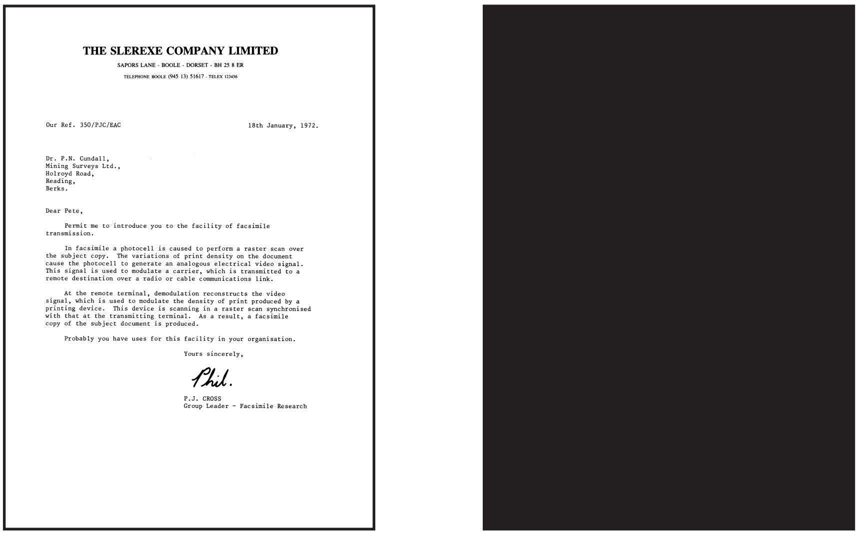


Fig. 5-5 Size of Information in One Page of an A4 Document

In this way, the size of information of a single A4-size page becomes roughly 2,000,000 bits. Let's try considering the time required to send 2,000,000 bits of information without coding.

When the document is transmitted using a 9600 bps MODEM, it takes three minutes 26 seconds, and when it is transmitted using a 14400 bps MODEM, it takes two minutes 17 seconds. Without coding, transmission of a standard A4 document will take longer than one minute. Why, then, can the transmission time be reduced with coding?

Normally, a document transmitted by a facsimile has lots of white areas. Text that is written in these white areas take on meaningful information. The white areas have no meaning. On a facsimile, white areas without text is "unwanted space," and black areas with text is "information." If an area is black, this does not necessarily mean that this is information; a completely black document, for example, has little "information" and can be termed a document having many "unwanted areas." The extent that these unwanted areas exist is called “redundancy”. The larger the redundancy, the greater the effect of coding becomes.



THE SLEREXE COMPANY LIMITED

SAPORS LANE - BOOLE - DORSET - BH 25 8 ER

TELEPHONE BOOLE (945 13) 51617 - TELEX 123456

Our Ref. 350/PJC/EAC 18th January, 1972.

Dr. P.N. Cundall,
Mining Surveys Ltd.,
Holroyd Road,
Reading,
Berks.

Dear Pete,

Permit me to introduce you to the facility of facsimile transmission.

In facsimile a photocell is caused to perform a raster scan over the subject copy. The variations of print density on the document cause the photocell to generate an analogous electrical video signal. This signal is used to modulate a carrier, which is transmitted to a remote destination over a radio or cable communications link.

At the remote terminal, demodulation reconstructs the video signal, which is used to modulate the density of print produced by a printing device. This device is scanning in a raster scan synchronised with that at the transmitting terminal. As a result, a facsimile copy of the subject document is produced.

Probably you have uses for this facility in your organisation.

Yours sincerely,

Phil.

P.J. CROSS
Group Leader - Facsimile Research

Example of document containing characters

Example of completely black document

Fig. 5-6 Examples of Documents with High Redundancy

Let’s consider the document shown in Fig. 5-7 below. When the focus is applied to a certain scanline, it will be noted that the scanline comprises white pixel groups and black pixel groups. The respective pixel groups are referred to as the “white run” and “black run.” This characteristic is used to allocate codes with high efficiency to these runs to reduce the size of the image information. This is called “redundancy suppression coding” or “redundancy compression coding”. From here on in this chapter, let’s simply refer to this as “coding.”

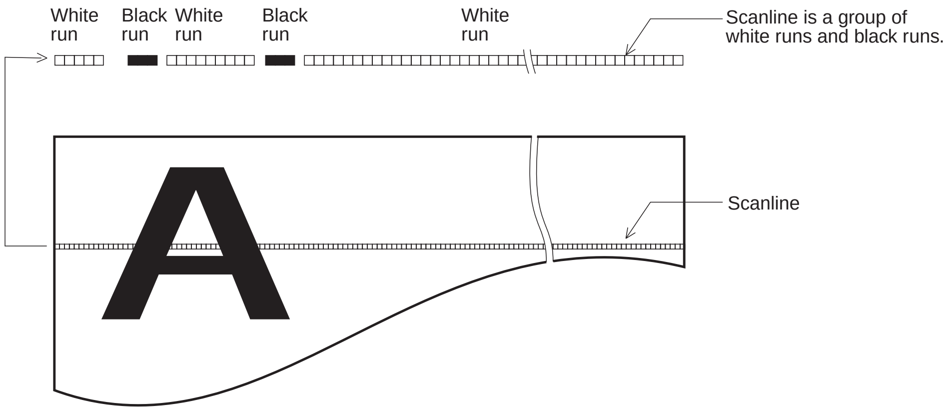


Fig. 5-7 Example of Document

Although various coding schemes are possible, the most efficient one is the Huffman scheme. A slightly modified version of this scheme, the Modified Huffman coding scheme (MH coding scheme), has been adopted as the standard coding scheme for G3 facsimiles.

The Modified READ coding scheme (MR coding scheme) and the Modified Modified READ scheme (MMR coding scheme) are widely used as optional coding schemes for G3 facsimiles.

The JBIG (Joint Bi-level Image experts Group) coding scheme that started to gain in popularity at the same time as V.34 MODEMs has also been recommended by ITU-T, and is expected to further gain in popularity.

The following describes the principles of operation of these coding schemes in order.

4.2 MH Coding Scheme (One-dimensional Coding Scheme)

The following describes an example using an A4 size document.

If a document is viewed in unit of single lines, text areas are black, and areas without text are white. All of the scanlines are expressed as a group of white runs and black runs.

The length of these runs is called the “run length”. The MH coding scheme codes each line using two elements, the run length and the run color.

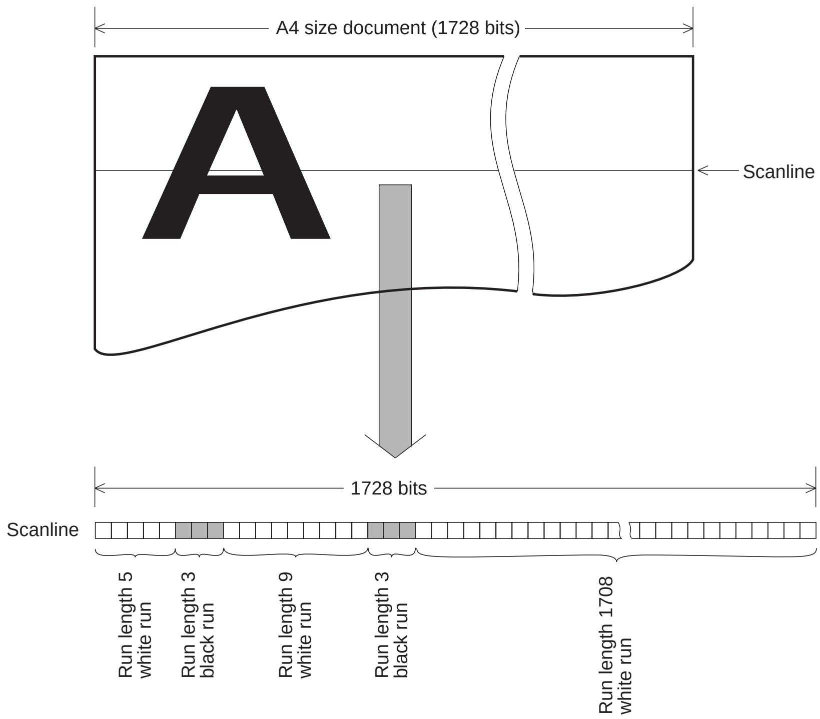


Fig. 5-8 Example of Scanline

4.2.1 Outline of MH coding scheme

Codes having a fewer number of bits are allocated to codes to be swapped for black and white that appear more frequently when coding is performed. By this allocation, the data ultimately becomes compressed data, and the transmission time is reduced. By the MH coding scheme, coding is performed taking only the horizontal scanning direction (one dimensional direction) into consideration. For this reason, it is called a "one-dimensional coding scheme." Whereas, a scheme where coding is performed in both the horizontal and vertical scanning directions (two-dimensional direction) is called the MR coding scheme (two-dimensional coding scheme) and is distinguished from the one-dimensional coding scheme.

4.2.2 MH coding scheme procedures

The image data read by the reading section is converted to run lengths for each scanline, and is then coded by MH coding. These processes are normally performed by the CPU, and the resulting image data is stored to memory. That data is then sent to the MODEM, where it is modulated and then transmitted to the telephone line. On the receiving side, the procedure is completely reversed, and the original data is restored by demodulation.

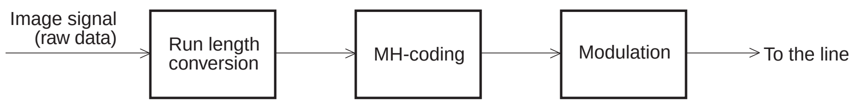


Fig. 5-9 Procedure for Image Data Processing on the Transmitting Side

Let's try actually converting the previously described scanlines.

(1) Run length

The raw data of the image that is read is converted to run lengths.

White run length 5	Black run length 3	White run length 9	Black run length 3	White run length 1708

Fig. 5-10 Scanlines after Conversion to Run Length

Of special note at this time, each scanline run must start from a white run. This rule exists so that the line starts from a white run as there is no means of notifying that the line starts with a black run or a white run. Accordingly, if the line starts from a black run, a dummy white run (run length 0) is added at the start of the line before coding is performed.

(2) MH coding

After being converted to run lengths, the scanlines are converted to MH codes. These MH codes comprise terminating codes and make-up codes. (See the table of page 5-14.) Different mechanisms are used for converting to MH codes for when the run length is 0 to 63, and when the run length is 64 or more.

- Coding when the run length is 0 to 63

In this case, coding is performed with a suitable terminating code depending on the color and length of the run.

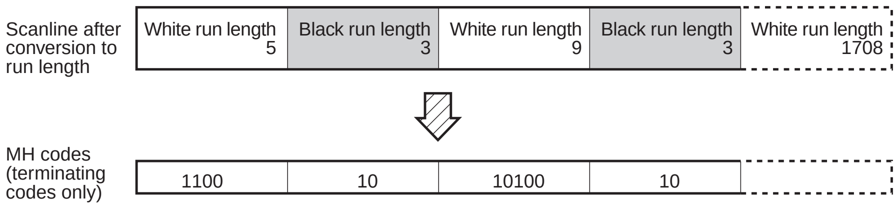


Fig. 5-11 MH Coding When The Run Length is 0 to 63

- Coding when the run length is 64 or more

In this case, coding is performed by a make-up code which shows the largest run length without exceeding the run length of that run. Next, the difference between the actual run length and the length of the make-up code is coded by a terminating code.

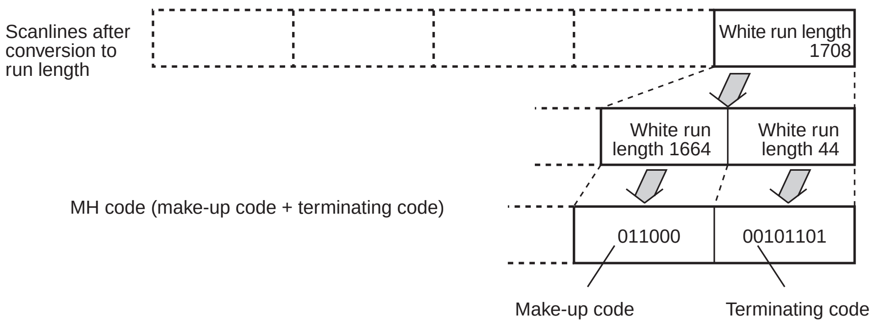


Fig. 5-12 MH Coding When The Run Length is 64 or More

(3) Coding of one scanline

Coding is completed by arranging the MH codes of each run consecutively. The code sequence for one scanline for which coding has been completed is called "data."

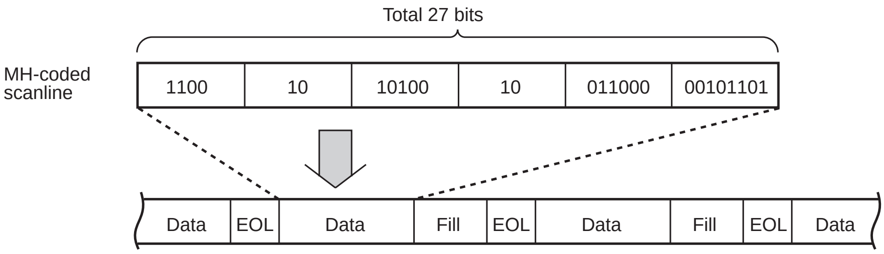


Fig. 5-13 MH-coded Scanline

- Information compression ratio of MH coding scheme

In case the scanline is MH-coded, the volume of information of 1,728 bits of raw data is compressed to 27 bits of coded data.
The compression ratio is calculated as follows:
Information compression ratio = Information size (bits) after compression / Information size (bits) before compression = 27/1728 = 1/64
Although the transmission time of the image data is not determined merely by the size of the data to be transmitted, the effect of data compression is to reduce the transmission time considerably.

5

NOTE

Image Data Unsuitable for Compression

If coding is performed, this does not necessarily mean that the size of the information of any document can be compressed to reduce the transmission time. The effect of coding is reduced on documents where short white runs and short black runs occur alternately (for example, halftone photographs in newspapers).
Though the following example will hardly occur, let's consider a scanline along which black and white runs one bit each exist alternately.

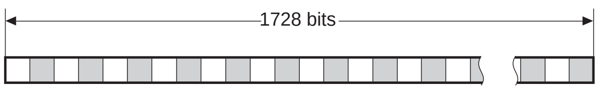


Fig. 5-14 Example of Scanline Unsuitable for Compression

White run length 1 → 6 bits of MH coding "000111"
Black run length 1 → 3 bits of MH coding "010"
For this reason, the size of the information in this scanline is as follows:
Size of information = $6 \times 1728/2 + 3 \times 1728/2 = 7776$ (bits)

Because of coding, the size of the information increased fourfold. In other words, this kind of document can be transmitted faster without it being coded.

Table 5-2 Terminating Code Table

White Run Length	Terminating Code	Black Run Length	Terminating Code
0	00110101	0	0000110111
1	000111	1	010
2	0111	2	11
3	1000	3	10
4	1011	4	011
5	1100	5	0011
6	1110	6	0010
7	1111	7	00011
8	10011	8	000101
9	10100	9	000100
10	00111	10	0000100
11	01000	11	0000101
12	001000	12	0000111
13	000011	13	00000100
14	110100	14	00000111
15	110101	15	000011000
16	101010	16	0000010111
17	101011	17	0000011000
18	0100111	18	0000001000
19	0001100	19	00001100111
20	0001000	20	00001101000
21	0010111	21	00001101100
22	0000011	22	00000110111
23	0000100	23	00000101000
24	0101000	24	00000010111
25	0101011	25	00000011000
26	0010011	26	000011001010
27	0100100	27	000011001011
28	0011000	28	000011001100
29	00000010	29	000011001101
30	00000011	30	000001101000
31	00011010	31	000001101001
32	00011011	32	000001101010

Table 5-2 Terminating Code Table

White Run Length	Terminating Code	Black Run Length	Terminating Code
33	00010010	33	000001101011
34	00010011	34	000011010010
35	00010100	35	000011010011
36	00010101	36	000011010100
37	00010110	37	000011010101
38	00010111	38	000011010110
39	00101000	39	000011010111
40	00101001	40	000001101100
41	00101010	41	000001101101
42	00101011	42	000011011010
43	00101100	43	000011011011
44	00101101	44	000001010100
45	00000100	45	000001010101
46	00000101	46	000001010110
47	00001010	47	000001010111
48	00001011	48	000001100100
49	01010010	49	000001100101
50	01010011	50	000001010010
51	01010100	51	000001010011
52	01010101	52	000000100100
53	00100100	53	000000110111
54	00100101	54	000000111000
55	01011000	55	000000100111
56	01011001	56	000000101000
57	01011010	57	000001011000
58	01011011	58	000001011001
59	01001010	59	000000101011
60	01001011	60	000000101100
61	00110010	61	000001011010
62	00110011	62	000001100110
63	00110100	63	000001100111

Table 5-3 Make-up Code Table

Make-up Code Table 1

White Run Length	Make-up Code	Black Run Length	Make-up Code
64	11011	64	0000001111
128	10010	128	000011001000
192	010111	192	000011001001
256	0110111	256	000001011011
320	00110110	320	000000110011
384	00110111	384	000000110100
448	01100100	448	000000110101
512	01100101	512	0000001101100
576	01101000	576	0000001101101
640	01100111	640	0000001001010
704	011001100	704	0000001001011
768	011001101	768	0000001001100
832	011010010	832	0000001001101
896	011010011	896	0000001110010
960	011010100	960	0000001110011
1024	011010101	1024	0000001110100
1088	011010110	1088	0000001110101
1152	011010111	1152	0000001110110
1216	011011000	1216	0000001110111
1280	011011001	1280	0000001010010
1344	011011010	1344	0000001010011
1408	011011011	1408	0000001010100
1472	010011000	1472	0000001010101
1536	010011001	1536	0000001011010
1600	010011010	1600	0000001011011
1664	011000	1664	0000001100100
1728	010011011	1728	0000001100101
EOL	000000000001	EOL	000000000001

Make-up Code Table 2

Run Length (white and black)	Make-up Code
1792	00000001000
1856	00000001100
1920	00000001101
1984	000000010010
2048	000000010011
2112	000000010100
2176	000000010101

Table 5-3 Make-up Code Table

Run Length (white and black)	Make-up Code
2240	000000010110
2304	000000010111
2368	000000011100
2432	000000011101
2496	000000011110
2560	000000011111

4.3 MR Coding Scheme (Two-dimensional Coding Scheme)

4.3.1 Outline of MR coding scheme

With G3 facsimiles, the MR coding scheme can be used as an option in addition to the MH coding scheme. “MR” stands for Modified READ, and “READ” stands for Relative Element Address Designative. This READ scheme was proposed for ITU-T by NTT and KDD. After revision, it was recognized as the Modified READ scheme. From here on, let’s describe simply how compression is performed.

Two consecutive scanlines are expanded as shown in Fig. 5-15. When the black and white changing pixels (shown by black dots) of each scanline are compared, it can be seen that they have shifted to the laterally. Data is compressed by comparing the black and white changing pixels with the previous scanline and by coding this shift.

Due to the fact that changes in the two-dimensional pixels are coded in an interlocked manner with the previous scanline, this is also called the “two-dimensional coding scheme.”

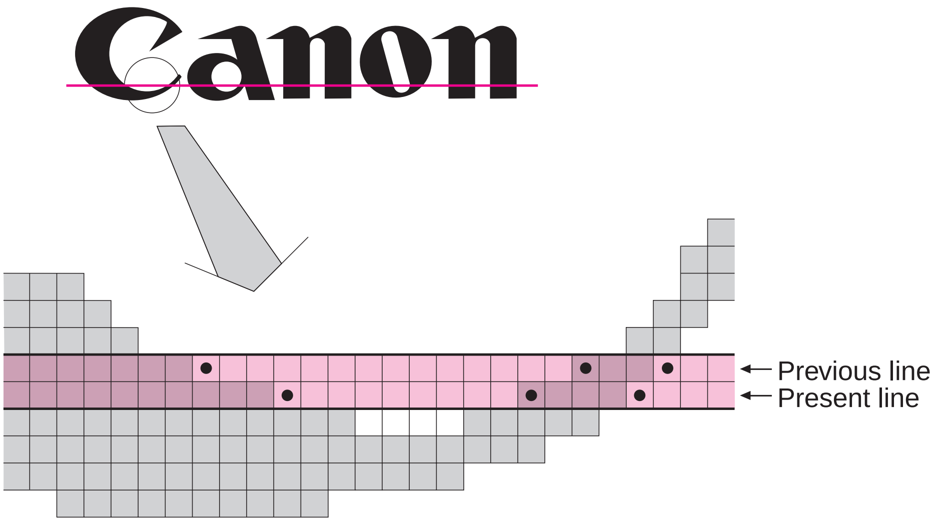


Fig. 5-15 Example of Two Consecutive Scanlines

This scheme is particularly effective in coding documents containing lots of text broadly spread vertically or horizontally (that is, documents containing few shifts of changing pixels).
By the MH coding scheme, 3-bit, 4-bit and at maximum 13-bit coded data must be used to express a single run length. However, with the MR coding scheme, the run length can be expressed just by coded data of one bit if the previous run length is the same as the current run length.

4.3.2 Combination of MH and MR schemes

Actually, a combination of the MH and MR coding schemes are used as the MR coding scheme. In other words, both the MH code table and MR code table are used for the following reason.

(1) By the MR coding scheme, coding must be started from completely describing the initial line. Otherwise, subsequent lines cannot be coded using the data that indicates the presence of changes.

(2) When a document is transmitted by only the MR coding scheme, the receiving side facsimile sometimes cannot correctly decode the scanline due to an error occurring midway during transmission. Because of the nature of the MR coding scheme, this transmission error will affect to the end of the following scanlines.

(2) above is an important issue, and is a disadvantage in the MR coding scheme. The MR coding scheme is a means for complementing this disadvantage. A number of scanlines in one page are combined and MH coding is carried out on every leading scanline. MR coding is performed on subsequent scanlines. The combined number of scanlines is referred to as

"parameter K". This is standardized as shown in the table below. By this measure, if, for example, a transmission error prevents data from being decoded correctly, decoding can be performed correctly from after the next MH data. The line that was coded by the MH scheme to be referenced to at this time is called the "reference line."

Table 5-4 Parameter K

Vertical Scanning Line Density	Parameter K
Standard (3.85 lines/mm)	2
Fine (7.7 lines/mm)	4
Super-fine (15.4 lines/mm)	4
Ultra-fine (15.4 lines/mm)	4

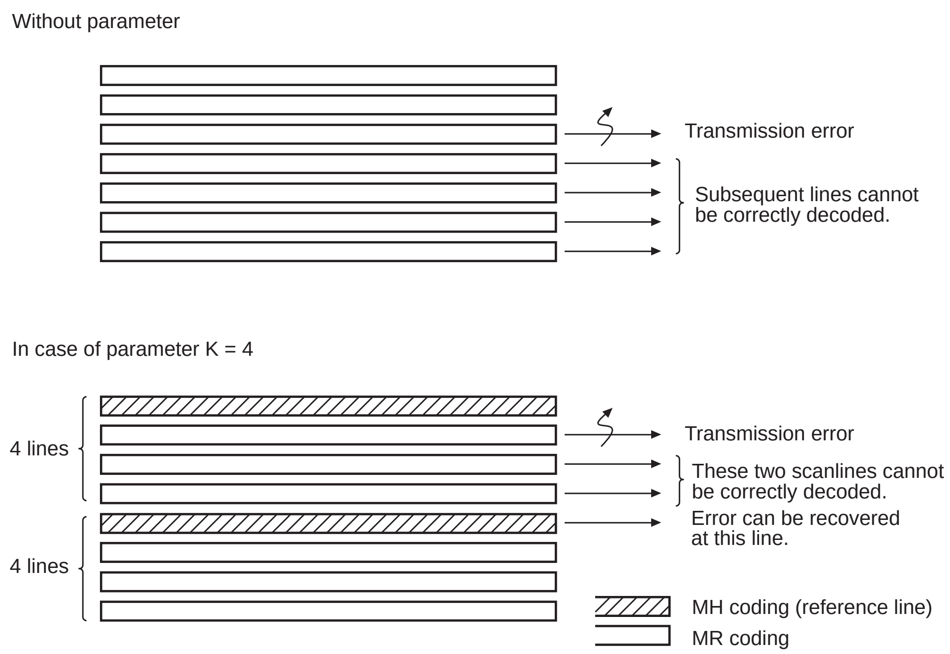


Fig. 5-16 Transmission Error and Parameter K

4.3.3 Structure of image signals in MR coding scheme

Fig. 5-17 shows the image signals when parameter K is 2.

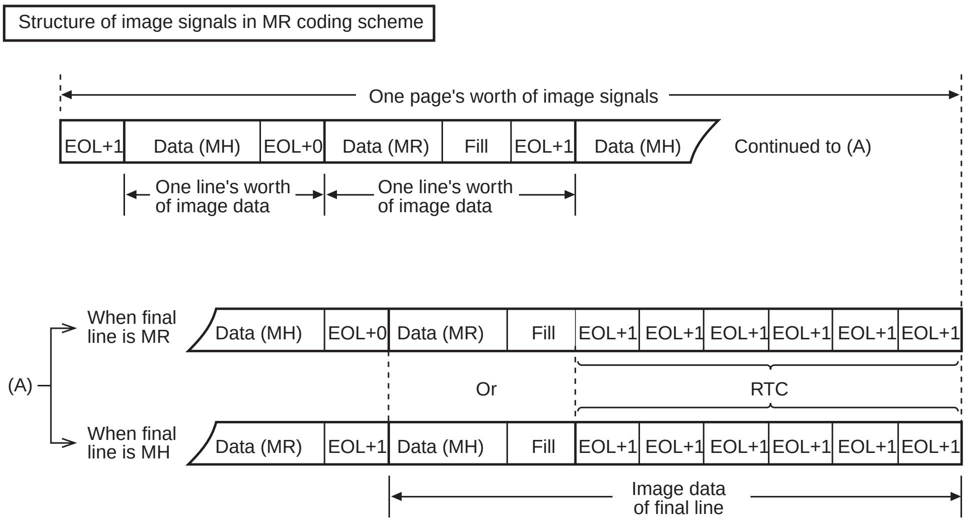


Fig. 5-17 Image Signal Structure in MR Coding Scheme
(in case of parameter K = 2)

As can be seen from this figure, the coding scheme applied to each line is shown by “additional” bits after EOL of the previous line. EOL+0 located at the end of the scanline shows that MR coding is used on the next line. EOL+1 shows that MH coding is used on the next line.

In the same way as MH coding, MR coding also is binary extracted from code tables. However, MR coding differs from MH coding in that the information of the run length and run color is not contained in the code table. The code table only contains information as to how a certain line has changed from the previous line.

4.3.4 MR coding scheme procedure

- Definition of changing pixels

Before we start explaining the coding procedure, let’s define what a “changing pixel” is.

A “changing pixel” is defined as a pixel whose “color” (i.e., black or white) is different from that of the previous pixel on the same line.

a0: The reference or the starting changing pixel on the coding line. At the start of the coding line, a0 is placed on an imaginary white changing pixel situated just before the first pixel on the line. During coding of the coding line, the positioning of a0 is defined by the previous coding mode.

a1: The next changing pixel to the right of a0 on the coding line

a2: The next changing pixel to the right of a1 on the coding line

b1: The first changing pixel on the reference line to the right of a0 and of opposite color to a0
b2: The next changing pixel to the right of b1 on the reference line

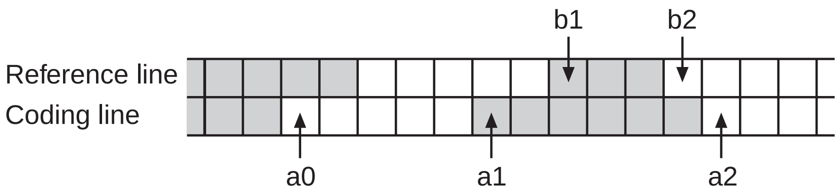


Fig. 5-18 Definition of Changing Pixels

NOTE

The coding mode is used to code each changing pixel on the coding line. There are three modes: pass mode, vertical mode and horizontal mode. Details of each coding mode are described in 4.3.5 Coding Modes.

5

- Coding procedure

The coding procedure detects the coding mode to be used for coding each of changing pixels on the coding line. When one of the three coding modes is detected according to Step 1 or Step 2 described below, an appropriate code word is selected from the code table shown in Table 5-5. This procedure is shown in the flow chart in Fig. 5-22.

[Step 1]

(1) When the pass mode is detected, coding is performed using the word "0001" (Table 5-5). After this, pixel a0' just under b2 is regarded as the new starting pixel a0 for the next coding operation.

(2) If the pass mode is not detected, then proceed to Step 2.

[Step 2]

(1) Determine the absolute value of the relative distance a1b1. (|a1b1|)

(2) If |a1b1| ≤ 3, as shown in Table 5-5, a1b1 is coded in the vertical mode, after which position a1 is regarded as the new starting pixel a0 for the next coding operation.

(3) If |a1b1| > 3, as shown in Table 5-5, following horizontal mode code "001", a0a1 and a1a2 are respectively coded by MH coding. After this, position a2 is regarded as the new starting pixel a0 for the next coding.

NOTE

Processing of First Pixel of Line

The first starting pixel a0 on each coding line is imaginarily placed at a position just before the first pixel, and is regarded as a white pixel.
The first run length on a line a0a1 is replaced by “a0a1-1”.
In other words, if the first run is black and is considered to be coded by the horizontal mode, then the first code word M(a0a1) corresponds to a white run of zero run length.

Processing of Last Pixel of Line

Coding of the coding line continues until the position of the imaginary changing pixel situated just after the last actual pixel has been coded. This may be coded as a1 or a2. Also, if b1 and/or b2 are not detected at any time during the coding of the line, they are positioned on the imaginary changing pixel situated just after the last actual pixel on the reference line.

4.3.5 Coding modes

One of the three coding modes is selected according to the coding procedure.

(1) Pass mode

This mode is stipulated when b2 lies to the left of a1.
When coding has been performed in this mode, a0 is placed on the pixel of the coding line below b2 in preparation for the next coding operation (i.e. on a0’).

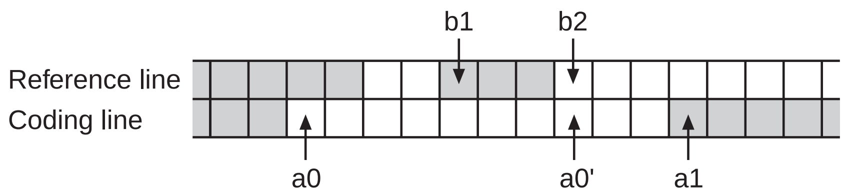


Fig. 5-19 Pass Mode

However, the state where b2 occurs just above a1 as shown in Fig. 5-20 is not considered to be the pass mode.

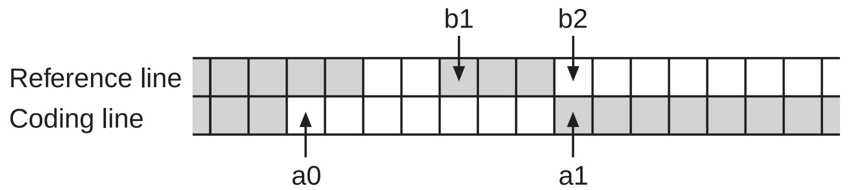


Fig. 5-20 Example Not Corresponding to Pass Mode

(2) Vertical mode

When this mode is detected, the position of a1 is coded at a position relative to the position of b1. The relative distance a1b1 can take on one of seven values V(0), VR(1), VR(2), VR(3), VL(1), VL(2) and VL(3), each of which is expressed by a separate code word. The subscripts R and L indicate that a1 is to the right or left respectively of b1, and the number in brackets indicates the value of the distance a1b1. After coding in the vertical mode has been performed, the position of a0 is moved to a1 (See Fig. 5-21).

(3) Horizontal mode

When this mode is detected, both the run lengths a0a1 and a1a2 are coded using the code words “H + M(a0a1) + M(a1a2)”. H is the flag code word “001” taken from the MR code table (Table 5-5). M(a0a1) and M(a1a2) are code words which represent the “length” and “color” of the runs a0a1 and a1a2 respectively, and are coded from the appropriate white or black MH code tables (Tables 5-2 and 5-3). After a coding in the horizontal mode is performed, the position of a0 is moved to a2 (see Fig. 5-21).

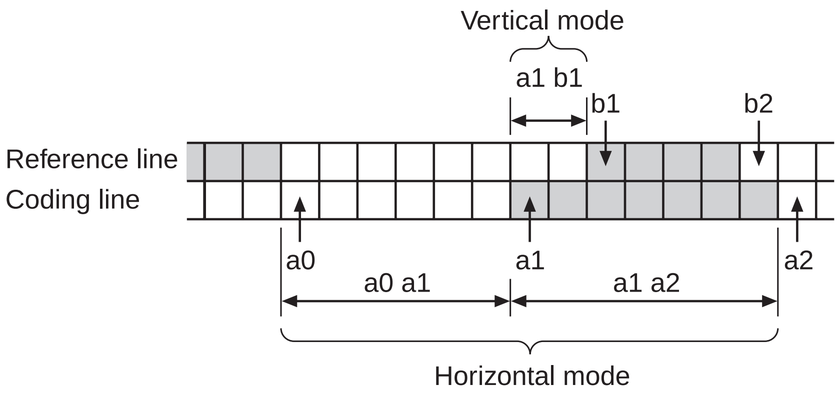


Fig. 5-21 Vertical Mode and Horizontal Mode

Table 5-5   MR Code Table

Mode	Elements To Be Coded		Notation	Code Word
Pass	b1, b2		P	0001
Horizontal	a0 a1, a1 a2		H	001+ M(a0 a1)+ M(a1 a2)*1
Vertical	a1 just under b1	a1 b1 = 0	V(0)	1
	a1 to the right of b1	a1 b1 = 1	VR(1)	011
		a1 b1 = 2	VR(2)	000011
		a1 b1 = 3	VR(3)	0000011
	a1 to the left of b1	a1 b1 = 1	VL(1)	010
		a1 b1 = 2	VL(2)	000010
		a1 b1 = 3	VL(3)	0000010

*1 Horizontal mode code “M( )” shows the MH code words in Tables 5-2 and 5-3.

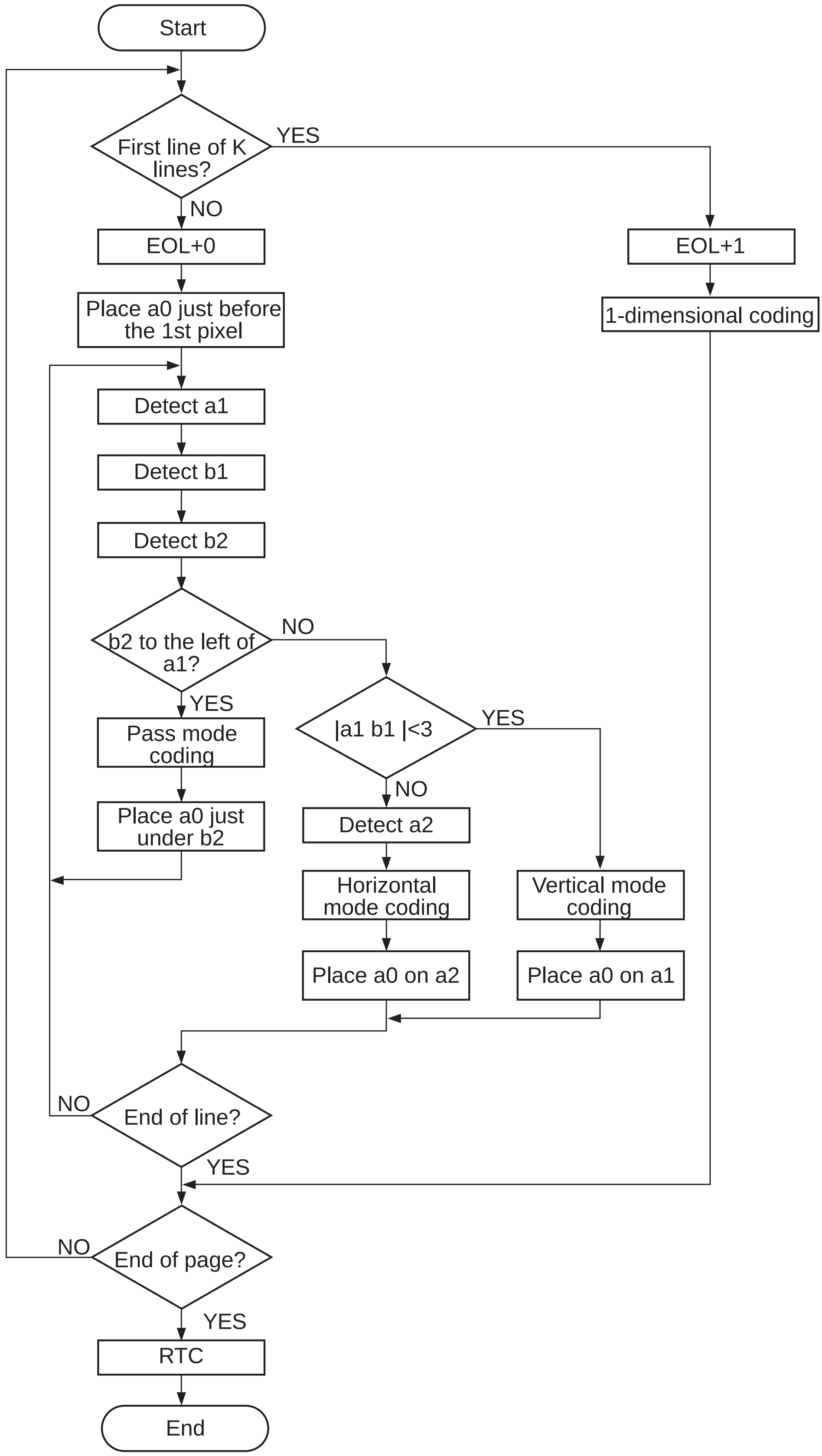


Fig. 5-22 MR Coding Flow Chart

- Example of MR coding

Let's try applying MR coding to the example A4 size document shown below, assuming that the parameter K is 4.

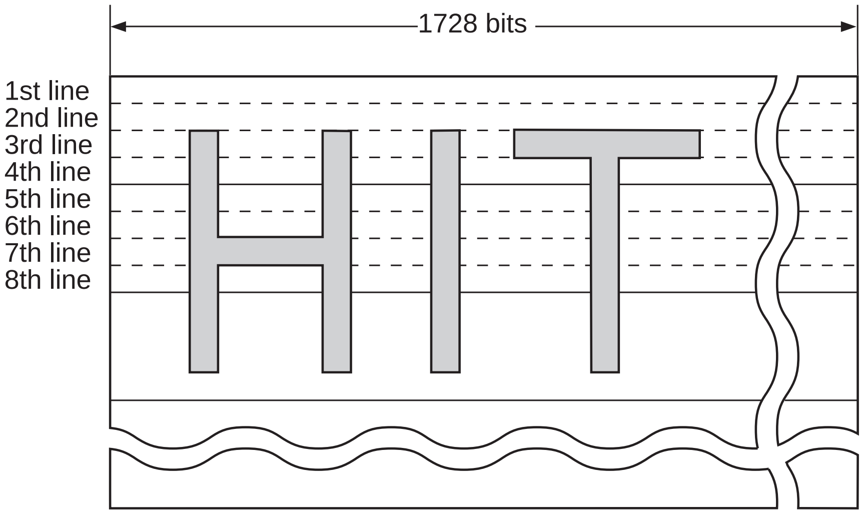


Fig. 5-23 Example of A4-size Document

Fig. 5-24 shows MR coding of the A4-size document. Fill bits are omitted in this example. Table 5-6 below is for explanatory notes for the coding example.

Table 5-6 Explanatory Notes for MR Coding Example

Item	Remarks
EOL+1	Shows that the following coded line is MH coded.
EOL+0	Shows that the following coded line is MR coded.
1728W	Shows that the white run has a run length of 1728.
1B	Shows that the black run has a run length of 1.
V(0)	Shows that the vertical mode has a relative distance value of 0.
H	Shows that coding is in horizontal mode.
P	Shows that coding is in pass mode.

1st line — MH coding

EOL+1	1728W	0W	EOL+0
0000000000011	010011011	0011010	0000000000010

2nd line — MR coding

V(0)	EOL+0
1	0000000000010

3rd line — MR coding

H+M(3)+M(1)	H+M(4)+M(1)	H+M(3)+M(1)
001 1000 010	001 1011 010	001 1000 010

H+M(2)+M(7)	V(0)	EOL+0
001 0111 00011	1	0000000000010

4th line — MR coding

V(0)	V(0)	V(0)	V(0)	V(0)	V(0)	VR(3)	VL(3)
1	1	1	1	1	1	0000011	0000010

V(0)	EOL+1
1	0000000000011

1

5th line — MH coding

3W	1B	4W	1B	3W	1B	5W	1B	1709W
1000	010	1011	010	1000	010	1100	010	011000 00000100

EOL+0
0000000000010

6th line — MR coding

V(0)	V(0)	V(0)	V(0)	V(0)	V(0)	V(0)	V(0)	V(0)	EOL+0
1	1	1	1	1	1	1	1	1	0000000000010

7th line — MR coding

V(0)	P	V(0)	V(0)	V(0)	V(0)	V(0)	V(0)	EOL+0
1	0001	1	1	1	1	1	1	0000000000010

8th line — MR coding

V(0)	H+M(1)+M(4)	V(0)	V(0)	V(0)	V(0)	V(0)	V(0)
1	001 010 1011	1	1	1	1	1	1

EOL+1
0000000000011

Fig. 5-24 Examples of MR Coding

4.3.6 Effect of MR coding scheme

The table shows the size of compressed data by the MR coding scheme and the MH coding scheme.

Table 5-7 Comparison of the Effect by MR Coding and MH Coding

	MR coding	MH coding
1st line	43 bits	41 bits
2nd line	14 bits	29 bits
3rd line	56 bits	56 bits
4th line	34 bits	54 bits
5th line	55 bits	54 bits
6th line	22 bits	54 bits
7th line	24 bits	48 bits
8th line	30 bits	54 bits
Total	278 bits	390 bits

In the document example in Fig. 5-23, the compression ratio becomes about 71% as shown in the following formula by the MR coding scheme compared with the MH coding scheme.

Data size by MR coding / Data size by MH coding = 278/390 = 0.7128 ... Approx. 71%

In actual coding of the document, the compression ratio becomes between about 70% to 90% depending on the pattern of the document and the vertical scanning line density.

4.4 MMR Coding Scheme

MMR stands for Modified Modified READ, and somewhat resembles the MR coding scheme. By MMR, coding starts from a white line, and there are no restrictions in parameter K. In other words, the initial line is taken to the be the reference line, and only differences from the previous line are coded by MR right until the end of the page. For this reason, as a condition for use of MMR, MMR is limited to instances where error-free communications can be assured. So, with G3 facsimiles, MMR is used only in combinations with the ECM (Error Correction Mode) of ITU-T described later.

4.5 JBIG Image Compression Encoding Scheme

4.5.1 Outline of the JBIG image compression encoding scheme

The JBIG Image Compression Encoding Scheme is recommended in ITU-T T.82/T.85 as a new bi-level (bi-level: White and Black) image compression encoding scheme developed by JBIG (Joint Bi-level Image experts Group).

The JBIG Image Compression Encoding Scheme has the following characteristics with regards to text documents, quasi-gray scale images with little continuous black and white, and gray scale images which use a dithering scheme: a higher compression rate (1.1 ~ 30 times higher) than the conventional MMR compression scheme, the encoded volume will not exceed the volume of original image information after compression, and when decoding, the image can be completely re-assembled to its original condition in the same way as with conventional MR/MMR.

A coding scheme such as this that allows the original image to be completely restored is called a “reversible scheme,” and a coding scheme that does not allow the original image to be completely restored an “irreversible scheme.”

There are two types of JBIG image compression coding sdhemes: Progressive Bi-level Image Compression and Single Progression Sequential Bi-level Image Compression.

The JBIG Image Compression Encoding Scheme contains Progressive Bi-level Image Compression for searching image databases, recommended in ITU-T T.82, and Single Progression Sequential Bi-level Image Compression for facsimile, recommended in ITU-T T.82 and T.85.

Images will take on the form shown below.

5

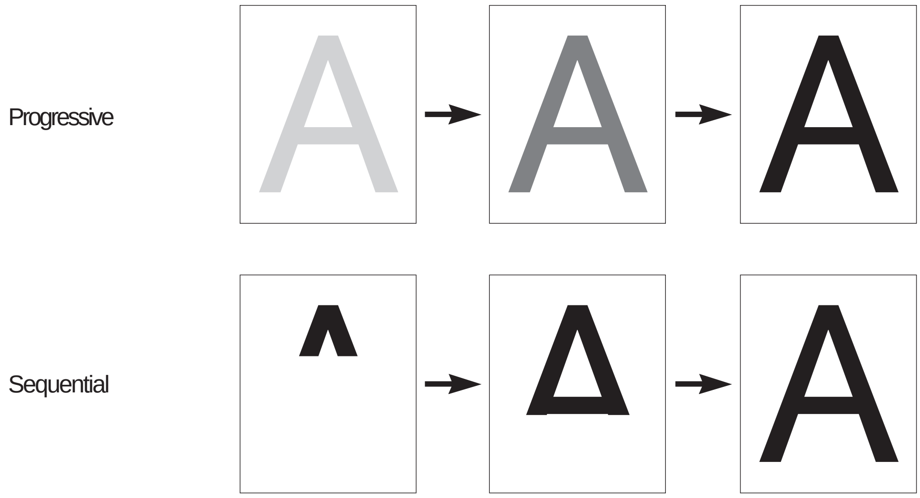


Fig. 5-25 Images

NOTE

The characteristics of Progressive Bi-level Image Compression are explained below as a reference. First of all, after the original image has been read in at high resolution, it is converted to low resolution, and this low resolution image data proceeds to be encoded (compressed). On the receiving end, the overall original image can be quickly recognized by the steps in which this low resolution image compression data is received.

Next, to improve the quality of the low resolution image already sent, only information needed to improve the resolution is forwarded. The previous low resolution image is decoded on the receiving side with this information, and following this, the high resolution image is displayed on top of the previous low resolution image.

It is easy to quickly recognize the original image in the process of displaying the image from low resolution to high resolution in order by using this scheme, with a CRT display for example. Also, according to the situation, it is possible to interrupt the image transfer at the point where the original image is recognized to some degree by the receiving side.

This scheme requires a page buffer memory for the low resolution image because the low resolution images are used for the purpose of high resolution image encoding.

4.5.2 Single progression sequential bi-level image compression scheme

The Single Progression Sequential Bi-level Image Compression Scheme used in this fax is explained below.

The Progressive Bi-level Image Compression Scheme uses multiple resolution layers on a single page (multi-level layers, low resolution layers to high resolution layers) to perform encoding/decoding. In the Single Progression Sequential Bi-level Image Compression Scheme, encoding is done in units of horizontal bands (a number of lines) called stripes, and is performed from left to right, top to bottom (this condition is called sequential), and in one resolution layer (single layer).

NOTE

In this scheme, the encoding is done in stripe units, so it is completed with a buffer memory much smaller than a page buffer memory.

The schemes by which encoding takes place and by which image data is constructed after encoding are explained below.

4.5.3 Encoding scheme

In the JBIG encoding used in the Single Progression Sequential Bi-level Image Compression Scheme, uses in the encoder shown below to encode to the original the results of comparison of the line currently being processed and the previous line, as well as the predicted value of an image pixel (white or black) used in a model template.

The study table used in the prediction makes the next prediction more accurate by learning and correcting the study table every time the model template moves to the adjoining pixel. It is characteristic of this scheme that if the prediction is accurate the amount of encoding will not increase, and if the prediction is off the amount of encoding increases, so the increase in prediction accuracy of this study table is very important.

An outline of the encoding procedure is shown below.

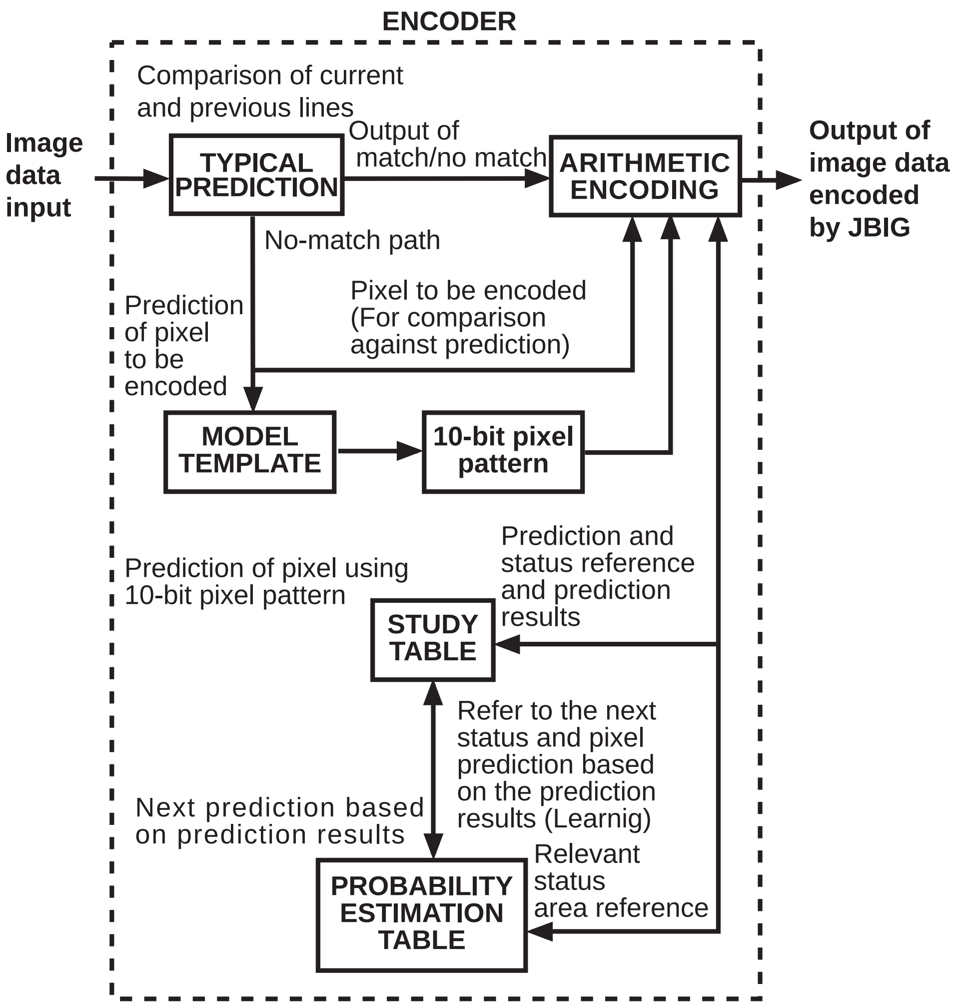


Fig. 5-26 Encoder and Flow of JBIG Encoding

(1) In the pattern prediction section, the line currently being processed and the current line are compared, and judged to match or not match. A flag showing whether or not the lines match (1 bit, 0: match, 1: don't match) is attached to the head of each line according to this judgment. When the lines match, only this flag is encoded in the arithmetic encoding section as a suspected pixel, the pixel of the line being currently processed is not encoded. When the lines do not match, the pixel of the line currently being processed is encoded in the arithmetic encoding section based on the results of a comparison of the value of the actual pixel and the pixel (white or black) which is predicted using the model template and the study table.

NOTE

When the lines are judged to match, the line currently being processed is said to be "typical". When the lines are judged to not match, the line is said to be "not typical". When the very first line of an image is predicted, the background color is used as the previous line.

(2) In the model template, the combination (10-bit pixel pattern) of 10 pixels is output to the arithmetic encoding section using the template shown below (inside the bold outline).
All of the 10-bit pixel patterns inside this template exist in the study table. This 10-bit pixel pattern is used by the arithmetic encoding section to refer to the predicted value of the pixel and the status number in the study table which correspond to the 10-bit pixel pattern.

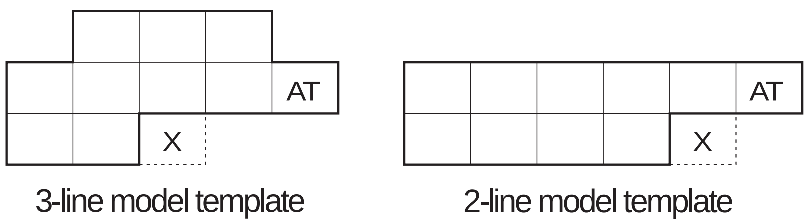


Fig. 5-27 Model Templates

NOTE

There are two types of model templates to 3-line and 2-line, and the one selected is designated by the LRLTWO inside the Bi-level Image Header section (BIH). The pixel shown by "X" is an encoded pixel and is outside of the template.
The pixel shown by "AT" is a special pixel known as an AT pixel. The AT pixel becomes a Adaptive Template by having its position moved, and is

very effective when encoding a periodic pixel, similar to a dither pattern image.

The position of AT in the figure is the beginning position of the AT pixel.

(3) The study table, as shown below, is constructed by all of the 10-bit pixel patterns output by the model template, and their corresponding status numbers and predicted values of the pixel to be encoded.

The predicted value of the pixel to be encoded and the status number is compared to the actual pixel in the arithmetic encoding section every time the model template is moved to the adjoining pixel.

The result of this comparison (matches / does not match predicted value) and the status number are then checked by comparison to the probability estimation table, and the study table is corrected (learned) to a new prediction value and status number which will be used when the same pixel pattern is found again.

By learning in this way, the probability of the study table matching the next time is increased, and the need for encoding decreased.

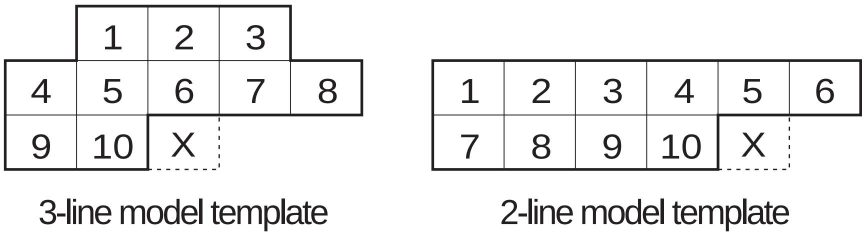


Fig. 5-28 Positions of Pixels in Model Template

Table 5-8 Study Table (Initial values)

Pixel pattern in the model template												Predicted value of pixel	Status No. (ST)
Hex	Dec	1	2	3	4	5	6	7	8	9	10		
000h	0	0	0	0	0	0	0	0	0	0	0	0 (White)	0
001h	1	0	0	0	0	0	0	0	0	0	1	0 (White)	0
002h	2	0	0	0	0	0	0	0	0	1	0	0 (White)	0
003h	3	0	0	0	0	0	0	0	0	1	1	0 (White)	0
004h	4	0	0	0	0	0	0	0	1	0	0	0 (White)	0
005h	5	0	0	0	0	0	0	0	1	0	1	0 (White)	0
3FBh	1019	1	1	1	1	1	1	1	0	1	1	0 (White)	0
3FCh	1020	1	1	1	1	1	1	1	1	0	0	0 (White)	0
3FDh	1021	1	1	1	1	1	1	1	1	0	1	0 (White)	0
3FEh	1022	1	1	1	1	1	1	1	1	1	0	0 (White)	0
3FFh	1023	1	1	1	1	1	1	1	1	1	1	0 (White)	0

Table 5-9 Probability Estimation Table

ST	LSZ	NLPS	NMPS	SWITCH	ST	LSZ	NLPS	NMPS	SWITCH
0	5A1Dh	1	1	1	57	01A4h	55	58	0
1	2586h	14	2	0	58	0160h	56	59	0
2	1114h	16	3	0	59	0125h	57	60	0
3	080Bh	18	4	0	60	00F6h	58	61	0
4	03D8h	20	5	0	61	00CBh	59	62	0
5	01DAh	23	6	0	62	00ABh	61	63	0
6	00E5h	25	7	0	63	008Fh	61	32	0
7	006Fh	28	8	0	64	5B12h	65	65	1
8	0036h	30	9	0	65	4D04h	80	66	0
49	0706h	79	50	0	106	50E7h	108	107	0
50	05CDh	48	51	0	107	4B85h	109	103	0
51	04DEh	50	52	0	108	5597h	110	109	0
52	040Fh	50	53	0	109	504Fh	111	107	0
53	0363h	51	54	0	110	5A10h	110	111	1
54	02D4h	52	55	0	111	5522h	112	109	0
55	025Ch	53	56	0	112	59EBh	112	111	1
56	01F8h	54	57	0					

ST: Status number in the study table
LSZ: Probability estimation value (range) for inaccurate prediction
NLPS: Next status destination when a prediction is inaccurate
NMPS: Next status destination when a prediction is accurate
SWITCH: Next prediction value reversed if SWITCH=1 when prediction is inaccurate

NOTE

Example:

A brief explanation of how the study table works is given below.

It is assumed that each of the model template pixels 1 to 10 in the image below are white.

- In this case, the model template pixel pattern is 000h.
- The predicted value of pixel pattern 000h for pixel “X” is “white,” but it is actually black. Thus the prediction is “inaccurate.”
- The status ST is “0”, so the probability estimation table is consulted, and the next status is moved to “1.” At the same time, by the reversal of the predicted value, the next prediction is for “black.”

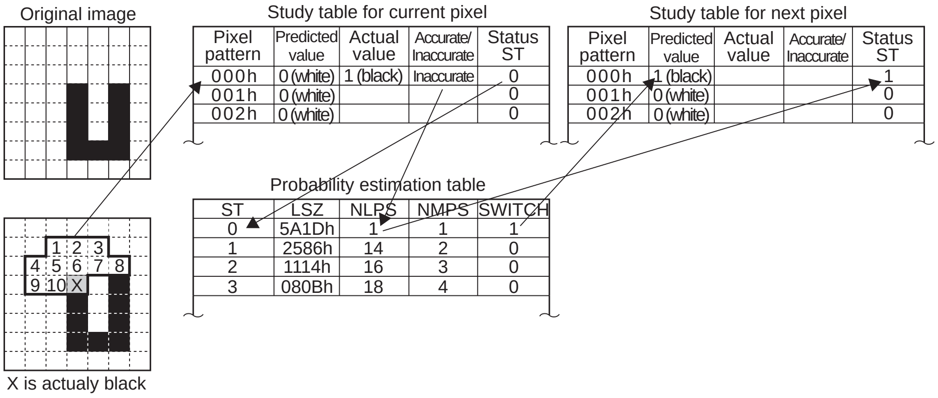


Fig. 5-29 Study Table Study Example 1

- Next, the model template is moved to the adjoining pixel in order to perform the next prediction. At this time, pixels 1 to 9 of the model template are white, and pixel 10 is black.
- In this case, the model template pixel pattern is 001h.
- The predicted value of pixel pattern 001h for pixel “X” is “white,” and it is actually white. Thus the prediction is “accurate.”
- The status ST is “0”, so the probability estimation table is consulted, and the next status is moved to “1”. The prediction for the next pixel remains “white”.

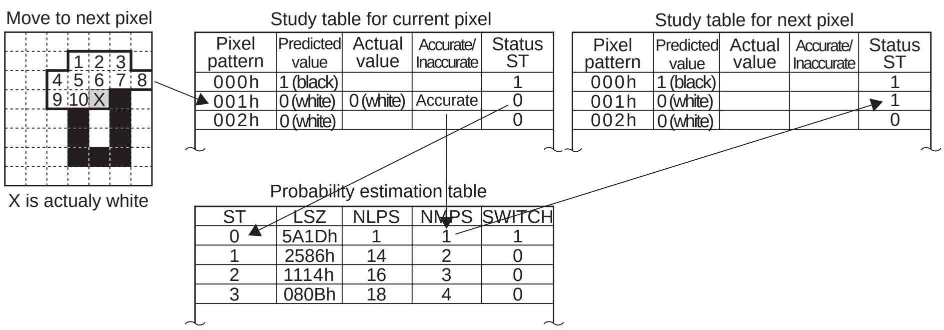


Fig. 5-30 Study Table Study Example 2

The study table is constantly updated in this way, increasing the probability of accurate predictions.

(4) The probability estimation table is published in the ITU-T T.82. Its contents are fixed, differing from those of the study table.

NOTE

This table shows probability of accuracy/inaccuracy in the form of a range, according to the accurate/inaccurate results of a given status prediction value.
The plan of the probability estimation table is such that if the prediction is accurate, the range of the next status number will be smaller than would be the case in an inaccurate prediction.
The status number with this smaller range will be selected to be the next status number.

5

(5) After the predicted value is found to be accurate/inaccurate by the actual pixel, the model template, and the study table, that accuracy/inaccuracy is encoded in the arithmetic encoding section, and the encoded image data is output.

(6) In the encoding (mathematical encoding) done in the arithmetic encoding section, there is no conversion table for encoding as is the case in encoding with conventional MH and MR. Using the LSZ (probability estimation value of an inaccurate prediction: the form of a range) of the probability estimation table and the accuracy/inaccuracy of the predicted value as a base, encoding is done by showing the position of the progress of the prediction on an integer line (between 0 to 1.0). Encoding shown as a position on this integer line, take a position under MPS in the case of accurate predictions, and under LPS in the case of inaccurate predictions, as shown in the figure below.
Furthermore, there is a concept of range (A) in this arithmetic encoding. This range (A)[*2] is shown as an MPS range in the case of accurate predictions and as an LPS range in the case of inaccurate predictions for each pixel. When these ranges (A) are below a certain range[*3], the leading edge bit (which excludes the encoding "0". shown by the position on the integer line) shifts one position to the left as encoded image data, and is output. At this time, the limit of this range (A) which was below the certain range is narrow and it is difficult to show a position more detailed than this, so the range (A) is magnified[*4] to show it in

more detail. This operation is called “Renormalization”, and this range (A) is reset to a value above a certain range*3.

The concept of alithmetic encoding is simply explained below.

The following assumptions are made in order to make the explanation easy to understand.

The probability of accuracy will be 50%, and the probability of inaccuracy will be 50%.*1

The area of accuracy will be MPS, and the area of inaccuracy will be LPS.

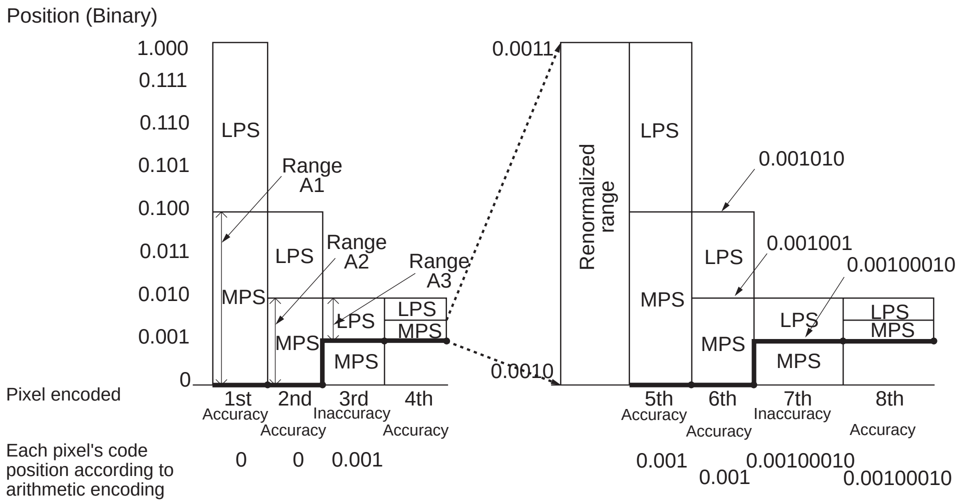


Fig. 5-31 Arithmetic Encoding Conceptual Diagram

The special characteristic of this arithmetic encoding is that an additional encoding bit is not needed because the integer line position is the same as the integer line position of the previous encoding data in the case of an accurate prediction. It follows that the amount of encoding will not increase if accurate predictions continue, and the rate of compression will increase. Conversely, with inaccurate predictions, an additional encoding bit will be necessary to show the position of the inaccuracy in detail, and thus the amount of encoding will increase and the rate of compression decrease. In this way, the study table learns in order to increase the rate of accurate predictions and to reduce the amount of encoding and raise the compression rate during the encoding process, and then corrects the table parameters.

NOTE

*1 The actual probability varies with the status because of the extent to which LSZ occupies in the range (A).

*2 The actual range is hexadecimal 8000 to 10000.

In the case of an accurate prediction, range A1= hexadecimal 10000-

LSZ, A2=A1-LSZ, and A3=A2-LSZ.

In the case of an inaccurate prediction, range A=LSZ.

*3 Actually, hexadecimal 8000.

*4 Actually, the hexadecimal value will be shifted to the left two times, and thehexadecimal will be over 8000.

Next, the encoding for continuos accurate predictions will be simply explained.

The assumptions below will be made for easy understanding.

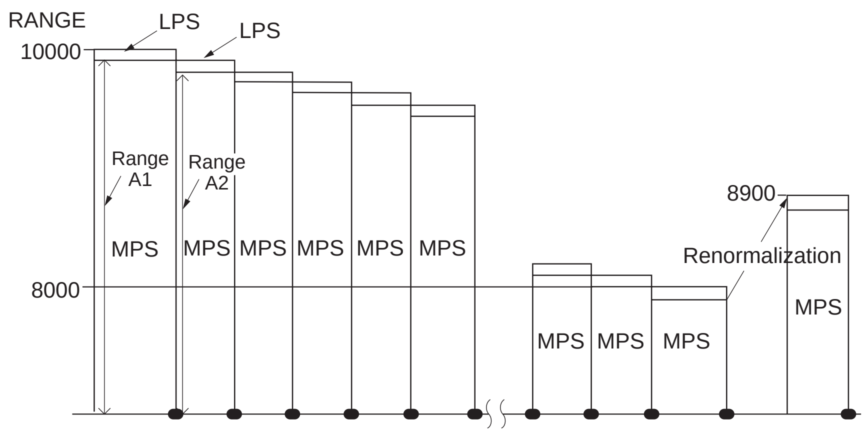
The value of an accurate LSZ will be decimal 100 in all statuses.

Range A will have limits of decimal 8000 to 10000, and when range A is below decimal 8000, the lead encoding bit will be pushed out, and the encoded image data will be output.

At this time, Range A will be adjusted so that it is over decimal 8000 (decimal 1000 added).

An accurate range will be MPS, and an inaccurate range will be LPS.

5



Pixel No. encoded	1	2	3	4	5	6		19	20	21		22
Accurate	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes		Yes
Encoding position	0	0	0	0	0	0		0	0	0		0
Range initial position	10000	9900	9800	9700	9600	9500		8200	8100	8000	7900	8900
Renormalization											1000	
New initial position											8900	
LSZ	100	100	100	100	100	100		100	100	100		100
Range A	9900	9800	9700	9600	9500	9400		8100	8000	7900		8800
Encoding output	No	No	No	No	No	No		No	No	Yes		No
Output encoding										1 bit 0		

Fig. 5-32 When Predictions are Continually Accurate

In this case, the encoding 1 bit is output for the first time when Range A falls becomes less than 8000 in the 21st pixel.

The following output encoding is shortened and its compression increased.

4.5.4 Construction of image data with JBIG image compression encoding

Images are encoded in block units called stripes, as shown in the figure below.

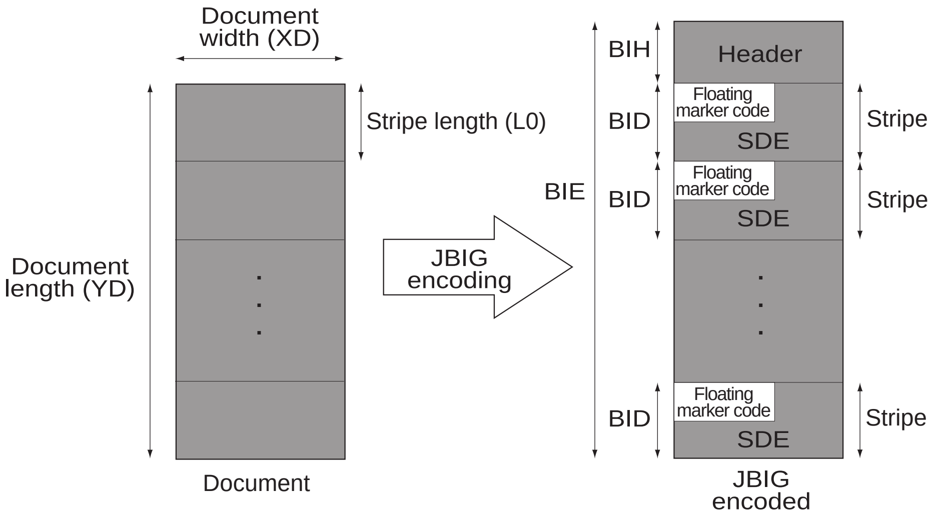


Fig. 5-33   Construction of JBIG Image Data

After being encoded, the image data is referred to as BIE (Bi-level Image Entity), and is constructed from the Bi-level Image Header (BIH) section and the Bi-level Image Data (BID) section shown in the figure below.

BIE (Bi-level Image Entity)			
BIH (Bi-level Image Header)	BID (Bi-level Image Data)	· · · · ·	BID (Bi-level Image Data)

Fig. 5-34   BIE Construction Diagram

4.5.5 Explanation of bi-level image header section (BIH)

The BIH is shown in the construction figure below. It designates the image size, number of lines per stripe, model template, etc.

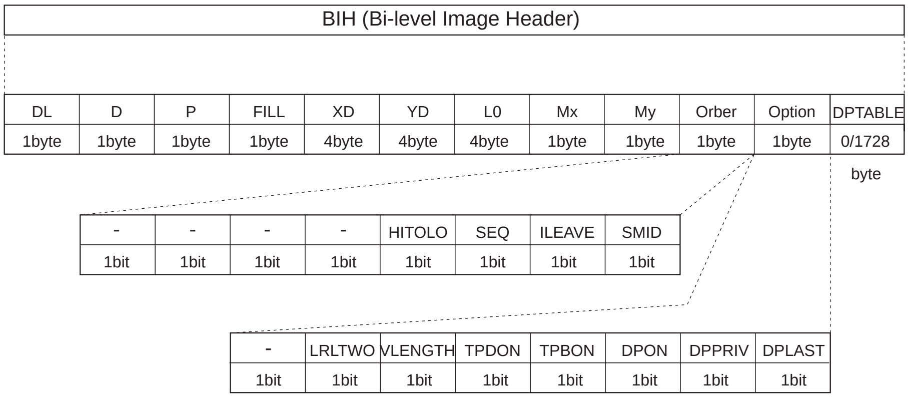


Fig. 5-35 BIH Construction Diagram

4.5.6 Explanation and parameters for each symbol used in BIH

The 0x of each parameter shows that the following integers are hexidecimal.

Symbol	Meaning	Parameter	Reference
DL	Initial layer to be transmitted	0x00 fixed	
D	Number of differential layers	0x00 fixed	
P	Number of bit planes	0x00 fixed	
FILL	Fill	0x00 fixed	
XD	Horizontal image size at layer D	0xXXXXXXXX	Document width (No. of bits)
YD	Vertical image size at layer D	0xXXXXXXXX	Document length (No. of bits)
L0	Lines per stripe at the lowest resolution	0xXXXXXXXX	Basically, 1 stripe is 128 lines (0x00000080). Stripes with other numbers of lines are possible when the other machine can receive in option mode.
Mx	Maximum horizontal offset allowed for AT pixel	0xXX	0-127 pixels
My	Maximum vertical offset allowed for AT pixel	0x00 fixed	
Order	The order in which stripe data is attached	Upper 4 bits 0 fixed	
Option	Option	Upper 1 bit 0 fixed	
DPTABLE	Private DP table	0 or 1728 bytes	
HITOLO	Transmission order of differential layers	1 bit 0 fixed	

Symbol	Meaning	Parameter	Reference
SEQ	Indication of progressive-compatible sequential coding	1 bit 0 fixed	
ILEAVE	Interleaved transmission order of multiple bit plane	1 bit 0 fixed	
SMID	Transmission order of stripes	1 bit 0 fixed	
LRLTWO	Number of reference lines	1 bit 0/1	0: 3 lines 1: 2 lines
VLENGTH	Indication of possible use of NEWLEN marker segment	1 bit 0/1	Use of 0: NEWLEN not allowed Use of 1: NEWLEN allowed
TPDON	Use of TP for Typical Prediction for differential layers	1 bit 0 fixed	
TPBON	Use of TP for base layer	1 bit 0/1	0: OFF 1: ON
DPON	Use of Deterministic Prediction	1 bit 0 fixed	
DPPRIV	Use of private DP table	1 bit 0 fixed	Has meaning when DPON is 1.
DPLAST	Use of last DP table	1 bit 0 fixed	Has meaning when DPON is 1.

4.5.7 Explanation of bi-level image data (BID) section

BID is as shown in the construction figure below, and consists only of the number of stripes.

BID is constructed by the connection of the floating marker code and the section which includes the actual image data encoded with JBIG image compression encoding, called SDE (Stripe Data Entity).

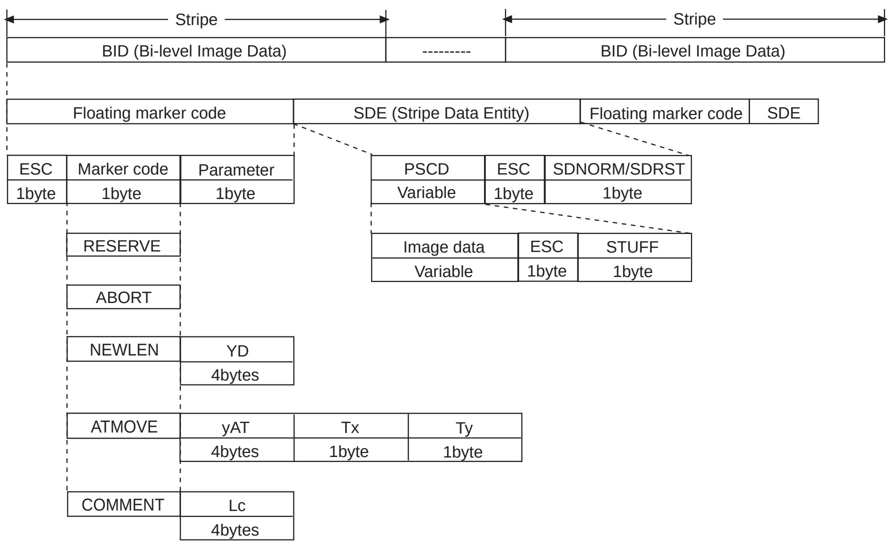


Fig. 5-36 BID Construction Diagram

4.5.8 Explanation and parameters for each symbol used in BID

(1) Floating marker code section

The floating marker code is set at the head of the stripe data entity (SDE). In order to distinguish the encoding and the floating marker code, it is imperative that ESC (escape code: 0xFF) be set at the head.

The following marker code and parameters are in the floating marker code. The 0x of each marker code shows that the following integers are hexadecimal.

ABORT (Abort: 0x05)

Encoding interruption. Only the abort code can be made to appear anywhere.

ESC	0x05

ATMOVE (AT move: 0x06)

Designates from which line the movement of the AT pixel starts, and where it wil move to.

ESC	0x06	yAT:Movement-starting line	Tx:Movement Position(X)	Ty:Movement Position (Y)

COMMENT (Private comment: 0x07)

An optional comment may be added.

ESC	0x07	Lc:Comment length

NEWLEN (New length: 0x04)

Redefine the document length. Only usable when VLENGTH=ON.

ESC	0x04	YD:Document length

RESERVE (Reserve: 0x01)

Only usable for characteristic use.

ESC	0x01

(2) Stripe data section

PSCD (Protected stripe encoding data)

The actual image data encoded with JBIG image compression is included in PSCD by the section remaining after the last 2 bytes from SDE, ESC and SDNORM or SDRST are omitted.

Image Data

The actual image data encoded with JBIG image compression.

STUFF

Image data is a variable, so STUFF:0 (zero) is adjusted by continuous sending so that the image data can be arranged into byte units or word (2 byte) units.

SDNORM (Stripe data completion: 0x02)

Shows the completion of stripe data

ESC	0x02

SDRST (The reset at completion of stripe data: 0x03)

Shows the completion of stripe data. Everything including the study table and the ATMOVE are reset.

ESC	0x03

NOTE

When the image data encoding is 0xFF, it is imperative to attach 0x00 after the image data encoding 0xFF in order to distinguish ESC(0xFF).

5. MODULATION METHOD

After the document is scanned, the resulting image data is converted to compressed digital data by coding described in the previous section. However, the telephone line that is used when transmitting that digital data is for transmitting analog signals “voice,” and the digital data cannot be transmit as it is. To transmit this data actually using the telephone line, the digital data must be converted to analog data. Conversion from digital signals to analog signals is performed by the facsimile’s MODEM. Here, let’s describe the various modulation systems that differ according to the MODEM in use.

5.1 Modulation and Demodulation

On a facsimile, the digitally coded image data varies the analog carrier wave. Converting digital signals to analog signals in this way is called “modulation.” When modulation processing is performed, the digital information is moved onto the changes in the carrier wave. Changing the carrier wave in this way is called modulation by digital signals. There are various modulation method: method that are amplitude-dependent, frequency-dependent and phase-dependent, for example.

Let’s describe modulation using digital signals using a simple example to aid understanding. Fig. 5-37 shows an example of Amplitude Shift Keying (ASK) method.

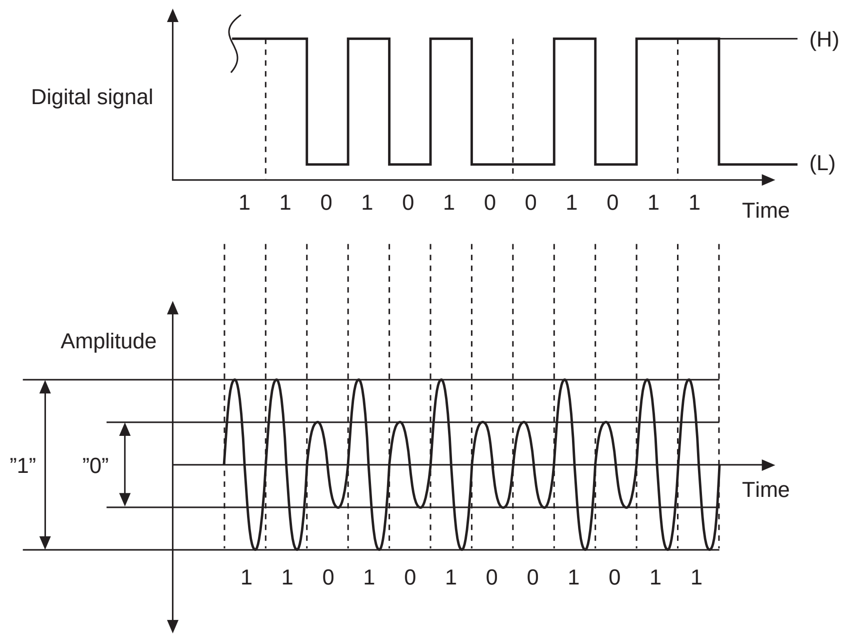


Fig. 5-37 Example of Amplitude Shift Keying Modulation

In this example, the digital signals change the amplitude of the carrier wave. For this reason, this modulation method is called “amplitude shift keying modulation.” As can be seen from the figure, the digital information (0, 1) is expressed by the size of the amplitude of the analog carrier wave.

Alternatively, the process of restoring the original digital signal from the modulated carrier wave is called “demodulation.”

Accordingly, the MODEM built into the facsimile unit has two operation modes. In other words, modulation is performed when data is transmitted, and demodulation is performed when data is received.

- Signals transmitted by MODEM

On a facsimile, coded image data can be mutually transmitted and received by the MODEM. However, a MODEM transmits and receivers not only image data. Control signals such as facsimile control procedure signals are also transmitted and received by the MODEM.

NOTE

Bandwidth of Telephone Line

There is also another important point in data transmissions using a public switched telephone line. That is the problem of the bandwidth of the telephone line. The actual bandwidth of a public switched telephone line is between 300 Hz and 3400 Hz. MODEMs assure facsimile data transmission within this bandwidth by using the carrier wave of frequencies of 3400 Hz or less.

5.2 Shift and Modulation Methods

“Shift” refers to changing of the carrier wave into a different form in response to the logical values of “1” and “0” of a binary digital signal. The carrier wave can be changed in various ways depending on which modulation method is adopted. The amplitude, frequency or phase of the carrier wave can be changed independently, or phase and amplitude can also be changed together.

In the amplitude shift keying modulation example on the previous page, the amplitude of the carrier wave is changed. For this reason, ASK is also called Amplitude Modulation (AM). Note, however, that this modulation method is currently not used on facsimiles.

5.3 Modulation Methods up to 9600 bps

Here, let's describe modulation methods having a data transmission speed up to 9600 bps that is currently used on almost all facsimiles.

5.3.1 Frequency shift keying

Frequency Shift Keying (FSK) is a modulation method that is widely used on facsimiles to transmit facsimile procedure signals. By FSK, the frequency of the carrier wave is changed to express digital data.

Fig. 5-38 shows an example of FSK. In this example, digital "0's" is expressed by a signal of 1850 Hz and digital "1's" is expressed by a signal of 1650 Hz. The length of frequency components that shows each numerical value is 1/300 seconds. In other words, 300 frequency components are transmitted in one second.

As each component is equivalent to a single bit, the data transmission speed using FSK becomes 300 bps.

This type of FSK system is recognized by ITU-T, and related recommendations are called ITU-T recommendation V.21.

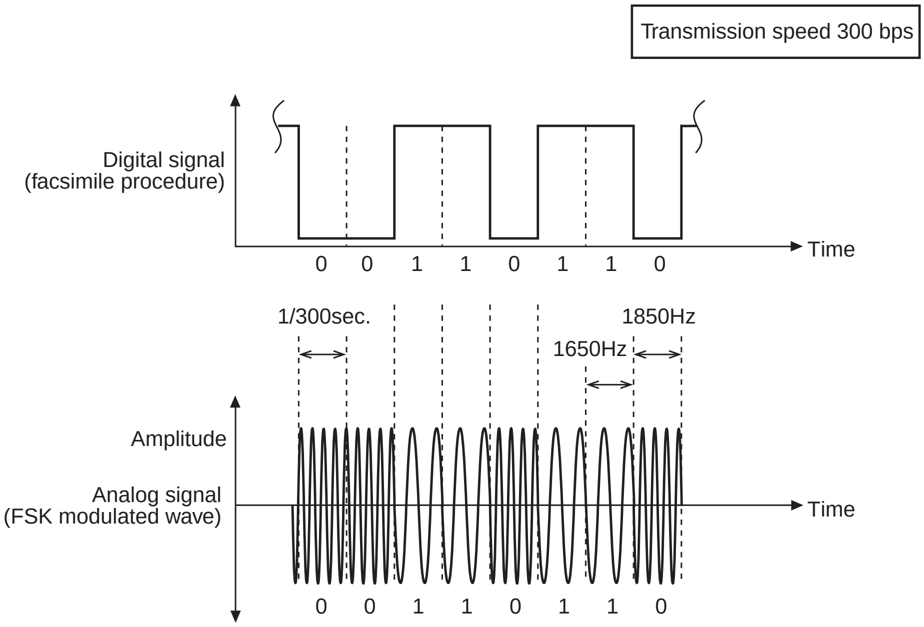


Fig. 5-38 Frequency Shift Keying

5.3.2 Phase shift keying

Phase Shift Keying (PSK) is a general-purpose modulation method that is used on facsimiles to transmit image signals. This system expresses digital data by changing the phase of the carrier wave. Here, let's describe PSK by starting with a description of the meaning of "phase change."

"Phase" refers to the relative position in time of the signal of a fixed frequency. A complete cycle of these signals contains a phase of 360°. Fig. 5-39 shows an example of the relative position between the carrier wave and the phase.

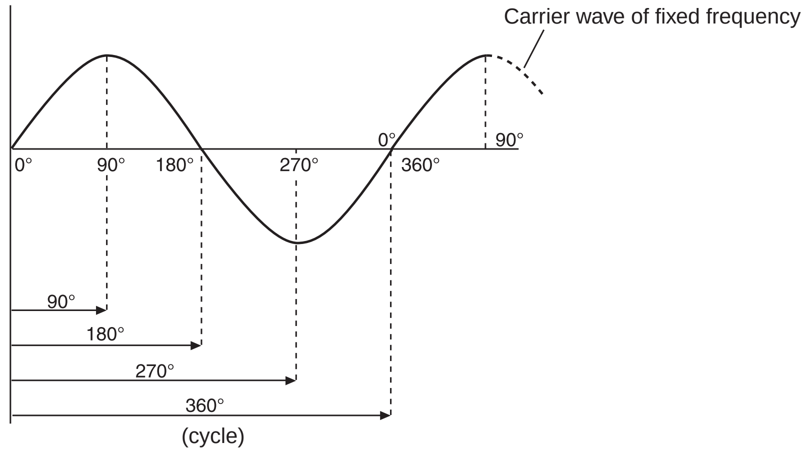


Fig. 5-39 Carrier Wave and Phase

As can be seen from this figure, the same start point is returned to if the 360° phase is advanced along the signal whichever point is taken as the start point. In other words, the position of 360° indicates exactly the same point as the position of 0° on the signal.

"Phase change" shows the size of the phase by which the signal is shifted. Fig. 5-40 shows a simple example to illustrate this. This example shows instances where the phase change is 0° (no phase change), 90° and 180°.

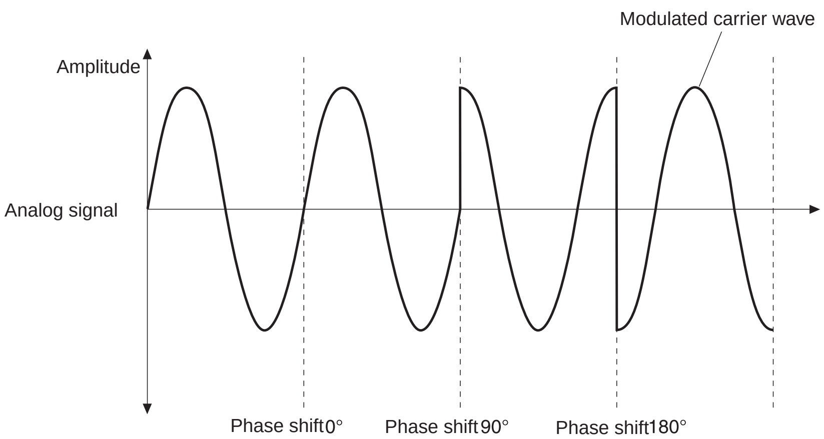


Fig. 5-40 Carrier Wave and Phase Change

(1) Concept of PSK method

The PSK method expresses digital information by changes in the phase of the carrier wave. The size of the change in the phase that occurs as a result of modulation differs according to the PSK method adopted. By the PSK method, information is not expressed by the actual shape of the carrier wave itself but by changes in the phase of the carrier wave. For this reason, "spatial diagrams" are used to show phase changes adopted by a certain particular modulation method. A spatial diagram is a two-dimensional diagram in which the carrier wave shows the phase of 360°. Diagram axes shows the amplitude range of the signal at each respective phase. The number of these axes is either four or eight depending on which PSK method is adopted.

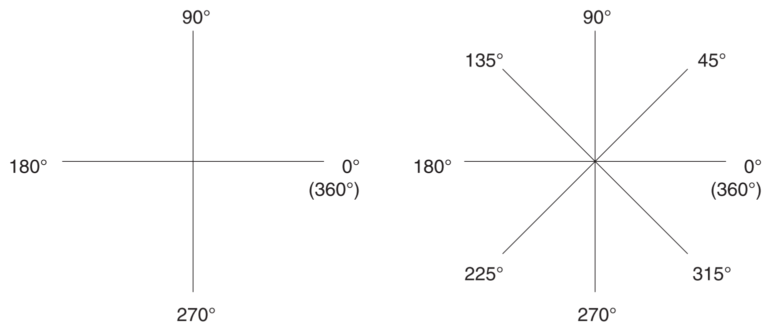


Fig. 5-41 4-phase and 8-phase Spatial Diagram

(2) 2400 bps PSK methods

By this PSK method on a facsimile, four relative phase changes are used to express digital signals. If we use the spatial diagram in Fig. 5-42 below, we can fully understand that this method uses the relative phase changes at 0°, 90°, 180° and 270°, and further that each of the phase changes expresses a combination of two digital bits called a "dibit."

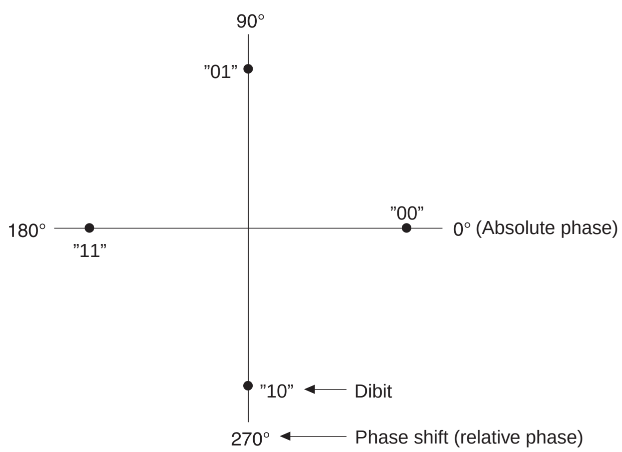


Fig. 5-42 Spatial Diagram of 4-phase PSK Method

Coded image data is grouped into two consecutive digital bits, and the carrier wave is modulated every 1/1200 seconds on each group. In other words, there are 1200 phase changes every second.

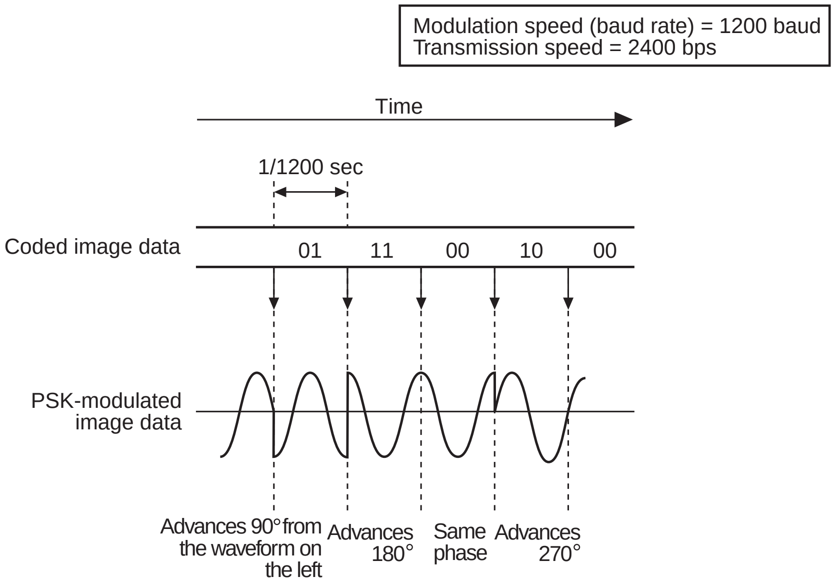


Fig. 5-43 4-Phase PSK Method Modulation Carrier Wave Image

- Modulation speed

  The number of changes that occur in the carrier wave per second is called the modulation speed (baud rate).

  The modulation speed of this method is 1200 baud. If the modulation speed is 1200, then the number of bits of digital data that corresponds to each relative phase changes is two, and so the bit rate (actual transmission speed) is 2400 bps.

- ITU-T recommendation V.27 ter

  ITU-T recognizes PSK methods that transmit data at a speed of 2400 bps, and related standards are called ITU-T recommendation V.27 ter.

(3) 4800 bps PSK methods

4800 bps modulation PSK methods are also used in facsimile data transmissions.

By this PSK methods, eight relative phase changes are used to express digital signals. If we use the spatial diagram in Fig. 5-44 below, we can fully understand that this method uses the relative phase changes at 0°, 45°, 90°, 135°, 180° , 225°, 270°, and 315°, and further that each of the phase changes expresses a combination of three digital bits called a “tribit.”

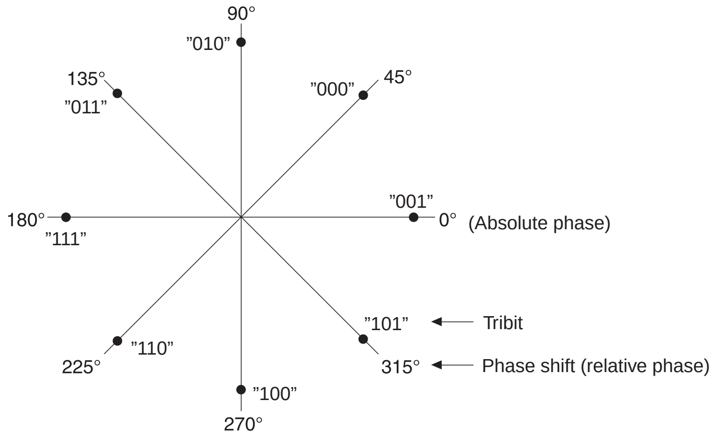


Fig. 5-44 Spatial Diagram of 8-phase PSK Method

Coded image data is grouped into three consecutive digital bits, and the carrier wave is modulated every 1/1600 seconds on each group. In other words, there are 1600 phase changes every second. Accordingly, the modulation speed of this system is 1600 baud. If the modulation speed is 1600, then the bit rate is 4800 bps.

4800 bps PSK methods are also called ITU-T recommendation V.27ter in the same way as 2400 bps PSK methods.

5

(4) Limits of PSK methods

Logically, PSK methods can be used to achieve transmission speeds of 7200 bps or higher. If we fully consider the 4800 bps 8-phase system described above, we can understand how this can be achieved. For example, if the modulation speed is increased to 2400 baud, then a transmission speed of 7200 bps can be obtained. However, transmission speeds this fast are not used in facsimile transmission. There are two reasons for this.

- As the bandwidth of telephone lines is limited, modulation speeds exceeding 2400 baud result in signal errors.
- By PSK methods, the number of phase changes cannot be set to eight or higher.

To achieve transmission speeds of 7200 bps or higher, a modulation method called QAM is used.

5.3.3 Quadrature amplitude modulation method

Quadrature Amplitude Modulation (QAM) is a modulation method that expresses digital information using the changes in both the amplitude and phase. From this, we can understand the following:

AM + PSK = QAM

(1) 9600 bps QAM method

This QAM method groups digital image data into 4-bit groups called “quad bits.” The initial bit of the quad bit determines the amplitude of the modulated carrier wave. The remaining three bits determine the relative phase changes to be applied to the carrier wave in the same way as in the PSK method.

Fig. 5-45 shows the spatial diagram of the QAM method. Here, too, we can see that the relative changes at 0°, 45°, 90°, 135°, 180° , 225°, 270°, and 315° are used, and further that each of the phase changes indicates a tribit. The figure also shows the fact that the carrier wave has two relative amplitudes.

These amplitudes are each identified as large amplitudes whose initial bit indicates digital “1” and small amplitudes whose initial bit indicates digital “0”.

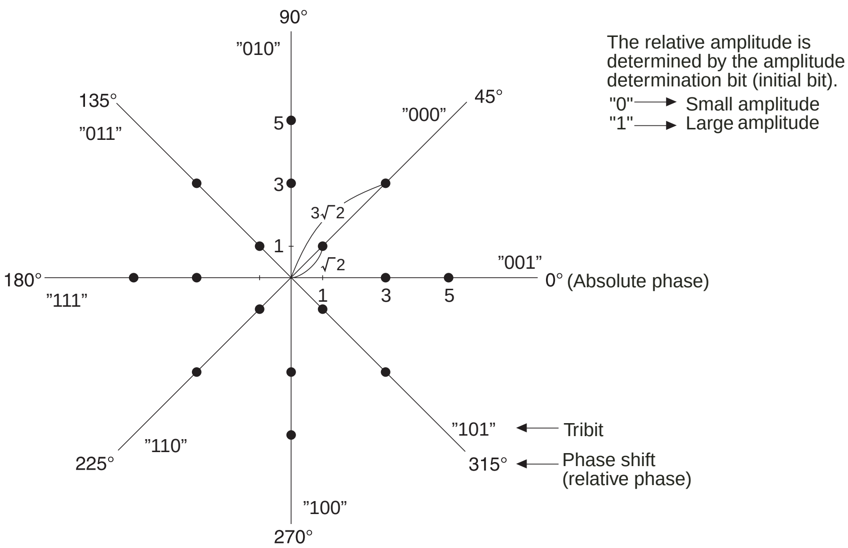


Fig. 5-45 Spatial Diagram of QAM Method

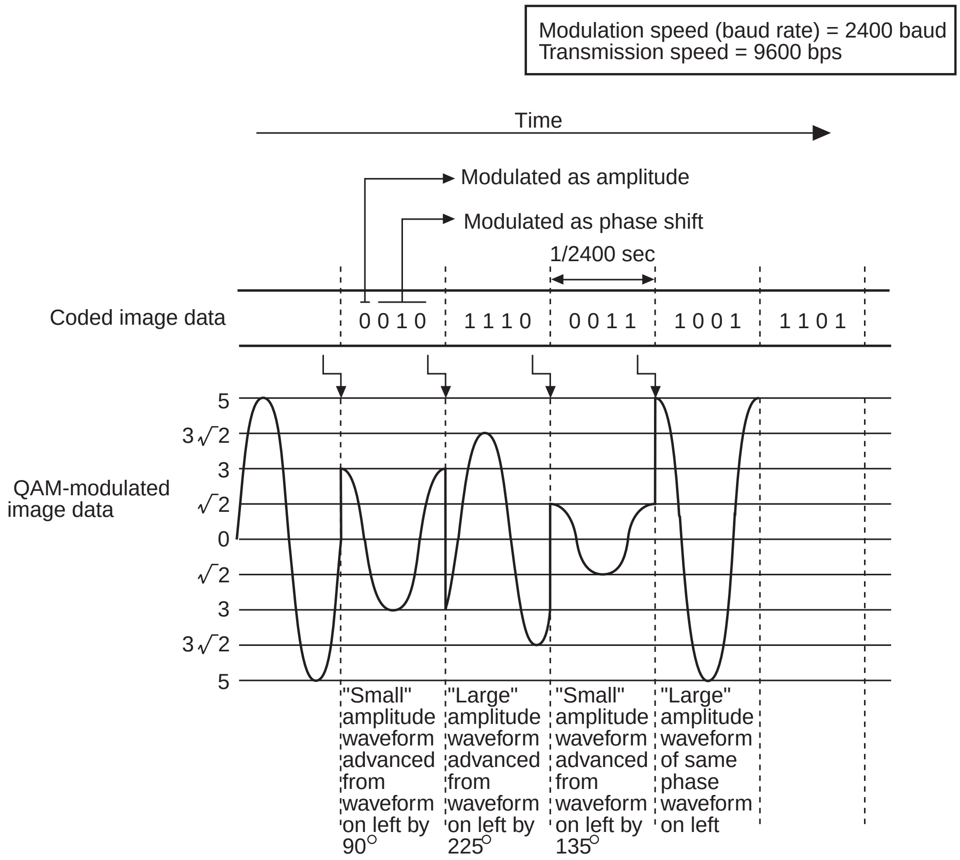


Fig. 5-46 Example of QAM Method (image)

- Modulation speed of QAM method

  The QAM method modulates the carrier wave every 1/2400 seconds. In other words, there are 2400 phase changes every second. Accordingly, the modulation speed of this QAM method is 2400 baud, and the transmission speed becomes 9600 bps.

- ITU-T recommendation V.29

  ITU-T recognizes QAM methods that transmit data at a speed of 9600 bps, and related standards are called ITU-T recommendation V.29.

(2) 7200 bps QAM methods

The 7200 bps QAM methods technically is the same as the 9600 bps QAM methods. The same phase changes are used, and the modulation speed is also the same. However, the 7200 bps QAM methods differs in respect that the carrier wave does not carry any information. In other words, the initial bit of the quad bit is fixed to “0” and is a so-called unwanted bit. The remaining bits are used to change the phase, and the modulation speed is 2400 baud. For this reason, the data transmission speed becomes 7200 bps. 7200 bps QAM systems are also called ITU-T recommendation V.29 in the same way as 9600 bps QAM methods.

(3) Additional explanation relating to QAM methods

The purpose of QAM methods is not to increase the transmission speed by generally increasing the number of phases in modulation processing. The reason for this is that as a distortion occurs due to the characteristics of telephone line which results in the position of the modulation signal shifting and amplitude change. The mutual interval between phase changes can be narrowed by increasing the phase changes. When this is performed, demodulation can no longer be executed due to the influence of line distortion. Fig. 5-47 illustrates this.

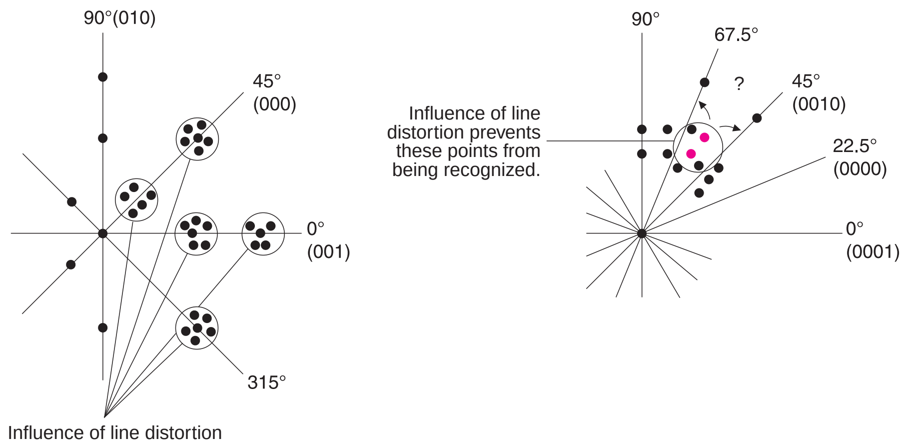


Fig. 5-47 QAM Method and Influence of Line Distortion

For this reason, only eight phase changes are used in QAM methods. The QAM method provides a “target” for each phase change and amplitude change. So that these change points are regarded as valid QAM signals, they must be positioned within the target range.

As shown in the figure below, demodulation will not be affected by influence of line distortion even if these points move within each target range.

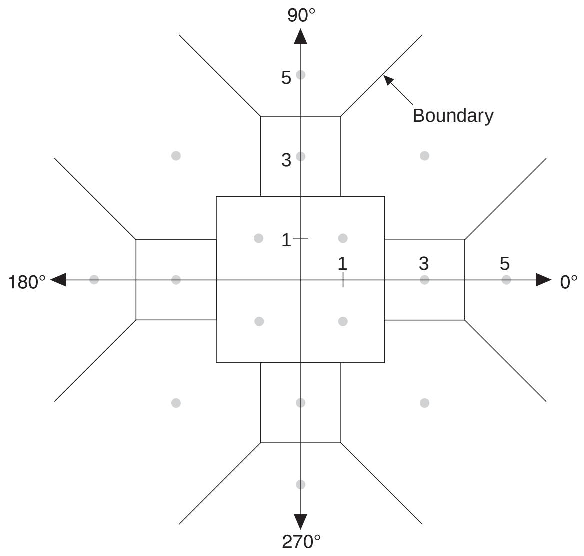


Fig. 5-48 Target of QAM Method and Spatial Pattern

5.4 High-speed MODEMs above 14400 bps

Since 9600 bps MODEMs recommended as V.29 in 1976 were adopted in facsimiles, MODEM technology has advanced all the more to the point that facsimiles capable of transmitting and receiving at transmission speeds exceeding 9600 bps are in the process of becoming mainstream. The standards for these MODEMs have already been recommended by ITU-T, and have gradually come to be installed even in low-price range products.

Of these MODEMs, let's describe an outline of the 14400 bps MODEM recommended in V.17 (V.33) and the 33600 bps MODEM recommended in V.34.

5.5 V.17 (V.33) MODEM Technology

V.17 (V.33) MODEMs recommended by ITU-T are capable of transmitting data at a high speed of 14400 bps. Until this recommendation was reached, several 14400 bps MODEMs using existing technology were put onto the market. PARADYNE Inc. first put a MODEM onto the market in 1980 and was followed by CODEX Inc. the following year in 1981, who announced a 14400 bps MODEM using multi-value QAM technology that had a 64-point signal constellation. These products improved transmission speeds by using spatial diagram patterns that were resistant to factors for impaired quality such as noise during communications. Then, in 1984, MODEMs using a modulation system called the "error correction coding QAM mehod" started to be developed, and a series of high-function MODEMs with transmission speeds exceeding 9600 bps were developed. Due to this background, ITU-T decided in 1985 on the standardization of a 14400 bps MODEM that used a coding QAM method as a MODEM exclusively for 4-wire exclusive lines. Then in 1988, this MODEM was officially recommended as V.33, and facsimiles that were capable of communicating with MODEMs made by other companies and that were capable of 14400 bps communications using proprietary modes were developed as MODEMs compliant with this recommendation. Then in 1991, a MODEM compliant with recommendation V.17 that was recommended officially by ITU-T as a 2-wire MODEM for facsimiles was developed. Recently, V.33 MODEMs are no longer used, and V.17 MODEMs that demonstrate excellent communicability with facsimiles made by other manufacturers have gained in popularity as MODEMs for facsimiles having transmission speeds in excess of 9600 bps.

The following describes trellis coding/Vitterbi decoding of error correction coding scheme that are currently used on V.17 MODEMs.

5.5.1 Basic principles of trellis coding and vitterbi decoding

Much research into error correction coding has been conducted since 30 to 40 years ago. This all began with Shannon in 1948 who announced that an error correction code capable of reducing the error rate exists after decoding is performed on a communications path that contains noise. Of the numerous error coding schemes, trellis coding and Vitterbi decoding that are currently used in V.17 MODEMs are suited to correction of random errors, and are known as error correction coding schemes that obtain extremely efficient coding gain. Vitterbi decoding was announced in 1967 by Vitterbi as a decoding method for trellis coding (also called “convolutional coding”).

(1) Trellis coding

Fig. 5-49 shows a basic convolutional coder. This convolutional coder comprises a two-stage shift register. Continuous input data is input to this shift register one bit at a time. Two bits of data are output at each input of one bit. Output data comprises data ([1] in figure) obtained by taking the sum of the input data and modulo 2 of the input data one bit before and two bits before that are currently stored to the shift register, and data ([2] in figure) obtained by taking the sum of the input data and modulo 2 of the input data two bits before that is currently stored to the shift register. In other words, the coding ratio is 1/2 as this coder outputs 2-bit coded data for one bit of input data. The length of input data that participates with output of coded data on a convolutional coder is called the “coding constraint length,” and is two in the case of the coder in Fig. 5-49.

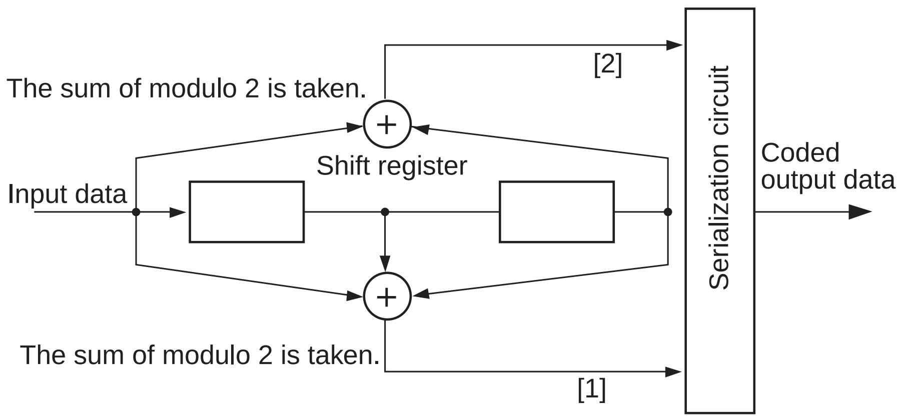


Fig. 5-49   Convolutional Coder

Here, let’s describe the regularity of the coded output data on the input data on a convolutional coder. In the coder in Fig. 5-49, the combinations of two bits 00, 10, 01 and 11 currently stored in the shift register can each be expressed by four states A, B, C and D. At this time, the relationship between these four states and one bit of input data can be expressed as the shift in states in Fig. 5-50. For example, in this figure, if the state of the shift register is A and 0 is input as the input data, coded data 00 is output, and the state remains at A. When 1 is added to the input data, coded data 11 is output which means that the state will shift to state B. In other words, from state A the state shifts only to state A or to state B.
The shift in states of other states B, C and D also have the same nature.

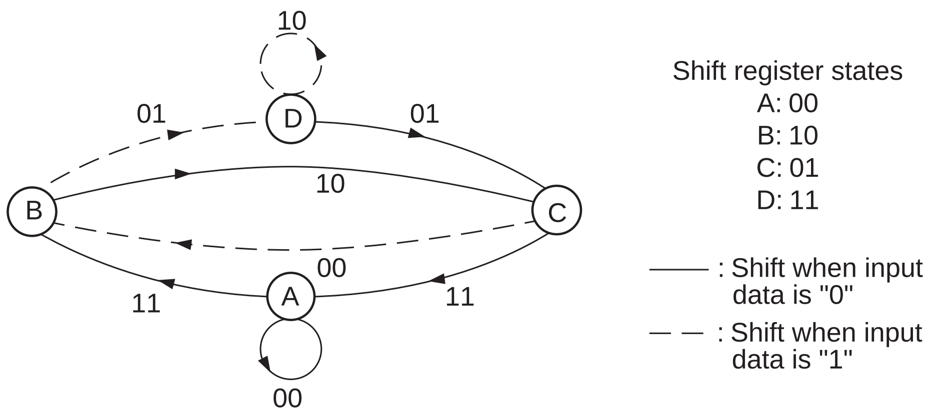


Fig. 5-50   Shift in States of Convolutional Coder

In Fig. 5-50, when input data is “0” for each of the internal states A, B, C and D of the shift register, the shift in state is expressed by the solid line, and when input data is “1”, the shift in state is expressed by the dotted line. The data of two bits shown on the solid line or dotted line shows the coded output data at that moment in time. In addition to Fig. 5-50, this nature of a convolutional coder can also be expressed by the figure of a trellis shape in Fig. 5-51. This figure is called a trellis diagram. As the nature of convolutional coding is expressed by this trellis diagram, convolutional coding is generally referred to as “trellis coding.”

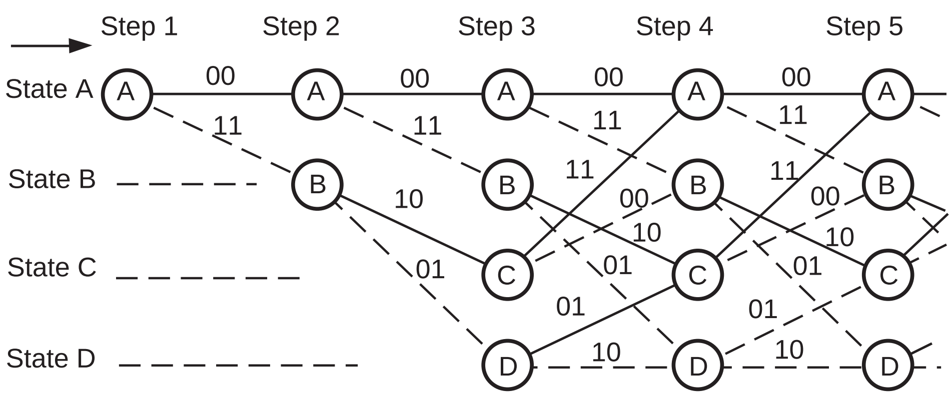


Fig. 5-51 Trellis Diagram

(2) Vitterbi decoding

The sequence of states in trellis coding is expressed by a simple repetitive structure. In information logic, this simple repetitive structure of this state sequences is generally expressed as the shift register processor, and that nature is a probability process called the Markov process. The “Markov process” is the process where the probability of generating output data of time K+1 is dependent only on states in time K when the state of time K+1 is predicted in a state up to time K that is the information source. Vitterbi decoding is a means of solving the state sequences in the Markov process, and can be applied as a decoding scheme for trellis coding. Before we discuss the Vitterbi algorithm, let’s discuss maximum likelihood decoding on which the Vitterbi algorithm is based.

Maximum likelihood decoding is a decoding scheme, when a coded data string output from the coder passes along the communications path and is received, where the most reliable-looking coded data is judged and decoded by calculating all of the Hamming distances between those received data strings and each of the possible coded data strings of all of these. Let’s try applying this maximum likelihood decoding to a communications system that uses the trellis coder in Fig. 5-49.

Assuming that the initial state of the shift register is A (=00), the coded data string becomes 110101 ...... when the data string whose initial three bits starts with 110 is input to the coder. If we assume that the 1st and 4th bits are in error while this coded data string passes along the communications path and is transmitted, then the receive data string becomes 010001. In this case, the Hamming distances between the receive data string

010001 and each of the eight possible coded data strings of all these become that as shown in Table 5-10. In this example, there are three coded data strings (000000, 000011 and 110101) for which the Hamming distance with receive data string 010001 is the minimum, and the Hamming distance is 2 in each case. At this point in time, candidates for the most reliable-looking decoding data has been narrowed down to three. Next, at the point where the data strings following input data 110 have finished being received, the decoding data for which the Hamming distance with the receive data string is the minimum is selected as 1. In the trallis diagram, the path of maximum likelihood is said to follow the transition condition. Input data is generated by reversing the coding procedure from the decoding data obtained in this way.

Table 5-10 Hamming Distance with Receive Data String

Coder Input Data	Coding Series	Hamming Distance with Data String 010001
000	000000	2
100	111011	3
001	000011	2
101	111000	3
010	001110	5
110	110101	2
011	001101	3
111	110110	4

By the procedure for judging the maximum likelihood path in maximum likelihood decoding and performing decoding, the number of coded data strings to be targeted increases exponentially when the receive data strings have increased. So, a coder that calculates all Hamming distances one by one will be a massively large-scale circuit. Whereas, Vitterbi decoding is a decoding scheme that suppresses and minimizes the number of calculations required for selecting the most reliable-looking coded data string to only the number of states that are determined by the structure of the trellis coder. It achieves this by making use of the repetitive structure of trellis coding, that is, the nature of the correlation between data. A feature relating to the repetitive structure of a trellis coder, for example, in the trellis diagram in Fig. 5-51, is that in each of the states from step 3 onwards, there are only two paths to be arrived at from the previous state. In each of the steps in this trellis diagram, of the two paths for arriving at the four states A, B, C and D, the path having the smaller distance with the receive data string is chosen, and this is stored and updated as the survivor path.

Here, the survivor paths in any step i exist individually in each of the respective states, and the distances (pathmetric) with receive data strings relating to each survivor path are assumed to Mai, Mbi, Mci and Mdi. At this time, the following operation is repeated in Vitterbi decoding.

(1) In each of states A, B, C and D of step i+1, the distance up to the receive data of the two branches arrived at from step i is calculated. (branchmetric)

(2) In each of the states of step i+1, the sum of branchmetric of the two branches arrived at from step i and the distance (that is, pathmetric) up to step i corresponding to this is calculated and compared. Whichever of the paths smaller than the sum of the distance of these two is taken to the survival path in step i+1. The sum of the distance in the survival path is taken to the new pathmetric in step i+1

(3) The survival path and pathmetric in each of the states in step i+1 obtained by the above calculation result are stored.

(4) The same operation is repeated in step i+2.

Fig. 5-52 shows the flow of the above operation. In the figure, operations in states A and B in step i+1 are shown. This update operation is called ACS (Add-Compare-Select) operation, and the distance is successively compared to select the survival path

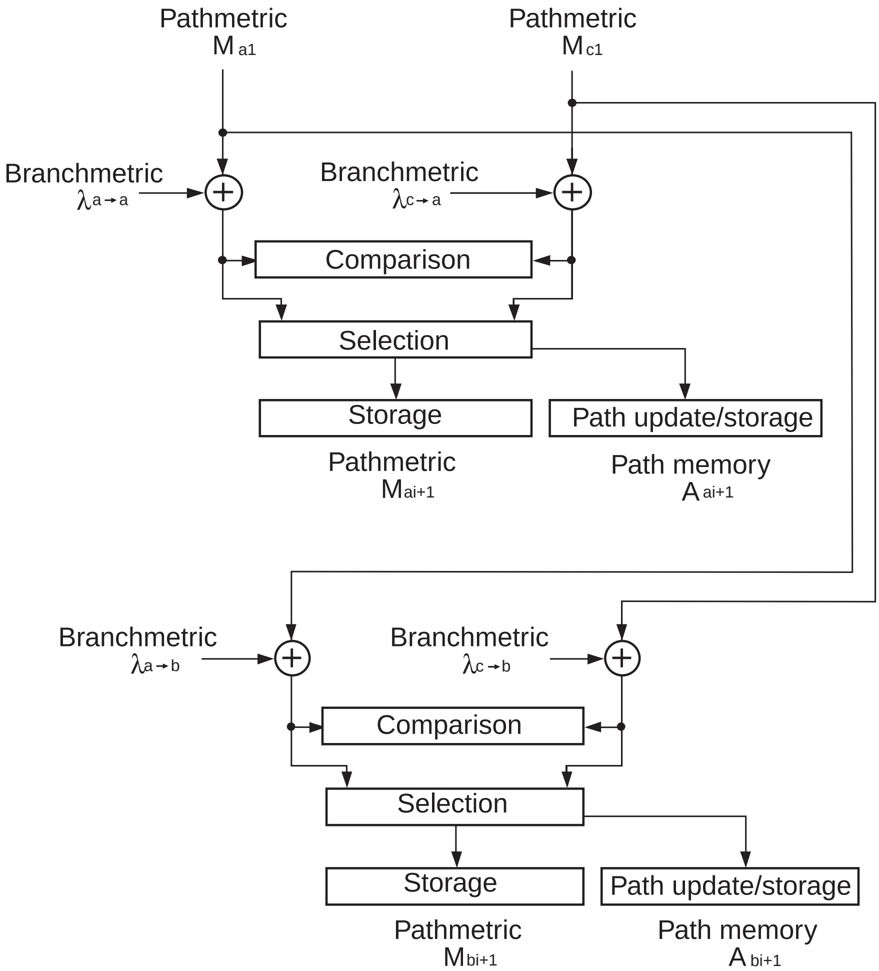


Fig. 5-52 Basic Flow of ACS Operation

This concludes a brief explanation of the principles of Vitterbi decoding. When this trellis coding/Vitterbi decoding scheme is used for voice band-width lines, generally, the branchmetric or pathmetric to the receive data string is calculated as a Euclidean distance. Though the Hamming distance is generally expressed as a Euclidean distance, the Euclidean distance is expressed as an analog amount. Conversion of the analog amount of this Euclidean distance to a digital amount is called “soft-judgment Vitterbi decoding.”

5

5.5.2 Trellis coding/vitterbi decoding on V.17 MODEMs

MODEMs support various modulation systems such as differential phase modulation and quadrature phase modulation. All of these modulation systems make the digital data correspond to analog signals and transmit information. The signals that are sent are influenced, for example, by line noise on the communications path and are deformed in greater or lesser degree. When trellis coding/Vitterbi decoding is applied to the MODEM's transmission system as an error correction mode, a method for performing error correction on the line noise is conceivable.

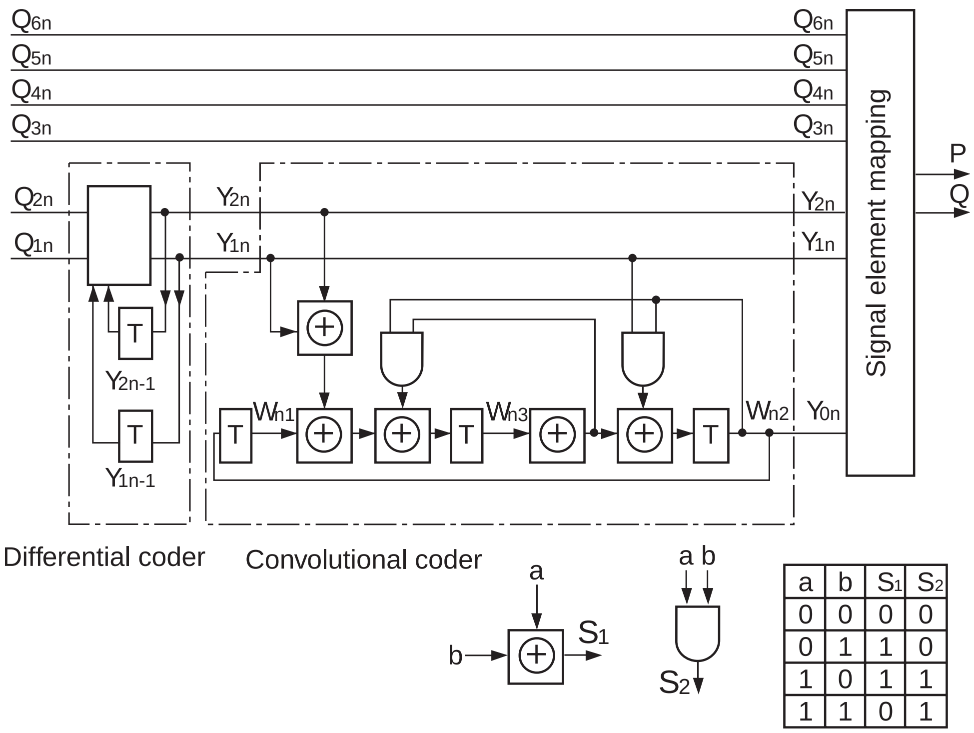
To perform error correction, the information is appended with a redundant bit before it is transmitted. Appending of the redundant bit causes the transmission efficiency to drop increasingly as the redundant bit is in a correlationship with faster data transmission speeds. The transmission efficiency, however, can be improved by performing error correction more times than the frequency of error occurrence according to impaired transmission quality caused by line noise, for example. As described above, the maximum likelihood decoding method calculates and compares the Hamming distance for judging the most reliable-looking bit targeting binary bits 0 and 1. Trellis coding/Vitterbi decoding on a MODEM, however, takes line noise generated on the transmission path into consideration, and adopts an error correction mode that uses Euclidean distance, in other words, the distance between satellite points for the receive signals as the method for judging the receive data.

Essentially, Euclidean distance is an analog amount, and a precision analog circuit is required to achieve trellis coding/Vitterbi decoding using the Euclidean distance. However, in practical terms it is difficult to achieve such as error correction scheme by an analog circuit. For this reason, the analog amount is converted to a digital amount by multi-value quantizing the Euclidean distance, and processing is then performed by a digital circuit. Decoding where the Euclidean distance is used in this way and judgment is performed according to multi-value quantized values is called "soft-judgment decoding." "Soft-judgment Vitterbi decoding" is the result of having applied soft-judgment decoding to Vitterbi decoding. When trellis coding/Vitterbi decoding that uses Euclidean distance is applied to a MODEM, coding by which the distance between signals in a constellation in a MODEM's modulated signals is made the largest is performed, and at the decoding stage, a method is used for demonstrating error correction capabilities most effectively is adopted by judging and generating signals based upon the points in the constellation that are the shortest distance with the receive signal. Though actual trellis coding as recommended is configured in accordance with the basic logic, the description relating to

Vitterbi decoding is not in the recommendation. However, at the present moment, Vitterbi decoding is generally used as it is the most efficient decoding scheme for trellis coding.

(1) 8-state trellis coding

Fig. 5-53 shows the trellis coder in V.17.



a	b	S_1	S_2
0	0	0	0
0	1	1	0
1	0	1	1
1	1	0	1

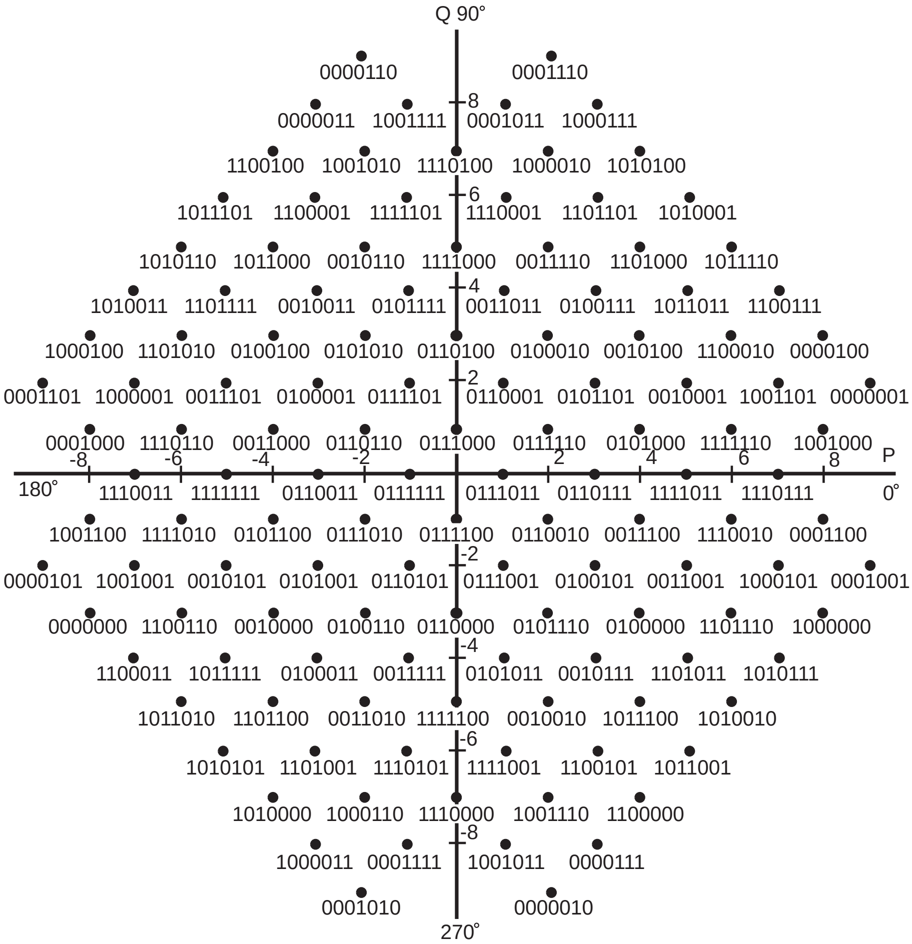
Fig. 5-53 Trellis Coder

The trellis coder comprises a mapping circuit for placing (mapping) the differential coder, convolutional coder and signals onto a signal spatial diagram (constellation). The data that is transmitted from the terminal device is sorted into data (symbols) every six bits by the parallelizing circuit, and is input to the trellis coder. In the coder, first of all, specific two bits Q1n and Q2n from among six bits Q1n to Q6n that were input are input to the differential coder to be differentially coded. After the two bits Q1n and Q2n are input to the differential coder, they are differentially coded as shown in Table 5-11, and are further input to the convolutional coder as 2-bit coded data Y1n and Y2n.

Table 5-11 Differential Coding in V.17

Input		Advance Input		Output	
Q_{1n}	Q_{2n}	Y_{1n-1}	Y_{2n-1}	Y_{1n}	Y_{2n}
0	0	0	0	0	0
0	0	0	1	0	1
0	0	1	0	1	0
0	0	1	1	1	1
0	1	0	0	0	1
0	1	0	1	0	0
0	1	1	0	1	1
0	1	1	1	1	0
1	0	0	0	1	0
1	0	0	1	1	1
1	0	1	0	0	1
1	0	1	1	0	0
1	1	0	0	1	1
1	1	0	1	1	0
1	1	1	0	0	0
1	1	1	1	0	1

By being coded, these 2-bit coded data Y1n and Y2n are appended a 1-bit redundant bit, and are output as 3-bit coded data Y0n, Y1n and Y2n. The 3-bit output coded data is mapped systematically on the signal spatial diagram as shown in Fig. 5-54 together with send data Q3n, Q4n, Q5n and Q6n that are not coded by the mapping circuit. In other words, the coding ratio is 6/7 as the trellis coder in Fig. 5-53 outputs seven bits of coded data on six bits of input data.



Q_{6n}, Q_{5n}, Q_{4n}, Q_{3n}, Y_{2n}, Y_{1n} and Y_{0n} are indicated in binary.

Fig. 5-54 Signal Spatial Diagram of Trellis Coding at 14400 bps

The repetitive structure of the coded data output from the coder is expressed by the state in shift diagram in 8-state shown in Fig. 5-55.

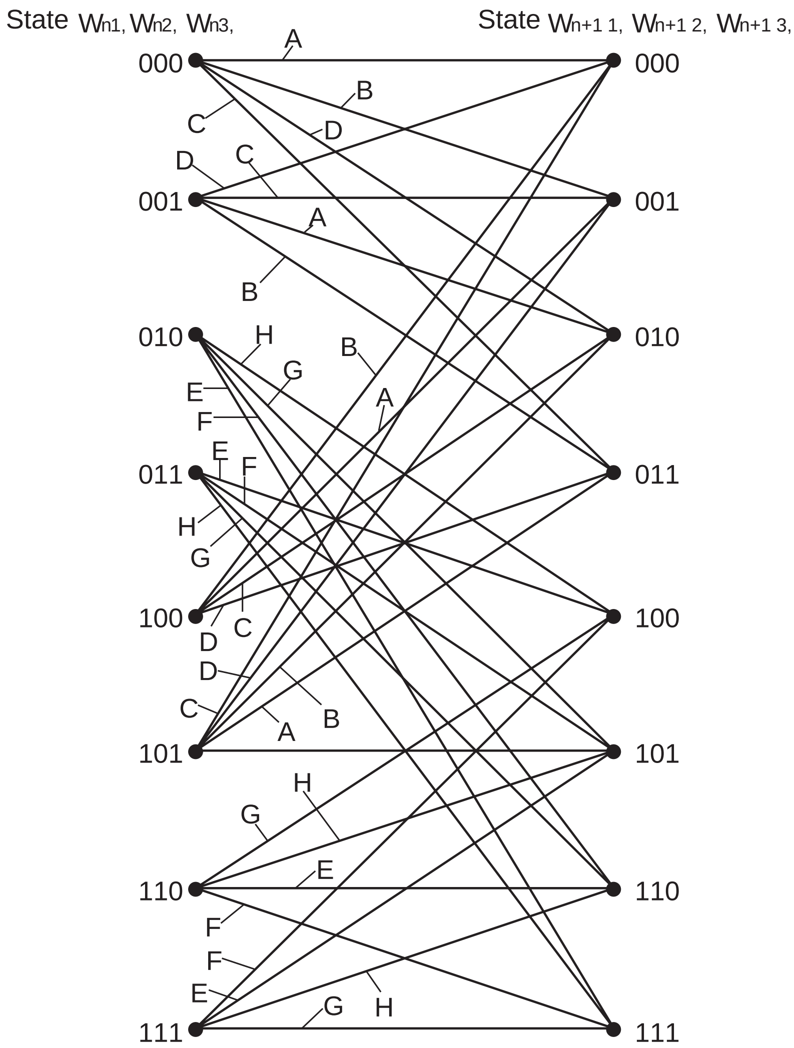


Fig. 5-55 Shift in States in 8-state Trellis Coding

At time n, when W2n from among three bits W1n, W2n and W3n currently stored on the convolutional coder is 0, one of 000(=A), 010 (=B), 001(=C) or 011(=D) is output as the coded bit string, and when W2n is 1, one of 110(=E), 101 (=F), 111(=G) or 100(=H) is output. In other words, the shift in states has regularity where there are only four shifts in state to the next state from the eight respective states. For this reason, we can try considering how the coded output data of this trellis coder is mapped. In mapping of output data from the trellis coder, the Euclidean distance between output signals that are coded as described above must be made as large as possible. With a trellis coder stipulated in V.17, the coded output data is three bits Y0n, Y1n and Y2n, and are mapped so that the distance between signals in the eight states expressed by these three bits becomes larger. For this reason, the seven bits that express each of the signal points of the signal spatial diagram in Fig. 5-54 are sorted into four bits of coded data Q3n, Q4n, Q5n and Q6n, and the eight points by three bits are each expressed by A to H, and the 16 points expressed by four bits are each expressed by 1 to 16.

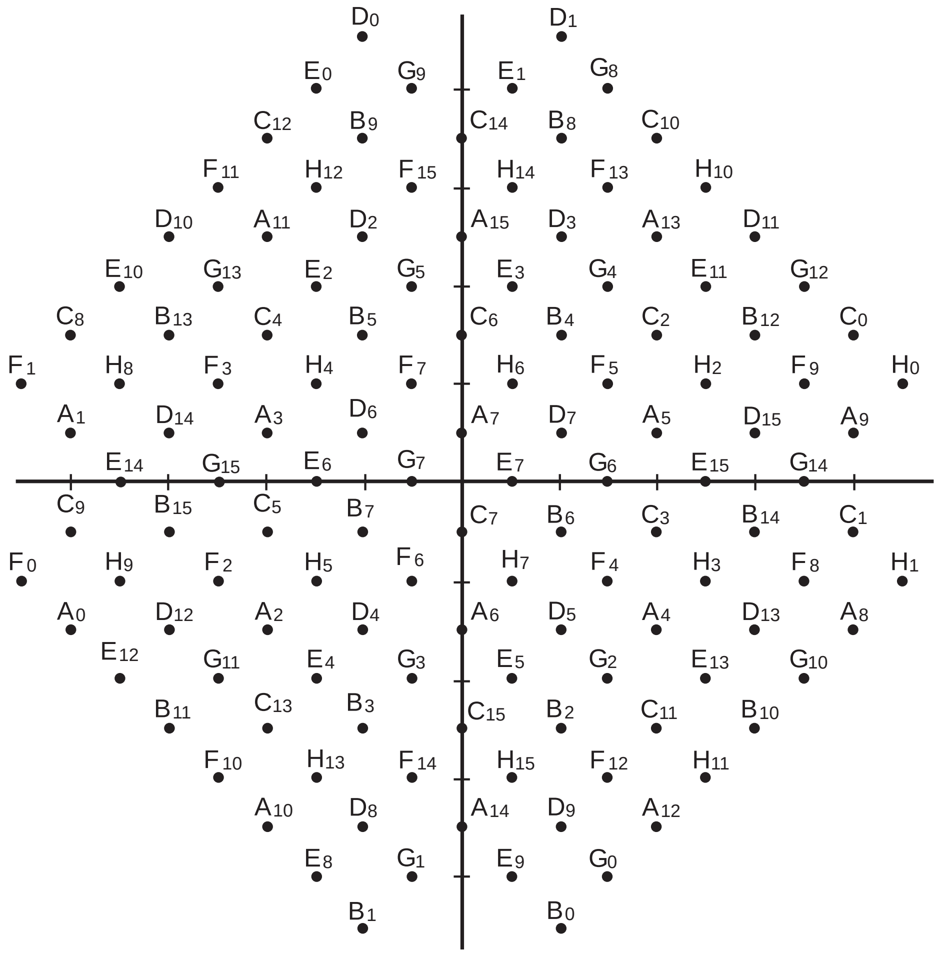


Fig. 5-56 Mapping Rules in Trellis Coding (1)

If we focus on only expression by A to H regarding these 128 signal points, of points A to H, four respective points A, B, C and D will be selected under the condition Y0n=0. If the condition Y1n=0 is added to each of these points A, B, C and D, the signal points to be selected will be limited to two points, A and C. Further, of points A and C, A will be selected if Y2n is 0, and C will be selected if Y2n is 1, and finally one of A to H will be determined. Fig. 5-57 shows the finally selected point as a large dot. If we focus on only the 16 points relating to point A selected here, it can be seen that the minimum distance between each of the 16 points will be mapped to become twice the root extraction of 2 of the minimum distance between each of the 128 points.

5

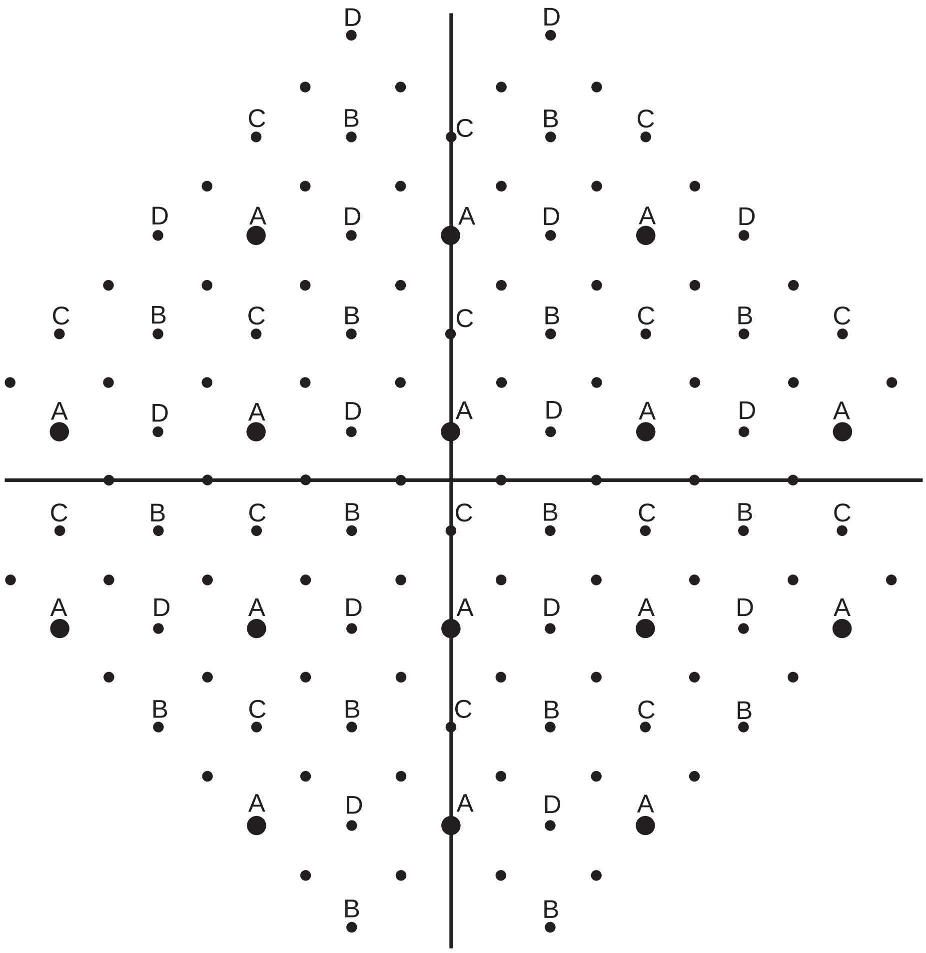


Fig. 5-57 Mapping Rules in Trellis Coding (2)

In other words, the area of these 16 points is four times the area of the original 128 points. This means that this area has a tolerance of four times with respect to data errors caused by line noise. According to the coding scheme described above, a coding gain of about 4dB can be obtained when converted to S/N ratio compared with a QAM system MODEM on which 64 points are not coded. The trellis coder in recommendation V.17 has an elimination function for phase uncertainty. Generally, on a MODEM that uses a phase modulation system or QAM modulation system, differential phase modulation system is performed; in other words, the data is replaced with the phase change of the carrier signal before it is transmitted. By this system, when an instantaneous phase change has occurred, an error will occur at that time. However, data from then on will not be affected. In V.17, the differential coder that is used as a pre-stage to the trellis coder is mounted for such kind of purpose, and has an elimination for 90°, 180° and 270° phase uncertainty. This trellis coder is configured so that receive data will not be in error in burst manner on an instantaneous phase hit of 90° according to the features of the repetitive structure and to the signal mapping rules onto the signal spatial diagram shown in Fig. 5-55.

(2) Soft-judgment Vitterbi decoding

Recommendation V.17 stipulates only 8-state trellis coding, and the fact that no stipulations whatsoever are made regarding decoding for this coding scheme is as already mentioned above. For this reason, the following describes an instance where soft-judgment Vitterbi decoding is used as a decoding method for trellis coding in a V.17 MODEM described above. The basic repetitive calculation of the trellis algorithm is as already described in item 5.5.1. Also, the branchmetric or pathmetric that is calculated in this algorithm shall be the one calculated by Euclidean distance. Now, signals that are transmitted after having passed through a trellis decoder at time n are demodulated by a QAM demodulator on the receiving side MODEM, and are shown in the signal spatial diagram in Fig. 5-56.

The received signals are expressed as points other than the 128 points as the receiver signals also generally contain line noise components, for example. Due to the fact that the trellis coder in a recommendation V.17 MODEM has the repetitive structure shown in Fig. 5-55, the branchmetric and pathmetric in the Vitterbi algorithm perform calculation on the eight states A to H.

For this reason, the branchmetric is calculated. In soft-judgment Vitterbi decoding that uses the Euclidean distance, this branchmetric is calculated as the Euclidean distance between the received signals and each signal point. At this stage, a single branch having the smallest distance is determined in the 16 signal point group for each of A to H. For example, the signal points for A are 16 points A1 to A16. Of these 16 points, a certain point is determined. In other words, the points for four bits that are not coded in Vitterbi decoding are of no concern to later calculations

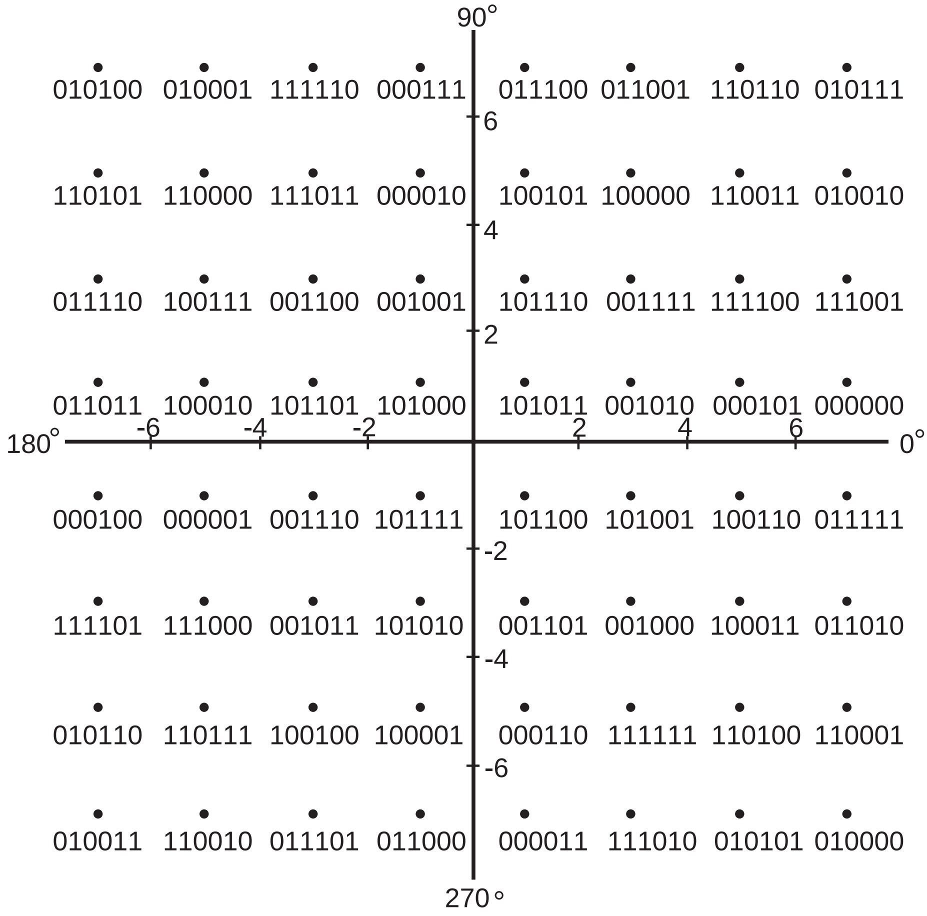
Next, the sum of the branchmetric of each calculated state and the pathmetric of each state in time n-1 corresponding to this branchmetric is calculated, and that sum is stored together with the survivor path as the pathmetric at time n. Decoded data is output after this repetitive calculation is executed for a certain fixed period of time. At this point, the problem of how long this period of time should be occurs. According to Ungerboeck's research, it was reported that the error correction capability of Vitterbi decoding is sufficiently demonstrated by storing over a period of time six times the number of bits that are stored to a convolutional coder. In other words, in V.17 MODEM coding, the survivor path and pathmetric are calculated and stored extending over 18 (3×6) modulation sectors, and decoded data is output by backtracking over the past 18 modulation sectors. When a pathmetric that extends like this over 18 modulation sectors is considered, it is anticipated that its value will increase considerably. An increase of the pathmetric to be stored means that hardware equivalent to that value will be required, and in terms of economy this cannot be said to be efficient. For this reason, the scale of the hardware can be reduced by configuring a circuit in such a way that the calculation of the pathmetric reduces fixed values at a certain point in time. This concludes discussion on trellis coding/Vitterbi decoding. It is considered that coding/decoding schemes such as these will be researched into all the more in the future.

5.5.3 Path signals

The modulation system of V.33 (same in V.17, too) is a QAM modulation system that uses a trellis coding-based ECM system. 128 points are mapped onto a signal spatial diagram (constellation) as discussed in the previous item. Otherwise, the main features of V.33 path signals are:

1. 12000 bps is stipulated as the fallback speed,
2. 1800 Hz is stipulated as the carrier frequency.

At initial stages when ITU-T deliberated V.33 as a MODEM standardized exclusively for telephone lines having a transmission speed exceeding 9600 bps, compatibility with V.29 was studied as V.33 was positioned as an extension of V.29, and work for standardization as a MODEM having fallback speeds of 12000 bps and 9600 bps was advanced. However, other work groups in ITU-T were already studying the transmission speeds of already recommended MODEMs with a view to reducing that speed as much as possible, and so the fallback speed was determined at only 12000 bps in keeping with that spirit. This fact means that compatibility with V.29 MODEMs has not been taken into consideration. Essentially, fallback is performed when it is difficult to secure a transmission speed of 14400 bps in a state where something has caused line quality to drop. In the case of a V.33 MODEM, it has actually been proven that equivalent performance to that of a V.29 MODEM can be obtained by trellis coding technology, for example, by causing a fallback to 12000 bps; and when the speed of 9600 bps in the V.29 system is to be secured, it is anticipated that the speed of 12000 bps of the V.33 system will be ensured. On the premise that a V.33 MODEM does not take compatibility with a V.29 MODEM into consideration, this fact means that a fallback speed of 9600 bps is not required. Due to this background, the fallback speed of a V.33 MODEM was determined to be only 12000 bps. When a fallback is made to 12000 bps, coding is performed excluding Q6n shown in the figure, and mapping shown in Fig. 5-58 is performed on the signal spatial diagram.



Q_{5n}, Q_{4n}, Q_{3n}, Y_{2n}, Y_{1n} and Y_{0n} are indicated in binary.

Fig. 5-58 Signal Spatial Diagram at 12000 bps

Due to the relationship between transmission bandwidth and modulation speed, the carrier frequency of V.29 is stipulated at 1700 Hz. When the carrier frequency of V.33 was studied by ITU-T, naturally, a MODEM for a telephone line exclusive to V.29 of the same modulation speed and a MODEM for a V.32 publicly switched telephone network were compared. The carrier frequencies of each differed at 1700 Hz and 1800 Hz in spite of the fact that they both used almost the same frequency bandwidth.

When the task of recommending the V.33 MODEM was rigorously deliberated by ITU-T, there was already broad consensus for the recommendation of the V.32 MODEM family, and the point of issue in the deliberation became whether to select 1700 Hz, the carrier frequency of a V.29 MODEM, or to select the 1800 Hz of the V.32 MODEM family as the carrier frequency on a recommendation V.33 MODEM. As V.33 is positioned as an extended version of the V.29 MODEM, there was a proposal from various countries that the carrier frequency should be selected as 1700 Hz. However, there was also a proposal that V.33 for recommending 1800 Hz, the carrier frequency of the V.32 MODEM family is the main frequency used by ATT in the United States and BT in the United Kingdom, be adopted. At the assembly, deliberation turned into an argument between US manufacturers and Japan who insisted on the different carrier frequency of 1700 Hz.

The insistence by ATT in the United States and BT in the United Kingdom was used, for example, for controlling data transmission due to the fact that 1800 Hz was used as the carrier frequency. Various reasons such as a secondary channel (backward channel) can be added easily to the low-frequency range, and 1800 Hz is more advantageous in the design of a MODEM device were put forward to advocate 1800 Hz.

On the other hand, some MODEM manufacturers, Japan and other countries insisted on 1700 Hz and counterargued that a V.33 MODEM was already positioned as part of the V.29 MODEM family; and that, for the 1800 Hz agreed upon for the recommendation V.32 MODEM family, it had not been confirmed that sufficient performance and reliability could be obtained in band circuits of frequency 3000 Hz that are frequently seen in submarine cable systems used exclusively for international lines. As a result of deliberation, a data transmission test by an 1800 Hz carrier frequency MODEM was conducted via a submarine cable system

mainly between ATT in the United States and KDD (Kokusai Denshi Denwa Company, Ltd. in Japan) over a 3000 Hz band telephone line. As a result of the test, it was proved that sufficient performance could be obtained even when 1700 Hz was taken to be the carrier frequency; that sufficient performance could be obtained even when the carrier frequency was taken to be 1800 Hz; and that the equivalent performance and reliability as that of a MODEM using a 1700 Hz carrier frequency could be obtained. Due to these test results and the background that there is fundamentally no compatibility with V.29 at fallback speeds, 1800 Hz was adopted as the carrier frequency in V.33. This concludes discussion of fallback speeds in V.33 and the carrier frequency. The following table cites parameters relating to transmission systems.

Table 5-12 Various Parameters on V.33 MODEM

Data Transmission Speed	14400	12000	bps
Modulation speed (baud rate)	2400	2400	Baud
Number of bits per modulation	6	5	bits
Number of states per modulation	128	64	State

5.6 V.34 MODEM Technology

The image transmission time is reduced drastically compared with the previous models by the V.34 modem (maximum transmission speed 33600 bps) recommended by ITU-T.

5.6.1 V.8/V.34 protocol

(1) Outline

- The V.8 protocol is used as the startup protocol to move to V.34. The V.8 protocol enables connection with fax machines, data modem and equipment using existing V-series modems. The V.34 modem contains a modem circuit based on the previous recommendation to connect with the previous modems and has upper compatibility.
- The actual data transmission speed is improved entirely on average by speeding the modulation scheme and utilizing new techniques, such as the pre-emphasis technique*1 for increasing the S/N (signal-to-noise) ratio and the probing technique*2 for measuring line characteristics and optimizing the modem operation according to the line condition.
- The V.8 protocol, V.34 pre-protocol and post-protocol use full-duplex transmission to speed the processing.
- Fourteen image transmission speeds*3 are available:
  33600, 31200, 28800, 26400, 24000, 21600, 19200, 16800, 14400, 12000, 9600, 7200, 4800, and 2400 bps
- The modulation speed (baud rate)*4 can be selected from among 2400, 3000, and 3200 symbols/sec (required) or 2743, 2800, and 3429 symbols/sec (option). The data transmission speed can be set more finely than the previous modems.

NOTE

*1 The output level of a high-frequency zone with comparatively high noise is raised, and then the transmission signal is sent.

*2 A tone signal known as a probing signal (L1 and L2) is output, and the receiving side measures the characteristics of the line.

*3 The data signaling rate is recorded in the ITU-T standards manual. Image transmission speed means the same as data signaling rate.

*4 The symbol rate is recorded in the ITU-T standards manual. Symbol rate means the same as moderation speed and baud rate.
2743 symbol/sec cannot be used with this fax.

NOTE

1. The V.34 protocol uses ECM. If the ECM SW in user data is set to OFF, the V.8 protocol is not executed. Therefore, the V.34 protocol is not used, and V.17 or a lower protocol is selected.
2. If the transmission speed is set to 14400 bps or lower, the V.8 protocol is not executed and V.17 or a lower protocol is selected.
3. After the V.21 protocol is selected first, it can be changed to V.8 or V.34. (See Fig. 5-60)
4. When the V.34 protocol begins, it falls back within the V.34 protocol, but it does not fall back to the V.17 mode or lower.

(2) Typical protocol

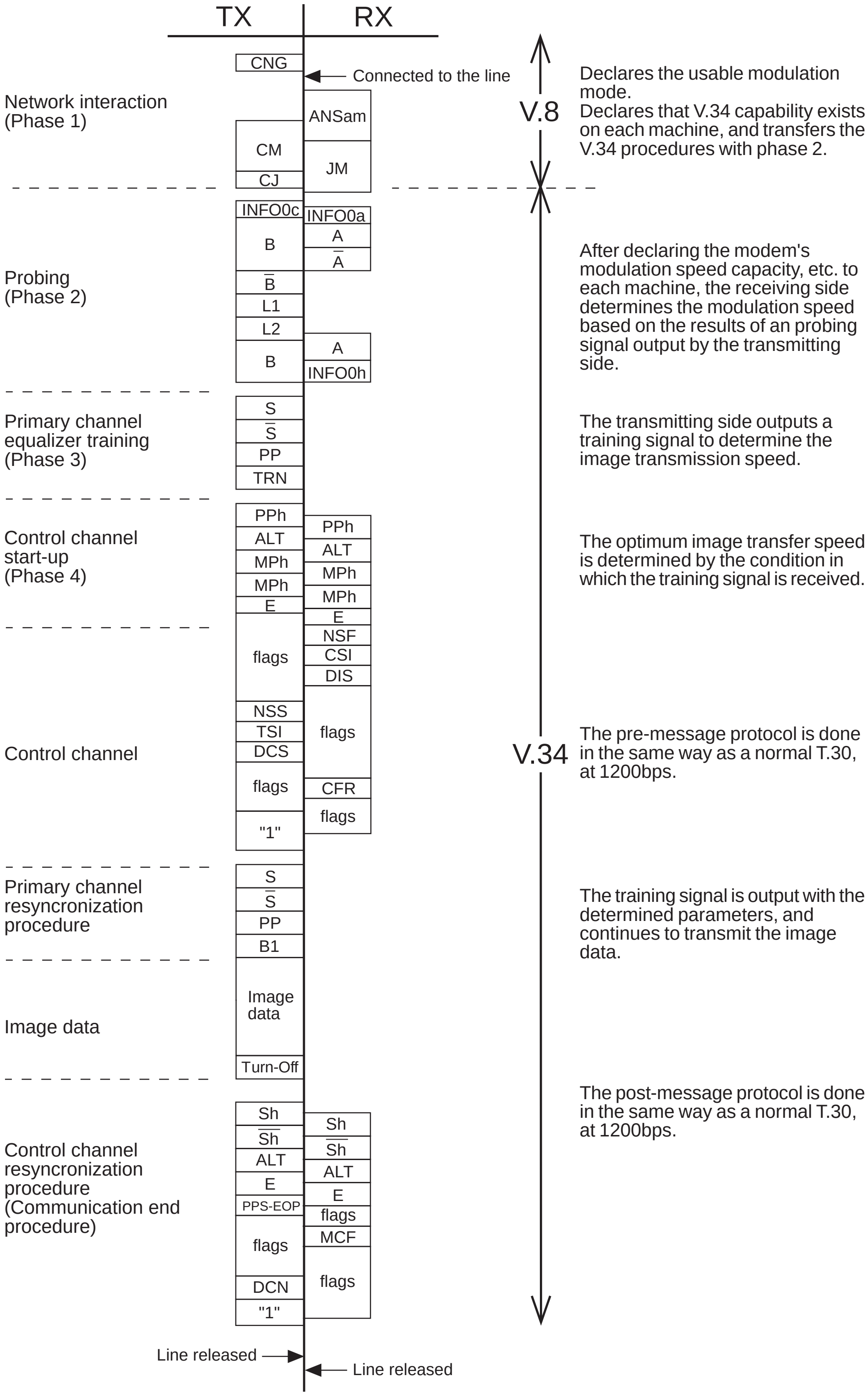


Fig. 5-59 Typical Protocol

- Network interaction (Phase 1)

  The V.8 protocol is used as the startup protocol for high-speed modem V.34.

  The V.8 protocol determines the best modulation scheme (V-series modem mode) that is available between the transmitter and receiver.

Transmitter

Signal	Abbre-viation	Meaning	Remarks
Calling tone	CNG	1100-Hz tone signal specified by T.30 to identify an automatic-calling fax machine.	
Call menu signal	CM	Indicate an available modulation scheme (V.21, V.27ter, V.29, V.17, or V.34).	Modulated by V.21(L)*1.
CM terminator	CJ	Indicate JM signal detection and CM signal termination.	Modulated by V.21(L)*1.
Call indicator signal	CI	Indicate the general transmission function. Sent to resume the V.8 protocol.	Late start only. (See Fig. 5-60) Modulated by V.21(L)*1.

Receiver

Signal	Abbre-viation	Meaning	Remarks
Modified answer tone	ANSam	2100-Hz tone signal amplitude-modulated by 15 Hz.	Equivalent to CED for previous models.
Joint menu signal	JM	Indicate the terminal type, such as a fax machine, and an available modulation scheme in response to the available modulation scheme reported by the CM from the transmitter.	Modulated by V.21(H)[*1].

*1 V.21(L): Low-frequency channel defined by V.21 recommendation
1080±100 Hz (980 Hz:1, 1180 Hz:0)
Transmission speed: 300bps
V.21(H): High-frequency channel defined by V.21 recommendation
1750±100 Hz (1650 Hz:1, 1850 Hz:0)
Transmission speed: 300bps

- Probing (Phase 2)

  The line characteristics are measured and modulation-related parameters, such as symbol rate, are set.

Transmitter

Signal	Abbre-viation	Meaning	Remarks
INFO sequence	INFO0c	Indicate modem capabilities, such as baud rate and frequency transmission function (two frequency bands used to measure line characteristics), and request adjustment.	Transmission speed: 600bps
Tone B	B	Modem synchronization with a 1200-Hz tone signal.	The phase of the B- signal is inverted 180 degrees from the phase of the B signal.
Tone $\overline{B}$	$\overline{B}$		
Probing signal L1	L1	Tone signal for analyzing line characteristics by probing.	Probing: Measurement of line characteristics. Tone signal in the range 150 to 3750 Hz in 150-Hz steps.
Probing signal L2	L2		

Receiver

Signal	Abbre-viation	Meaning	Remarks
INFO sequence	INFO0a	Report the modem capabilities, such as baud rate and frequency transmission ability.	Transmission speed: 600bps
Tone A	A	Modem synchronization with a 2400-Hz tone signal.	The phase of the A- signal is inverted 180 degrees from the phase of the A signal.
Tone $\overline{A}$	$\overline{A}$		
INFO sequence	INFO0h	Report the pre-emphasis filter and baud rate used for data transmission based on the result of analysis of the probing signal.	Transmission speed: 600bps

- Primary channel equalizer training (Phase 3)

Filters, such as equalizers, are trained (adjusted) with the parameters set in phase 2.

Transmitter

Signal	Abbre-viation	Meaning	Remarks
S signal	S	Short training	The phase of $\overline{S}$ is shifted from the phase of S.
$\overline{S}$ signal	$\overline{S}$		
PP signal	PP	The other modem uses this signal to train the equalizer.	
TRN signal	TRN	The receiver uses this signal to determine the transmission speed.	

- Control channel start-up (Phase 4)

  Select the maximum data signalling rate and trellis encoder and set the data signalling rate that can be supported.

Transmitter/receiver

Signal	Abbre-viation	Meaning	Remarks
PPh signal	PPh	The other modem uses this signal to train the equalizer.	
ALT signal	ALT	—	
Modulation parameter	MPh	Indicate the image transmission parameters, such as maximum data signal speed, control channel data signal speed, trellis coding type, pre-coding type, and baud rate.	
E sequence	E	—	20-bit sequence of binary 1’s.

- Control channel

  The conventional T.30 protocol is executed.

  The transmission speed is 600bps.

Transmitter

Signal	Abbre-viation	Meaning	Remarks
Flag	flags	Maintain synchronization.	7E (H)
Non-standard facilities set-up	NSS	Receive NSF from the other party, select an available mode from it, and instruct reception.	
Transmitting subscriber identification	TSI	Report the transmitter telephone number.	
Digital command signal	DCS	Instruct the available mode.	
—	1	Declare to switch to high-speed protocol.	Transmit 1's.

5

Receiver

Signal	Abbre-viation	Meaning	Remarks
Non-standard facilities	NSF	Report functions not recommended by ITU-T, user's ID, manufacturer code, etc.	
Called subscriber identification	CSI	Report the receiver telephone number.	
Digital identification signal	DIS	Report standard ITU-T-recommended functions.	
Flag	flags	Maintain synchronization.	7E (H)
Confirmation to receive	CFR	Report that modem training ends and image signal reception is ready.	

NOTE

In the control channel, signals which differ according to the frequencies of both TX and RX are output. It follows that the effects of the echo are not received because the frequencies of the signal returned by echo and the signal output by the other machine are different.

- Primary channel resyncronization procedure

Training is performed with the parameters set in phase 4.
The transmission speed is 1200bps.

Transmitter

Signal	Abbre-viation	Meaning	Remarks
S signal	S	Short training	The phase of $\overline{S}$ is shifted from the phase of S.
$\overline{S}$ signal	$\overline{S}$		
PP signal	PP	The other modem uses this signal to train the equalizer.	
Sequence B1	B1	Scramble data frame transmitted at the end of start-up protocol.	

- Image data

Transmit image data.

Transmitter

Signal	Abbre-viation	Meaning	Remarks
Image data	Image data	Encoded image data	
—	Turn-off	—	Send scrambled 1’s for 35 ms.

- Control channel resyncronization procedure (Communication end procedure)

  Protocol for terminating transmission.

  The transmission speed is 1200bps.

Transmitter

Signal	Abbre-viation	Meaning	Remarks
Sh signal	Sh	Short training	
$\overline{\text{Sh}}$ signal	$\overline{\text{Sh}}$		
ALT signal	ALT	—	
E sequence	E	—	
End of procedures	PPS-EOP	One page is transmitted.	
Flag	flags	Maintain synchronization.	7E (H)
Disconnect signal	DCN	Disconnect the line.	

Receiver

Signal	Abbre-viation	Meaning	Remarks
$\overline{\text{Sh}}$ signal	$\overline{\text{Sh}}$	Short training	
Sh signal	Sh		
ALT signal	ALT	—	
E sequence	E	—	
Flag	flags	Maintain synchronization.	7E (H)
Message confirmation	MCF	Indicate that the receiver has received the image signal correctly and can receive the next document immediately.	

(3) Examples of sequences

The signals in the shaded areas are important in the protocol.

- Late start

Since the receiver cannot detect the CM signal while sending the ANSam signal, it sends the DIS signal containing the “V.8 protocol” declaration. The transmitter sends the CI signal to request the receiver to send the ANSam signal again to move to V.8 protocol.

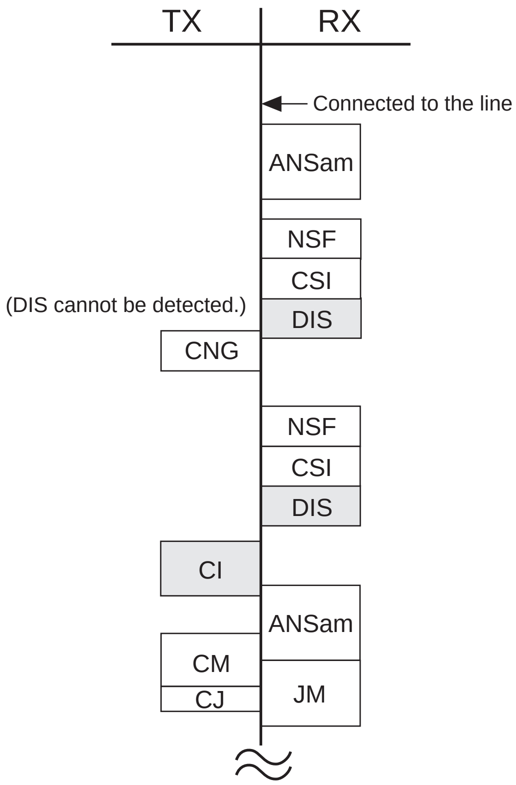


Fig. 5-60 Late Start

- Between-page sequence

  The transmitter sends image data, then the PPS-MPS signal in the same as for the T.30 protocol. The receiver sends the MCF signal to receive the next page.

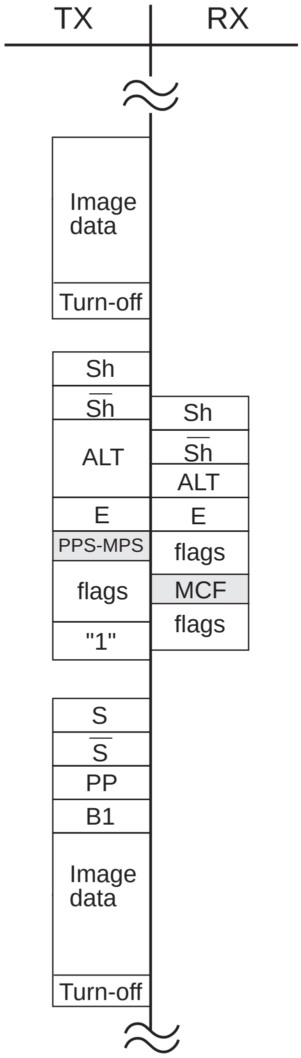


Fig. 5-61   Between-page Sequence

- Mode change

  The transmitter sends PPS-EOM and the receiver sends the MCF signal. Then the receiver sends the DIS signal and the transmitter sends the DCS signal to change the mode.

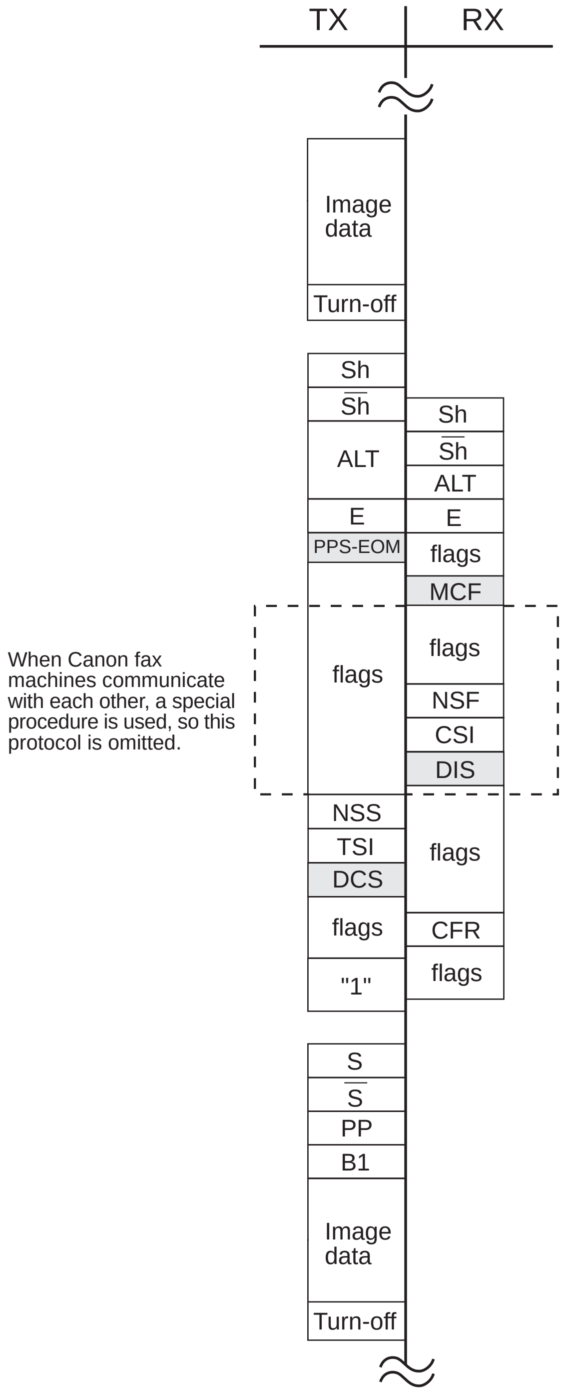


Fig. 5-62 Mode Change

- Image transmission speed change from the receiver

  The receiver returns to the PPh signal in response to the Sh signal from the transmitter. The image transmission speed is then determined by the MPh sequence sent from both modems.

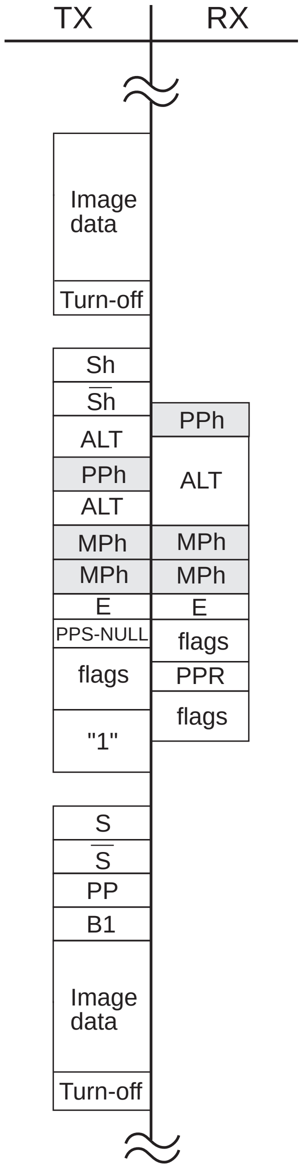


Fig. 5-63 Image Transmission Speed Change from the Receiver

- Image transmission speed change from the transmitter

  The transmitter sends image data, and then the PPh signal, and the receiver returns the PPh signal to the transmitter. The image transmission speed is then determined by the MPh sequence sent from both modems.

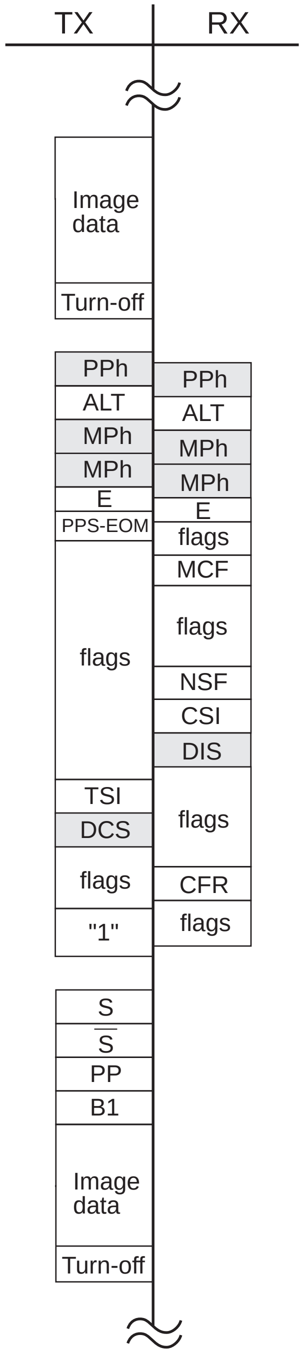


Fig. 5-64 Image Transmission Speed Change from the Transmitter

6. TRANSMISSION CONTROL PROCEDURES

With G3 facsimiles, the document size, recording paper size, MODEM type and other factors differ according to the product. For this reason, G3 facsimiles use special signals to handle mutual information about functions and states on the transmitting and receiving sides. This handling of information for ensuring that communications is proceeded with smoothly is called “transmission control,” and the procedure for transmission control is called “transmission control procedure.”

Here, let’s describe the transmission control procedures that are currently used on G3 facsimiles.

6.1 Outline of Transmission Control Procedures

When transmission is performed on G3 facsimiles, first the signal of the receiving side is asked for to verify the performance and functions of the other party. Next, the mode to transmit is notified and the coded image is sent. When transmission of the image ends, the receiving side is notified as to whether there is another page after that page or that is the end of the image. After verification is obtained, communications is ended.

In this way, the image signals are not only sent; signals are handled between facsimiles before and after the image signals. All handling of this information is performed by digital signals of 1/0. These meaningful digital signals are called “binary signals” due to the fact that they are expressed in binary, and these procedures are called “binary procedures.”

6.2 Signal Types

In G3 facsimile communications, various signals are used in addition to the previously described binary signals.

Table 5-13 Signal Types

Type of Signal	Meaning
Preamble signal	Signal prefixed to binary signal
Binary signal	Signal expressed by 0 or 1 to communicate meaning of procedure
Image signal	Signal of coded image
Tonal signal	Signal obtained by giving meaning to type of tone (frequency)

(1) Preamble

The preamble is the signal that prefixes the binary signal, and is a series of the flags for about 1 sec. A “flag” comprises eight bits “01111110” (7E when expressed in Hex), and the preamble comprises about 37 continuous flags. Synchronization of the MODEM signals for procedure signals is performed by prefixing the preamble with binary signals.

(2) Binary signal

Binary signals are signals by which facsimile procedures are handled, and are obtained by frequency-modulating 1/0. Low-speed signals are used to prevent transmission errors from occurring at a data transmission speed of 300 bps. The MODEM used at this time uses the modulation system recommended in ITU-T recommendation V.21. Binary signals have a function for checking for errors in the transmitted data.

(3) Image signal

On a G3 facsimile, image signals are coded by coding schemes such as MH and MR. The image signal modulation system and the transmission speed differ according to the MODEM in use. Image signals are transmitted at data speeds within the range 2400 bps to 33600 bps. Before image signals are transmitted, they are prefixed with a “training” signal.

(4) Tonal signal

The sine wave of a determined frequency, in other words a tone, is used as the tonal signal. This means that the height of the tone has meaning. The procedure for using this signal is called the “tonal procedure.”

6.3 Basic Transmission Control Procedure

This is the basic transmission control procedure in G3 communications. We recommend fully understanding this control procedure as it is the most basic of the procedures.

Note, however, that operation differs on V.34 MODEM installed facsimiles as they use the V.8 procedure. For details, see 5.6 V.34 MODEM Technology.

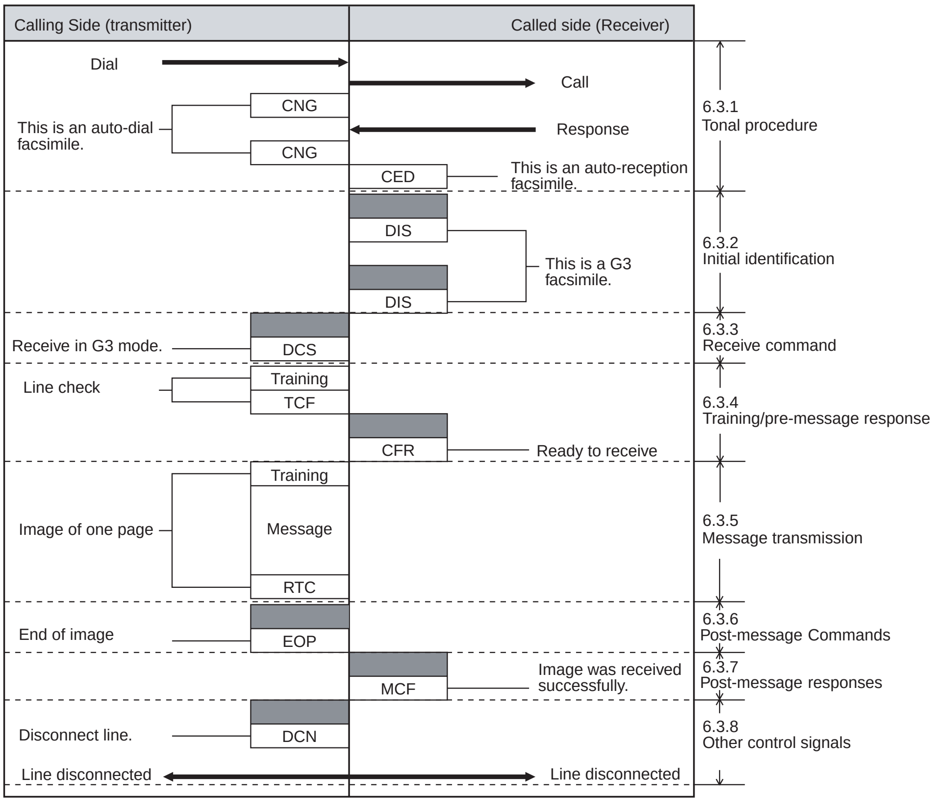


Fig. 5-65 Basic Transmission Control Procedure

The following describes the basic transmission control procedure with specific parts of the overview in Fig. 5-65 extracted for explanatory purposes.

6.3.1 Tonal procedure

Transactions are performed using only tonal signals, and whether the communicating side is the G3 transmitting side or receiving side is notified. The tonal procedure is also called center identification or phase A.

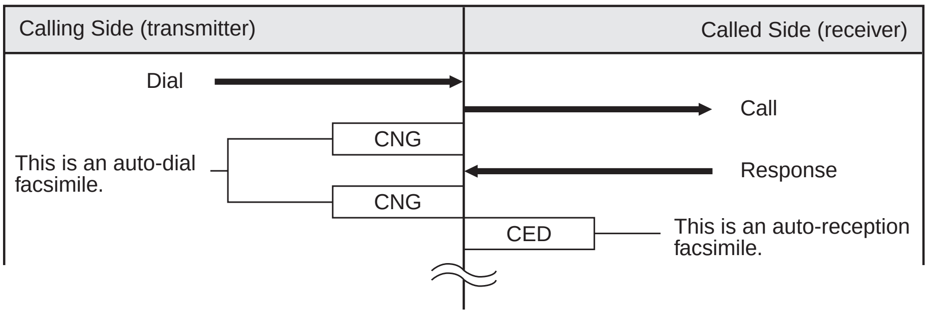


Fig. 5-66 Tonal Procedure

Overview

The transmitter transmits CNG after dialing. The receiver responds to the call up and returns CED.

CNG	Transmission → Reception	Tonal signal
This signal notifies the other party that the facsimile is an auto-dial facsimile.		
CNG can be output even on manual transmission transmitters. Some receiver models have a function for switching to the facsimile when CNG is received.		

CED	Transmission ← Reception	Tonal signal
This signal notifies the other party that reception is automatic.		
CED can also be output even during manual reception.		

6.3.2 Initial identification

The facsimile transmits its own capabilities to the destination by using the initial identification. If optional signals are used, the indispensable DIS is transmitted last.

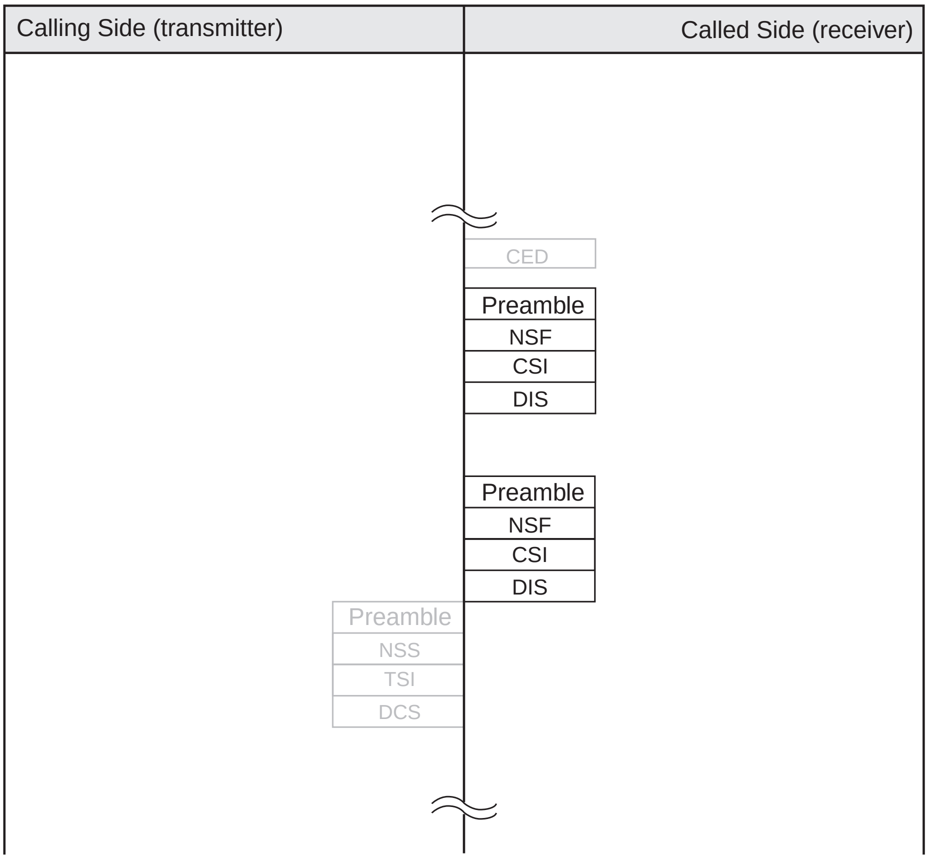


Fig. 5-67 Initial Identification

Overview

The receiving side transmits NSF, CSI and DIS after transmitting CED. NSF, CSI and DIS are repeatedly transmitted for a fixed period of time until DCS is returned.

DIS	Transmission ← Reception	Binary signal
This signal communicates to the other party that the function is a standard function recommended by ITU-T. (mandatory)		
Communicates the recording paper size, transmission speed, MTT, coding scheme, recording resolution, and other information.		

NSF and CSI are option signals. They are described in 6.7 Option Signals (described later).

6.3.3 Receive command

This command is transmitted after the initial identification or the transmit command is received from the other party. (For details on the transmit command, see 6.9.1 Polling (reception on calling side) (described later).)

Overview

When DIS is received from the receiver, the transmitter sends the DCS.

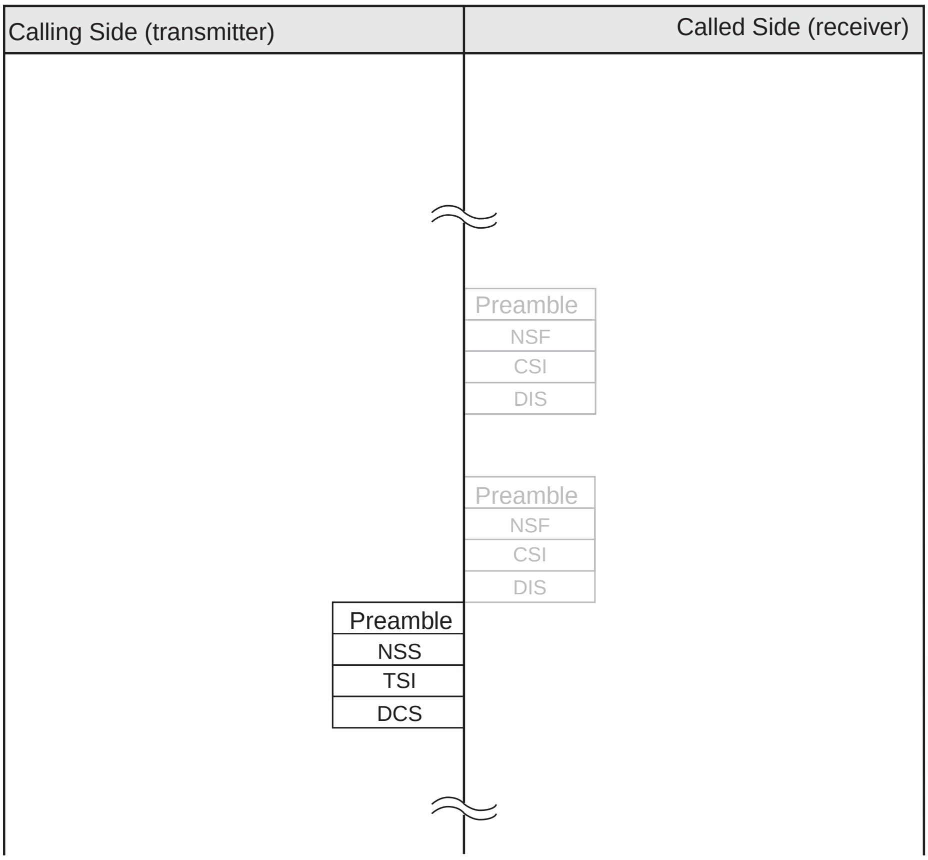


Fig. 5-68 Receive Command

DCS	Transmission → Reception	Binary signal
This signal instructs the other party to receive in the possible communications mode selected from the content of the received DIS. (mandatory)		
Communicates the recording paper size, transmission speed, MTT, coding scheme, recording resolution, and other information.		

NSS and TSI are option signals. They are described in 6.7 Option Signals (described later).

6.3.4 Training/Pre-message response

By training, TCF is transmitted at the transmission speed by which images are actually transmitted after the receive command to check whether or not images will be transmitted without a transmission error occurring.

The pre-message response is a response that is transmitted by the receiver that has received the receive command and training/TCF.

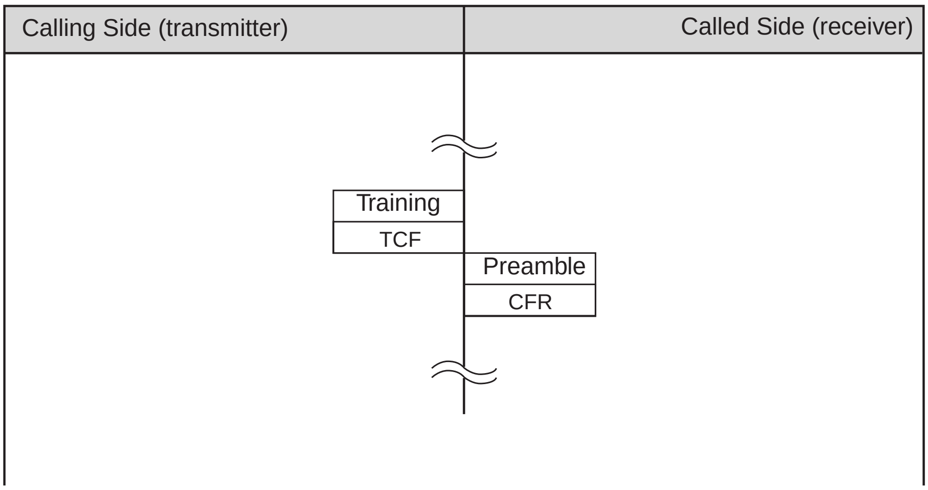


Fig. 5-69 Training/Pre-message Response

Training	Transmission → Reception	Same modulation signal as image signal
This signal is for performing equalization on the MODEM when transmitting at the image transmission speed, and is performed for successfully receiving the following TCF. (For details, see 6.5 Training)		

TCF	Transmission → Reception	Same modulation signal as image signal
This test signal transmits a constant signal at the transmission speed used for sending the image before the actual image is transmitted to verify that it can be transmitted successfully.		
This signal is a string of “0” and is transmitted for about 1.5 seconds.		

CFR	Transmission ← Reception	Binary Signal
This signal notifies the other party that TCF can be received normally and that the receiver is ready to receive.		
When there is a problem on either side, FTT is transmitted instead of CFR. (See 6.5.3 When TCF cannot be successfully received.)		

6.3.5 Message transmission

This is the body of the image signal and comprises training, message and RTC.

The message is transmitted from the transmitting side after it has been verified that the CFR has been received from the receiving side and that training has been performed correctly.

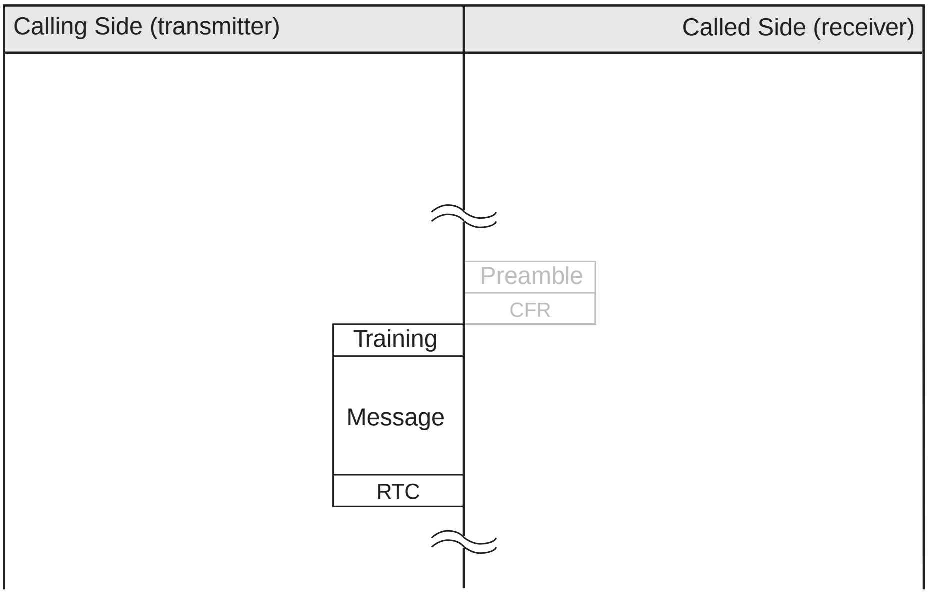


Fig. 5-70 Message Transmission

Training	Transmission → Reception	Same modulation signal as image signal
This signal is for performing equalizing of the MODEM when transmission is performed at the image transmission speed.		

Message	Transmission → Reception	Image signal
Coded image signal		

RTC	Transmission → Reception	Same modulation signal as image signal
This signal is added after the final line of the image signal is coded.		
Six EOLs showing the end of the page are transmitted.		

6.3.6 Post-message commands

The transmitter notifies the other party that transmission has ended after the image signal has finished being transmitted.

The signal to be transmitted sometimes changes when the next document is prepared or when the transmission mode is to be changed. In this example, EOP is transmitted as the image data is only one page. MPS and EOM are also transmitted.

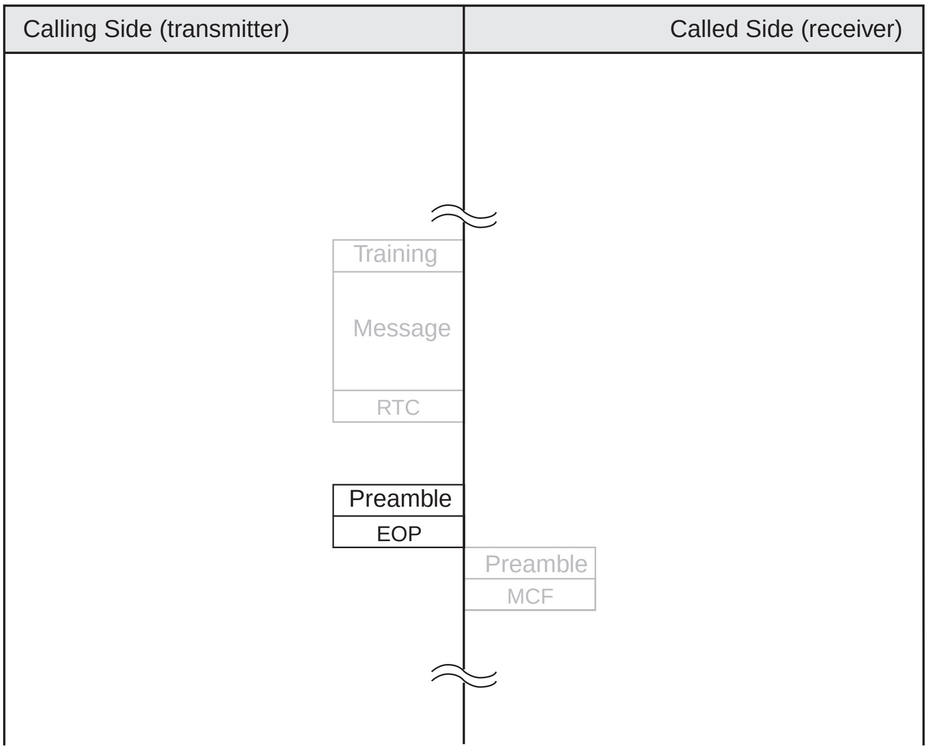


Fig. 5-71 Post-message Commands

EOP	Transmission → Reception	Binary signal
This signal shows that transmission of images of one page is complete and that the next document is not prepared.		

6.3.7 Post-message responses

The receiver transmits signals for notifying the transmitter whether or not that page could be received successfully at each reception of a single page. In this example, MCF is transmitted as the page was successfully received. RTP and RTN are also transmitted.

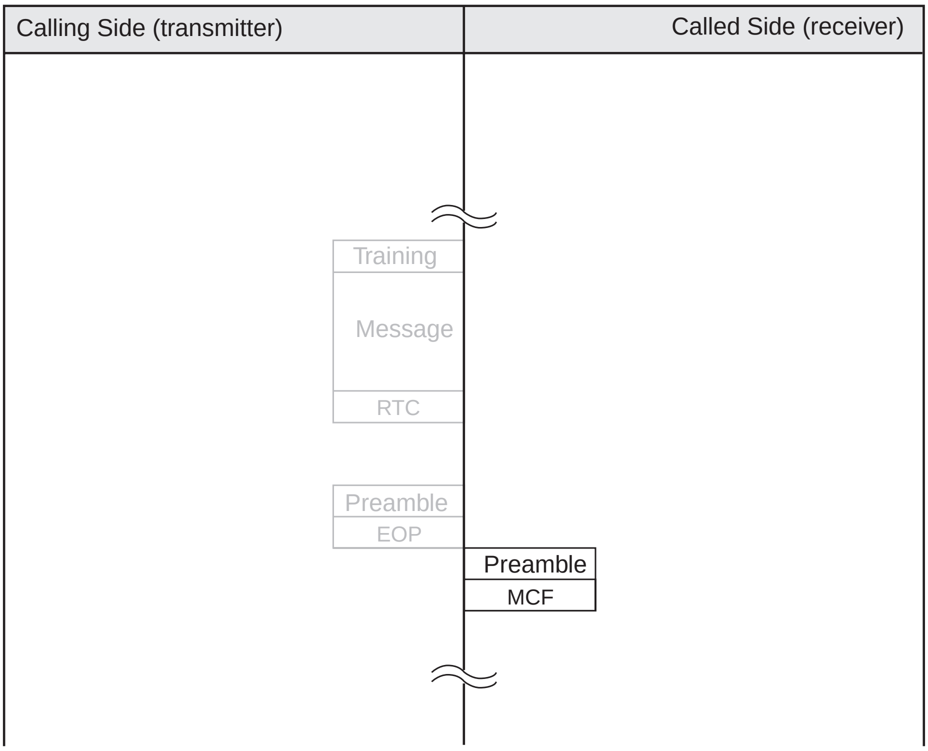


Fig. 5-72 Post-message Responses

MCF	Transmission ← Reception	Binary signal
Shows that the image was successfully received and that the next document can be received immediately.		

6.3.8 Other control signals

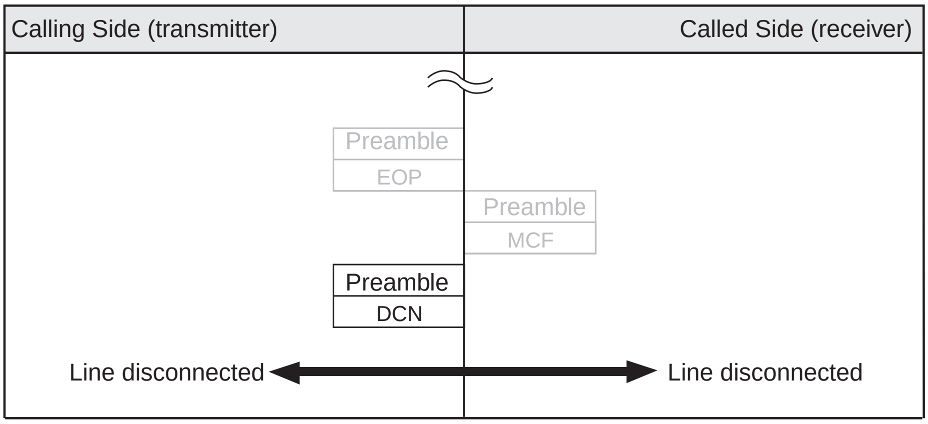


Fig. 5-73 Other Control Signals

These signals are for disconnecting the line, and do not require a response from the other party.

DCN	Transmission → Reception	Binary Signal
Signal for instructing disconnection of the line		

6.4 Procedures for Performing Individual Page Control (Q signals)

“EOP” is transmitted on the facsimile transmitting side as the signal for showing the end of one page’s worth of image. Nevertheless, as the way of sending on the transmitting side, there are times when multiple-sheet documents are to be transmitted and the next page of the document is to be transmitted at a different resolution.

“MPS” or “EOM” is used in these cases. These EOP, MPS and EOM are collectively referred to as “Q signals.”

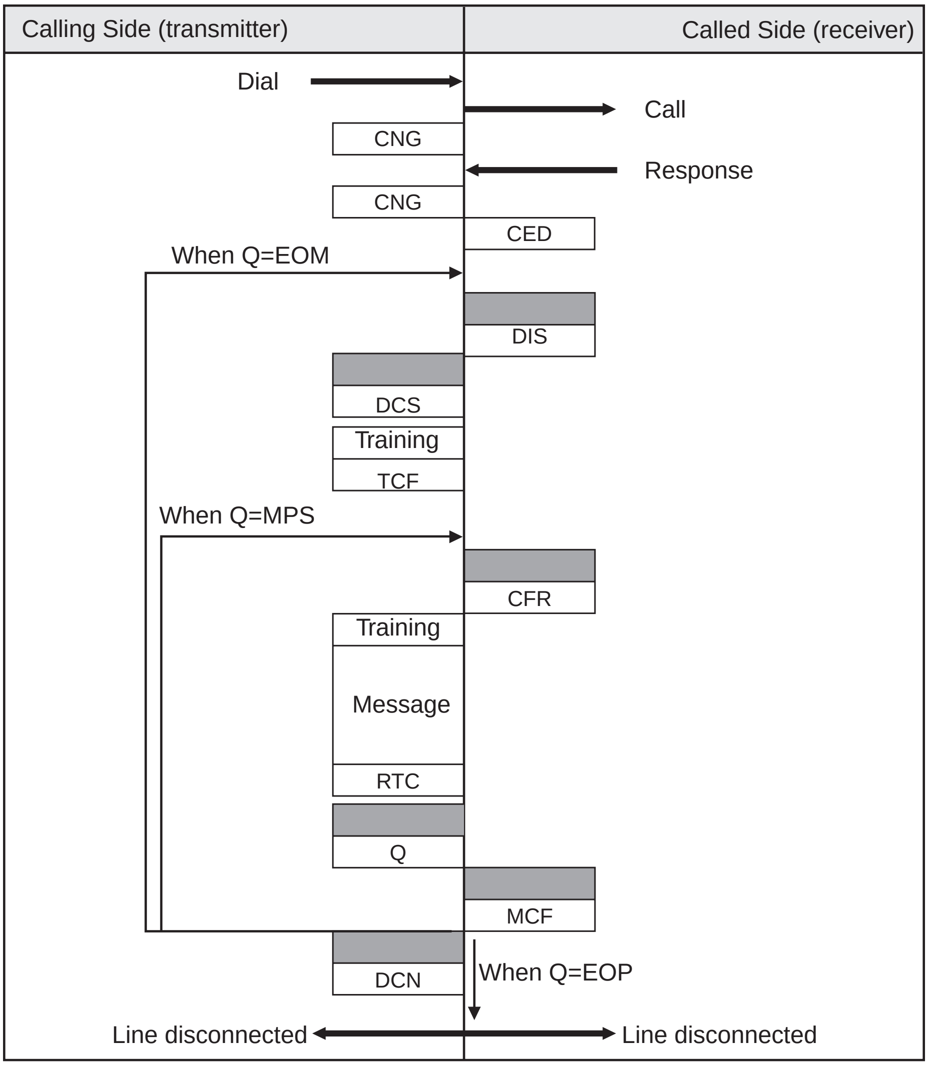


Fig. 5-74 Example of Communications by Difference in Q Signals

EOP	EOP is transmitted when a document was transmitted continuously by EOM and MPS and there are no more documents to send. EOP is also transmitted when there is only one document sheet to transmit. When MCF is received from the other party, DCN is transmitted to disconnect the line.

MPS	MPS is transmitted when there is another document and that document is to be transmitted without changing the communications mode. When the MCF arrives from the receiver, the next page of the document is transmitted.

EOM	EOM is used where there is another document and that document is to be transmitted in a different communications mode as the present page (for example, when transmitting documents containing small-size text in the fine mode). By EOM, DIS on the receiver is verified again, and the communications mode is communicated by DCS to the receiving side after verification that there is no contradiction with the functions of the transmitter. When MCF is received from the other party, arrival of DCS is waited for, and the mode-changed DCS is transmitted after DIS is received to communicate the mode to communicate by to the receiving side.

6.5 Training

The compensation of line characteristics such as attenuation distortion or group delay distortion that occurs on telephone lines is “equalizing.” “Training” is the procedure where equalizing is performed to reliably transmit image signals. To be more precise, various pattern signals are output from the transmitting side at the same transmission speed as the image signals before the image signals are transmitted. This is to start the automatic equalizer built into the MODEM on the receiver so that the image signals can be transmitted successfully. An “automatic equalizer” is in effect a circuit that performs equalizing automatically. “Equalizing” refers to the compensation of line characteristics such as attenuation distortion or group delay distortion that occurs on telephone lines. The discovery of the optimum value in equalizing during training is referred to as “MODEM convergence,” while the failure to discover the optimum value is referred to as “MODEM divergence.”

6.5.1 Training check (TCF)

Training is performed to transmit image signals correctly. If image signals are transmitted immediately after training, errors may occur in the image signals when training is not performed properly.

Following training, “TCF” (a check as to whether training has been performed correctly) is transmitted at the same transmission speed as the image signals. A TCF is a signal of continuous “0” lasting about 1.5 seconds.

6.5.2 When TCF can be successfully received

The receiving side judges that training is normal when TCF has been received successfully. The receiving side transmits CFR and notifies the transmitting side that TCF was received successfully to prepare for image reception. After the transmitting side has received CFR, training is performed again (called “re-training”) and then the image signal is transmitted.

6.5.3 When TCF cannot be successfully received

Training is judged to have failed when TCF cannot be successfully received due to noise in the line state. FTT is then transmitted to notify the transmitting side that TCF could not be received successfully. After receiving FTT, the transmitting side outputs DCS again to instruct the receiving side to receive at a delayed transmission speed. In this case, the next training operation is performed at a transmission speed that was communicated by DCS. Delaying the transmission speed in this way when a communications error has occurred at the current transmission speed is called “fallback.” When FTT is returned (when TCF cannot be successfully received) even if fallback is repeated, the transmitting side judges that communications is not possible on the current line, and the communications ends in error.

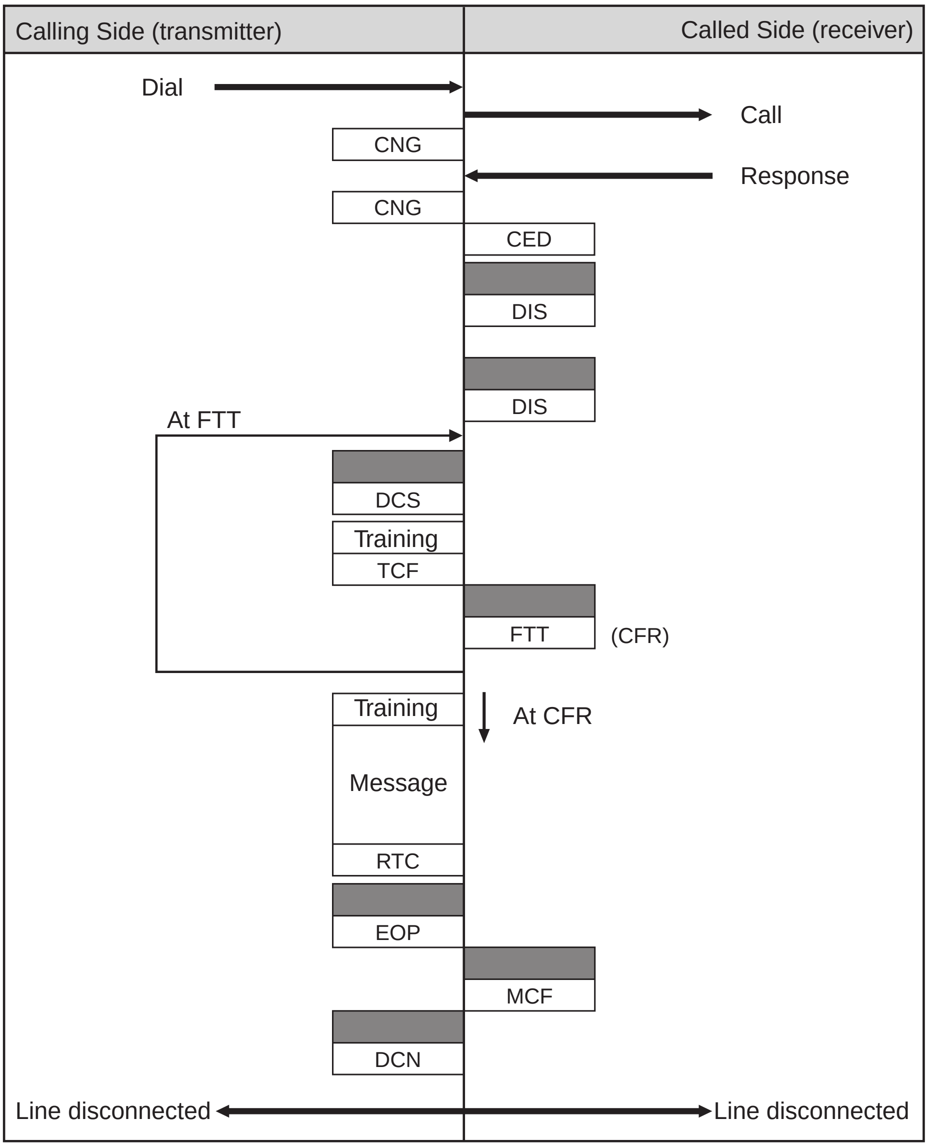


Fig. 5-75 Training

6.6 Method for Detecting Image Signal Transmission Errors

Although image signals are sent after equalizing the MODEM and training, a transmission error may occur when sudden noise or an instantaneous power interruption is generated during image signal transmission. To detect whether a transmission error has occurred in the image signal on the receiving side, the number of bits in each line after decoding is compared with the specified number of bits according to the document size (1728 bits for A4). If the number of bits match, then it is judged that there is no transmission error. If they do not match, it is judged that something has caused a transmission error.

6.6.1 When there are no errors in the received image

The receiver returns the MCF that shows that the image was received successfully.

6.6.2 When errors are detected in the received image

When an transmission error has occurred on the receiving side, all of the data to be recorded for that line is lost. However, with a regular image, the omission of several lines will not greatly affect the image. For this reason, a reference is provided and occurrence of an error of a fixed amount is counted as the record of the error. If the error occurs at this reference or less, it is judged that the image was received successfully. In this case, the lines for which the error occurred are not printed, and the next line is printed. Note, however, that some facsimiles have a function for selecting re-printing of the previous line.

6.6.3 RTN and RTP

When an error has occurred in excess of the fixed amount in the received image, the receiving side returns the RTN instead of the MCF. This means that that page could not be received successfully. When RTN is received, an error occurs on the transmitting side, and communications is ended if there are no more documents. If the next document is present, DCS is returned to and a fallback is caused to enable transmission of the next document. On facsimiles transmtting by memory transmission, a fallback to the document that was in error can also be made to transmit the document. If the number of occurrences is at the reference or less, if an error has occurred, the RTP is returned instead of RTN. In this case, that page is regarded as a successfully received page. However, to transmit documents from the next page onwards, DCS is returned to in the same way as RTN, a fallback is made to repeat the procedure from training again and the transmission speed is determined again to enable more reliable communications.

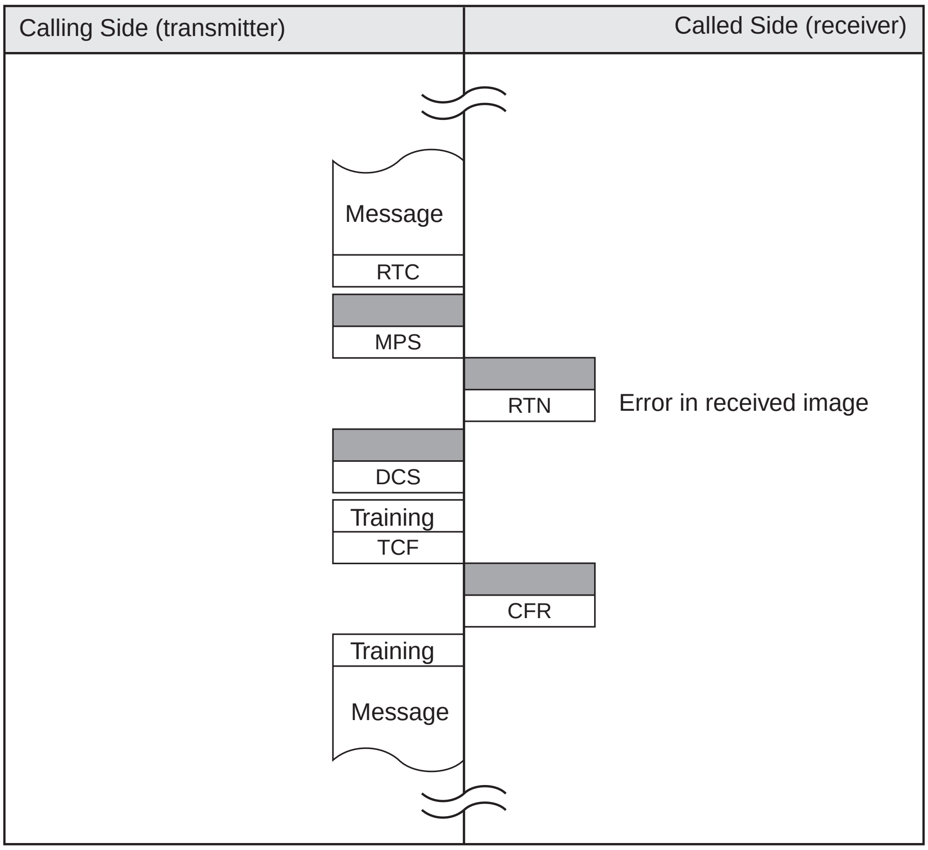


Fig. 5-76 RTN Signal

6.7 Option Signals

There are also option signals in addition to mandatory transmission control signals. Let's describe communications using option signals.

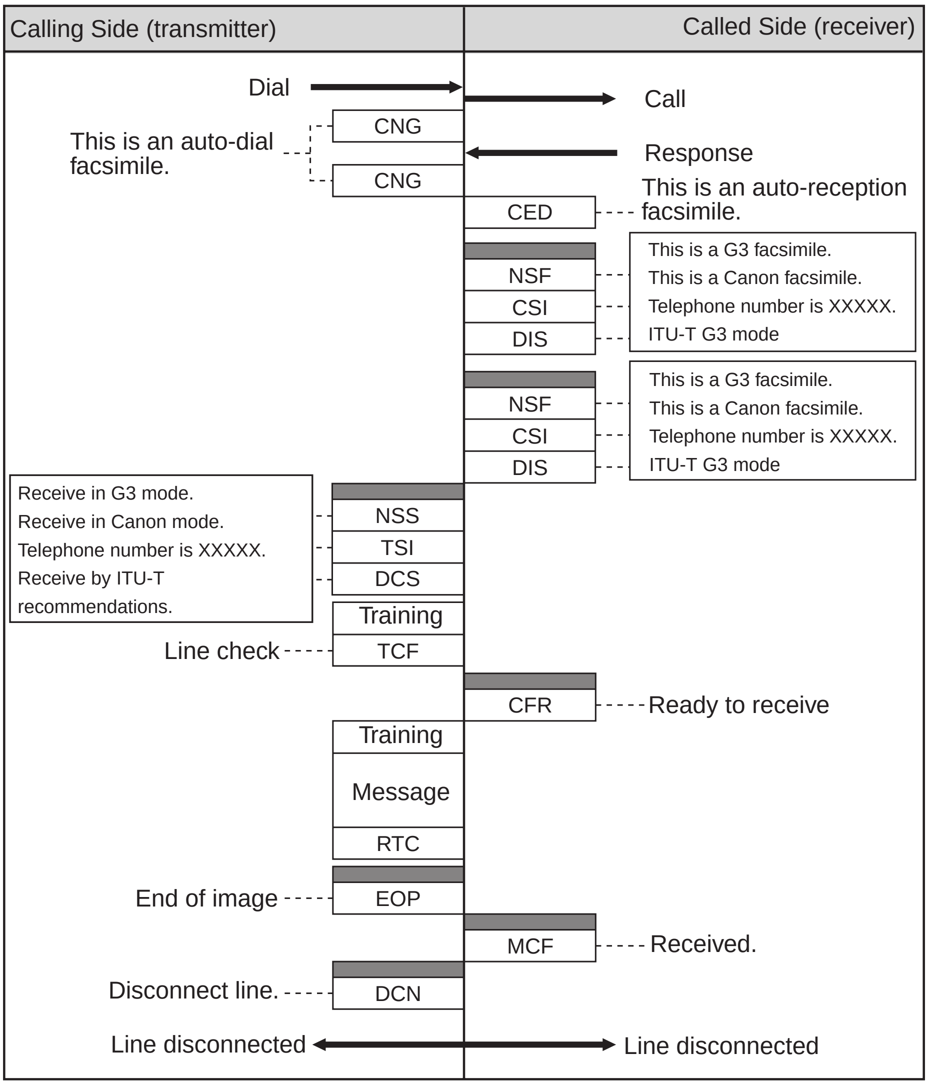


Fig. 5-77 Example of Communications Using Option Signals

NSF	Transmission ← Reception	Binary signal
Signals for communicating capabilities (functions unique to manufacturer and proprietary functions not provided in DIS) other than ITU-T recommendations to the other party		

CSI	Transmission ← Reception	Binary signal
Signal for communicating the telephone number on the receiving side to the other party		

NSS	Transmission → Reception	Binary signal
Signal (including user name and maker code) that communicates to the other party that transmission will be performed using a function other than that recommended by ITU-T (functions unique to manufacturer that are not provided in DCS).		

TSI	Transmission → Reception	Binary signal
Signal for communicating the telephone number of the transmitter to the other party.		

6.8 Structure of Binary Signals

There are various types of binary signals, and I am sure that you now understand that they each have special meanings. Here, let's describe the structure of binary signals in further detail.

Binary signals consist of a "preamble signal" that prefixes the binary signal and "binary coded information". Binary coded information comprises one or multiple frames (HDLC frame). Each frame comprises some "sequences" and "fields." This structure is called an HDLC structure.

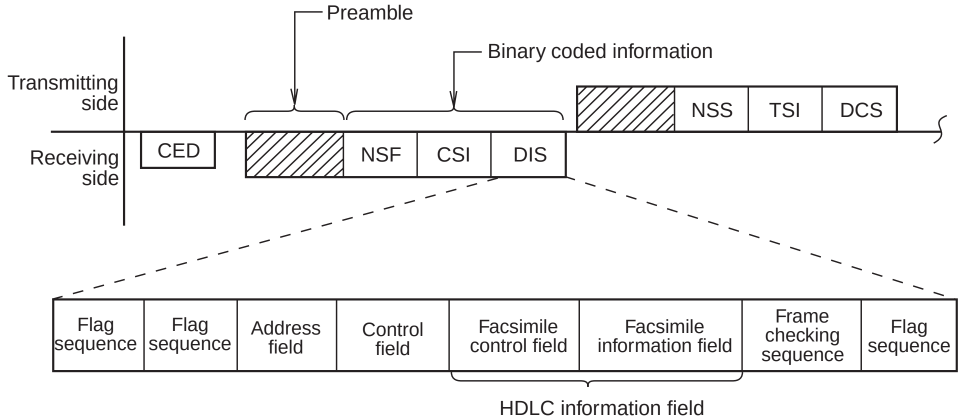
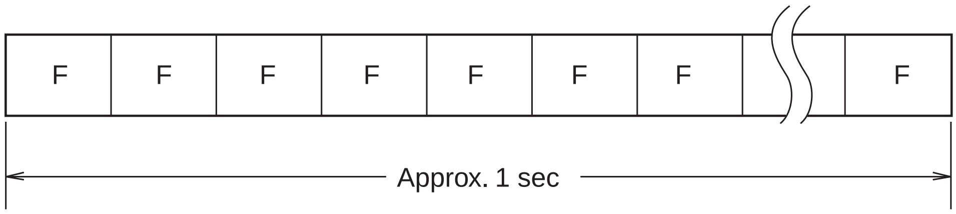


Fig. 5-78 Structure of Binary Signal

6.8.1 Preamble

The preamble is the signal that prefixes the binary signal, and is a series of the flags for about 1 sec. A “flag” comprises eight bits “01111110” (7E when expressed in Hex), and the preamble comprises about 37 continuous flags. Synchronization of the MODEM (ITU-T V.21) for the procedure signal must be performed by prefixing the binary signal. Also, in international communications, the preamble guards against the loss of binary signals by an echo suppresser, for example.



F: Flag sequence(01111110=7EH)

Fig. 5-79 Preamble

6.8.2 Structure of binary coded information

Binary coded information comprises a data structure called an “HDLC frame.” “HDLC” stands for High level Data Link Control, a method of achieving highly efficient and highly reliable transmission control procedures. A feature of HDLC is a structure that checks for transmission errors in the transmitted data itself. HDLC is stipulated by ISO standards as one transmission control procedure, and is also used in exchanging ISDN packets. The structure of HDLC is called a “frame” because the information is prefixed and appended with signals called “flags.” The following describes the names of each field in this structure and their content.

Fig. 5-80 Structure of Binary Coded Information

F	Flag sequence
Shows the beginning and the end of the frame, and is also used for MODEM synchronization.	
Format	01111110(=7E H)
Remarks	With the head, there are cases where there is 1 of this signal and cases where there are 2 of this signal.

A	Address field
Although this is used for the terminal device ID in data communications, it is fixed to a single format for the facsimile.	
Format	11111111(=FF H)
Remarks	Signal for maintaining the format of HDLC

C	Control field
This is used to control the terminal device in data communications, and to determine whether that the frame is the final frame or not in the case of multiple frames.	
Format	In case of final frame 11001000 (=C8H) In case of non-final frame 11000000 (=C0H)
Remarks	

5

FCF	Facsimile control field
Shows the type of binary signal and the name of the binary signal used for the frame.	
Format	Refer to Table 5-14. 8-bit or 16-bit
Remarks	16 bits of FCF1 and FCF2 are used in ECM.

FIF	Facsimile information field
This indicates the details of facsimile capabilities that FCF cannot cover. The length of this field is not fixed.	
Format	See 6.8.4 Details of FIF.
Remarks	

FCS	Frame checking sequence
This sequence is used to check whether there are transmission errors in this frame.	
Format	2-byte code
Remarks	See Note on page 5-121.

NOTE

There are two types of frames, frames with a frame information field (FIF) and frames without. Sometimes multiple signals such as NSF, CSI and DIS are output as a continuous string to the transmission control signals. The control field (C) is used for identifying the final frame at this time.

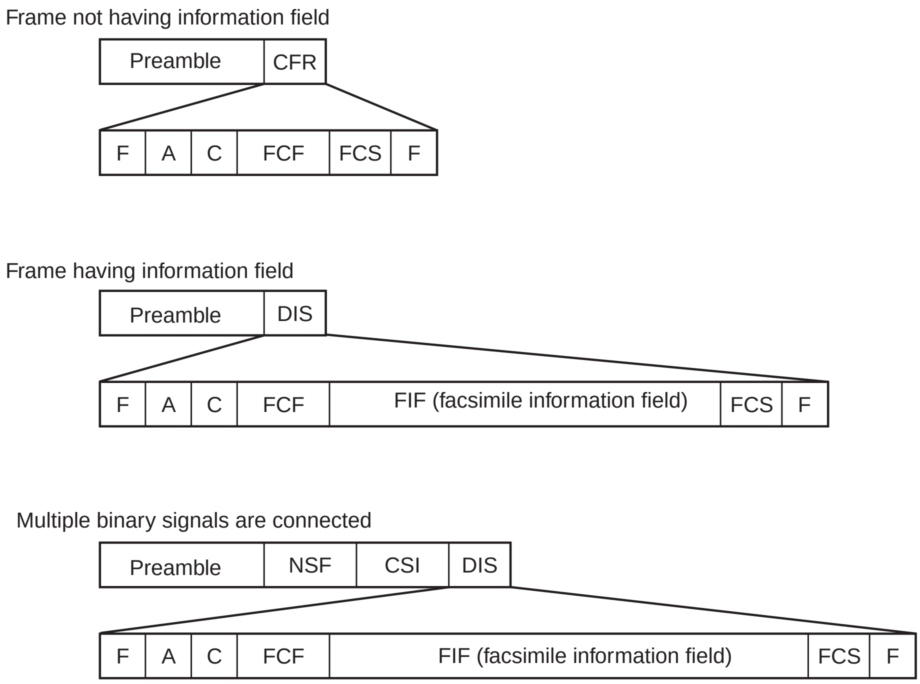


Fig. 5-81 Example of G3 Transmission Control Signal

6.8.3 Details of FCF

The FCF for each signal is determined as shown in the following table.

Table 5-14 Correspondence between Signal Name and FCF

	Signal Name	FCF	Remarks
Initial identification	NSF	00000100	FIF follows right after.
	CSI	00000010	
	DIS	00000001	
Transmit command	NSC	10000100	
	CIG	10000010	
	DTC	10000001	
Receive command	NSS	X1000100	
	TSI	X1000010	
	DCS	X1000001	
Pre-message responses	CFR	X0100001	
	FTT	X0100010	
Post-message Commands	EOM	X1110001	FIF does not follow.
	MPS	X1110010	
	EOP	X1110100	
Post-message responses	MCF	X0110001	
	RTP	X0110011	
	RTN	X0110010	
Others	DCN	X1011111	

(Note)

According to the ITU-T recommendation:

The side that receives DIS first X → "1"

the other side X → "0"

that is, In regular communications:the calling side:X = 1

the called side:X = 0

In polling: the calling side: X = 0

the called side:X = 1

- Ordinarily, X is "0" and becomes "1" when DIS is received.
  This also implies protection against echo.
- X may not be a factor in cases of other manufacturer's facsimiles.

5

6.8.4 Details of FIF

FIF is used for incorporating information that cannot be expressed by FCF alone.

As the format of FIF differs according to each signal, let's describe FIF in order.

- FIF of DIS, DTC

The FIF of DIS and DTC has the same format and the same meaning. By DIS, the receiver notifies the other party of functions relating to self-reception at normal transmission, and DTC is a signal used during polling.

Table 5-15 FIF of DIS, DTC

Bit No.	Meaning/Function
1 to 5	G1/G2 functions = "00000000"
6	V.8 function
7	"0"= 256 octet priority "1"= 64 octet priority
8	Pending
9	Has G3 transmission functions (polling standby)
10	Has G3 reception functions "1"
11,12, 13,14	Image transmission speed (0000) = V.27ter fallback mode (0100) = V.27ter (4800bps, 2400bps) (1000) = V.29 (9600bps, 7200bps) (1100) = V.27ter, V.29 (1101) = V.27ter, V.29 V.17 (14400bps, 12000bps, 9600bps, 7200bps) (other) = Not used or reserved
15	Vertical scanning line density: (0) = Standard only (1) = Standard and fine
16	Coding scheme: (0) = Only MH (1) = Both MH and MR
17,18	Recording paper width (00) = A4 (10) = A4 and B4 (01) = A4, B4 and A3 (11) = Disabled (interpreted as 01)
19,20	Recording paper length (00) = A4 (10) = No limit to recording paper length (01) = A4 and B4 (11) = Disabled

Table 5-15 FIF of DIS, DTC

Bit No.	Meaning/Function
21,22, 23	Minimum transmission time: (000) = 20 ms in standard, 20 ms in fine (001) = 40 ms in standard, 40 ms in fine (010) = 10 ms in standard, 10 ms in fine (100) = 5 ms in standard, 5 ms in fine (011) = 10 ms in standard, 5 ms in fine (110) = 20 ms in standard, 10 ms in fine (101) = 40 ms in standard, 20 ms in fine (111) = 0 ms in standard, 0 ms in fine
24	Extension field: (1) = FIF is extended by 8 bits after this bit. (0) = FIF is up to this bit.
25	= “0”
26	Uncompressed mode: (0) = Not provided, (1) = Provided, (0) on Canon machines
27	ECM: (0) = Not provided, (1) = Provided
28	= “0”
29	= “0”
30	= “0”
31	T.6 coding capability: (0) = Not provided, (1) = Provided
32	Extension field: (1) = FIF is extended by 8 bits after this bit. (0) = FIF is up to this bit.
33	Field disabling capability: (0) = Not provided, (1) = Provided
34	Multiple selection polling capability: (0) = Not provided, (1) = Provided
35	PSA capability: (0) = Not provided, (1) = Provided
36	T.43 coding: (0) = Not provided, (1) = Provided
37	Plain interleaving: (0) = Not provided, (1) = Provided
38	Pending
39	Pending
40	Extension field: (1) = FIF is extended by 8 bits after this bit. (0) = FIF is up to this bit.
41	R8 dots/mm × 15.4 lines/mm (super-fine): (0) = Not provided, (1) = Provided
42	300 × 300 dpi
43	R16 dots/mm × 15.4 lines/mm and/or 400 × 400 dpi : (0) = Not provided, (1) = Provided
44	Resolution in inch units is desirable.
45	Resolution in mm units is desirable.
46	Min. scanline time capability at high resolution “0” : T15.4 = T7.7 “1” : T15.4 = 1/1 T7.7
47	Selection polling capability: (0) = Not provided, (1) = Provided

Table 5-15 FIF of DIS, DTC

Bit No.	Meaning/Function
48	Extension field: (1) = FIF is extended by 8 bits after this bit. (0) = FIF is up to this bit.
49	Sub-address capability: (0) = Not provided, (1) = Provided
50	Password: (0) = Not provided, (1) = Provided
51	Ready to send data file (polling)
52	Pending
53	Binary file transmission (BFT): (0) = Not provided, (1) = Provided
54	Document transmission mode (DTM)
55	Electronic data interchange (EDI): (0) = Not provided, (1) = Provided
56	Extension field: (1) = FIF is extended by 8 bits after this bit. (0) = FIF is up to this bit.
57	Basic transmission mode (BTM): (0) = Not provided, (1) = Provided
58	Pending
59	Character or mixed mode Ready to send document (polling): (0) = Not provided, (1) = Provided
60	Character mode: (0) = Not provided, (1) = Provided
61	Pending
62	Mixed mode (T.4 Recommendation Appendix D)
63	Pending
64	Extension field (1) = FIF is extended by 8 bits after this bit. (0) = FIF is up to this bit.
65	Processable mode 26 (T.505): (0) = Not provided, (1) = Provided
66	Digital network capability: (0) = Not provided, (1) = Provided
67	Full-duplex and half-duplex operation: (0) = For half-duplex operation only (1) = Full-duplex and half-duplex operation
68	JPEG coding: (0) = Not provided, (1) = Provided
69	Full color mode: (0) = Not provided, (1) = Provided
70	= “0”
71	12 bits/number of image components: (0) = Not provided, (1) = Provided
72	Extension field: (1) = FIF is extended by 8 bits after this bit. (0) = FIF is up to this bit.
73	Sub-sampling: (0) = Not provided, (1) = Provided
74	Non-standard irradiated light: (0) = Not provided, (1) = Provided
75	Non-standard gamut range: (0) = Not provided, (1) = Provided
76	North American letter: (0) = Not provided, (1) = Provided
77	North American legal: (0) = Not provided, (1) = Provided
78	Single-layer sequential coding (recommendation T.85) basic capability: (0) = Not provided, (1) = Provided

Table 5-15 FIF of DIS, DTC

Bit No.	Meaning/Function
79	Single-layer sequential coding (recommendation T.85) optional L0: (0) = Not provided, (1) = Provided
80	Extension field: (1) = FIF is extended by 8 bits after this bit. (0) = FIF is up to this bit.
81	HKM key management capability: (0) = Not provided, (1) = Provided
82	PSA key management capability: (0) = Not provided, (1) = Provided
83	Override mode capability: (0) = Not provided, (1) = Provided
84	HFX40 cipher capability: (0) = Not provided, (1) = Provided
85	Substitute cipher No.2 capability: (0) = Not provided, (1) = Provided
86	Substitute cipher No.3 capability: (0) = Not provided, (1) = Provided
87	HFX40-I hashing capability: (0) = Not provided, (1) = Provided
88	Extension field: (1) = FIF is extended by 8 bits after this bit. (0) = FIF is up to this bit.
89	Substitute hashing system No.2 capability: (0) = Not provided, (1) = Provided
90	Substitute hashing system No.3 capability: (0) = Not provided, (1) = Provided
91	Pending for security in the future
92	Pending
93	Pending
94	Pending
95	Pending
96	Extension field: (1) = FIF is extended by 8 bits after this bit. (0) = FIF is up to this bit.

- FIF of DCS

The FIF of DCS communicates which function the receiver is used to send the document.

Table 5-16 FIF of DCS

Bit No.	Meaning/Function
1 to 5	G1/G2 functions = “00000000”
6 to 9	= “0”
10	Transmission capability of G3 = “1”
11,12, 13,14	Transmission speed for image signal (0000) = 2400bps (V.27ter) (0100) = 4800bps (V.27ter) (1000) = 9600bps (V.29) (1100) = 7200bps (V.29) (0010) = Not used (0110) = Not used (0001) = 14400bps (V.17) (0101) = 12000bps (V.17) (1001) = 9600bps (V.17) (1101) = 7200bps (V.17) (others) = Reserve
15	Vertical scanning line density: (0) = Standard, (1) = Fine
16	Coding scheme: (0) = MH (1) = MR
17,18	Document width (00) = A4 (10) = B4 (01) = A3 (11) = Disabled
19,20	Document length (00) = A4 (10) = B4 (01) = No limit to document length (11) = Disabled
21,22, 23	Minimum transmission time (000) = 20ms (100) = 5ms (001) = 40ms (111) = 0ms (010) = 10ms Others = Disabled
24	Extension field: (1) = FIF is extended by 8 bits after this bit. (0) = FIF is up to this bit.
25	= “0”
26	Uncompressed mode: (0) = Not provided, (1) = Provided, (0) on Canon machines
27	ECM: (0) = Regular transmission, (1) = ECM transmission
28	ECM frame size: (0) = 256 bytes, (1) = 64 bytes
29	= “0”
30	= “0”
31	T.6 coding capability: (0) = Not provided, (1) = Provided
32	Extension field: (1) = FIF is extended by 8 bits after this bit. (0) = FIF is up to this bit.
33	Field disabling capability: (0) = Not provided, (1) = Provided
34	= “0”

Table 5-16 FIF of DCS

Bit No.	Meaning/Function
35	= “0”
36	T.43 coding selection: (0) = Selected, (1) = Not selected
37	Plain interleave selection: (0) = Selected, (1) = Not selected
38	Pending
39	Pending
40	Extension field: (1) = FIF is extended by 8 bits after this bit. (0) = FIF is up to this bit.
41	R8 dot/mm × 15.4 lines/mm (super-fine) selection: (0) = Selected, (1) = Not selected
42	300 × 300 dpi selection: (0) = Selected, (1) = Not selected
43	R16 dots/mm × 15.4 lines/mm Or, 400 × 400 dpi selection: (0) = Selected, (1) = Not selected
44	Resolution type selection: (0) = mm unit resolution, (1) = inch unit resolution
45	Optional
46	Optional
47	= “0”
48	Extension field: (1) = FIF is extended by 8 bits after this bit. (0) = FIF is up to this bit.
49	Sub-address transmission selection: (0) = Selected, (1) = Not selected
50	Transmitter ID transmission selection: (0) = Selected, (1) = Not selected
51	= “0”
52	Pending
53	Binary file transmission (BFT) selection: (0) = Selected, (1) = Not selected
54	Document transmission mode (DTM): (0) = Selected, (1) = Not selected
55	Electronic data exchange (EDI): (0) = Selected, (1) = Not selected
56	Extension field: (1) = FIF is extended by 8 bits after this bit. (0) = FIF is up to this bit.
57	Basic transmission mode (BTM) selection: (0) = Selected, (1) = Not selected
58	Pending
59	= “0”
60	Character mode selection: (0) = Selected, (1) = Not selected
61	Pending
62	Mixed mode selection: (0) = Selected, (1) = Not selected (T.4 Recommendation Appendix D)
63	Pending
64	Extension field: (1) = FIF is extended by 8 bits after this bit. (0) = FIF is up to this bit.

5

Table 5-16 FIF of DCS

Bit No.	Meaning/Function
65	Processable mode 26 (T.505) selection: (0) = Selected, (1) = Not selected
66	Digital network capability selection: (0) = Selected, (1) = Not selected
67	Full-duplex and half-duplex operation: (0) = For half-duplex operation only (1) = Full-duplex and half-duplex operation
68	JPEG coding selection: (0) = Selected, (1) = Not selected
69	Full color mode selection: (0) = Selected, (1) = Not selected
70	Huffman indication is desirable.
71	12 bits/image component selection mode: (0) = Selected, (1) = Not selected
72	Extension field: (1) = FIF is extended by 8 bits after this bit. (0) = FIF is up to this bit.
73	Sub-sampling (1:1:1): (0) = Selected, (1) = Not selected
74	Non-standard irradiated light selection: (0) = Selected, (1) = Not selected
75	Non-standard gamut range selection: (0) = Selected, (1) = Not selected
76	North American letter (215.9 × 279.4 mm) capability: (0) = Not provided, (1) Provided
77	North American legal (215.9 × 355.6 mm) capability: (0) = Not provided, (1) Provided
78	Single-layer sequential coding (recommendation T.85) basic capability selection: (0) = Selected, (1) = Not selected
79	Single-layer sequential coding (recommendation T.85) optional L0 selection: (0) = Selected, (1) = Not selected
80	Extension field: (1) = FIF is extended by 8 bits after this bit. (0) = FIF is up to this bit.
81	HKM key management selection: (0) = Selected, (1) = Not selected
82	PSA key management selection: (0) = Selected, (1) = Not selected
83	Override mode selection: (0) = Selected, (1) = Not selected
84	HFX40 cipher selection: (0) = Selected, (1) = Not selected
85	Substitute cipher No.2 selection: (0) = Selected, (1) = Not selected
86	Substitute cipher No.3 selection: (0) = Selected, (1) = Not selected
87	HFX40-I hashing selection: (0) = Selected, (1) = Not selected
88	Extension field: (1) = FIF is extended by 8 bits after this bit. (0) = FIF is up to this bit.
89	Substitute hashing system No.2 selection: (0) = Selected, (1) = Not selected
90	Substitute hashing system No.3 selection: (0) = Selected, (1) = Not selected

Table 5-16 FIF of DCS

Bit No.	Meaning/Function
91	Pending for security in the future
92	Pending
93	Pending
94	Pending
95	Pending
96	Extension field: (1) = FIF is extended by 8 bits after this bit. (0) = FIF is up to this bit.

- FIF of CSI, CIG, and TSI

The FIF of CSI, CIG, and TSI communicates the other party of its own telephone number. Up to 20 digits including numerals and spaces can be entered in this FIF. 20 digits are entered to FIF as international telephone numbers are considered to have 20 digits.

One digit comprises one byte. "ASCII codes" shown in Table 5-17 are used.

Table 5-17 ASCII Codes Used for FIF of CSI, CIG and TSI

Numbers and Space	Binary Codes MSB ↓							LSB ↓	Hexadecimal Codes
0	0	0	1	1	0	0	0	0	30
1	0	0	1	1	0	0	0	1	31
2	0	0	1	1	0	0	1	0	32
3	0	0	1	1	0	0	1	1	33
4	0	0	1	1	0	1	0	0	34
5	0	0	1	1	0	1	0	1	35
6	0	0	1	1	0	1	1	0	36
7	0	0	1	1	0	1	1	1	37
8	0	0	1	1	1	0	0	0	38
9	0	0	1	1	1	0	0	1	39
Space	0	0	1	0	0	0	0	0	20

MSB: Most Significant Bit
LSB: Least Significant Bit

In the actual format, the last digit of the telephone number becomes the first digit of FIF as indicated in Fig. 5-82. LSB becomes the start within the same digit.

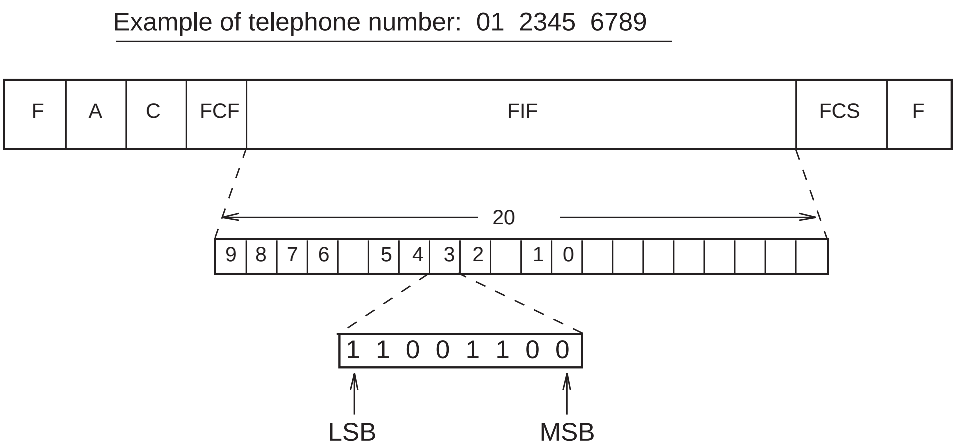


Fig. 5-82 Content of FIF of CSI, CIG and TSI

- FIF of NSF, NSC and NSS

The FIF of NSF, NSC, and NSS contains the information for communications between facsimiles made the same manufacturer in modes other than the ITU-T recommendation. The figure below shows the structure of the FIF for NSF, NSC and NSS.

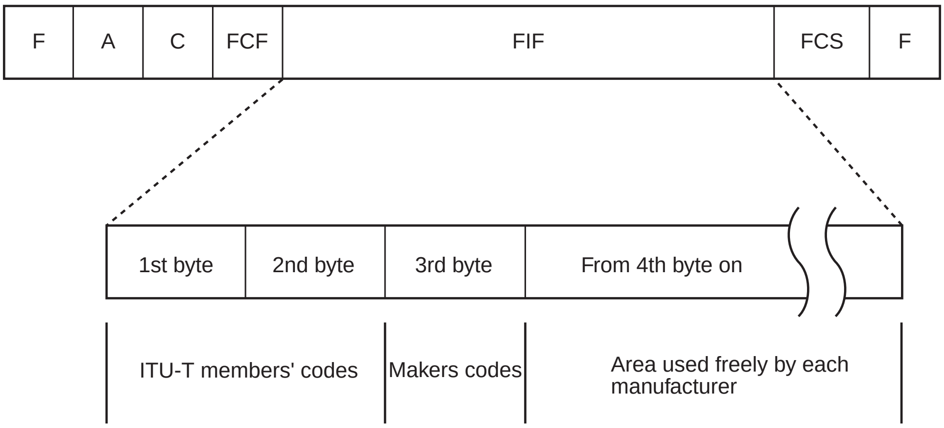


Fig. 5-83 Structure of FIF of NSF, NSC and NSS

The following shows the function of the respective bytes.

Table 5-18 Content of FIF of NSF, NSC and NSS

Byte	Content	
1st and 2nd bytes	ITU-T members' codes	Code which indicates the nationality of the manufacturer. Japan: All bits "0"
3rd byte	Maker code	Code which indicates the name of the manufacturer. Canon code is 88H. (See Appendix 10. MAKER CODES TABLE.)
From the 4th byte onwards	Free area	Manufacturers can freely use this area. The contents of other manufacturers are unknown. At Canon, information such as the "user's name" and "non-standard functions" is entered.

NOTE

What Is The "Frame Checking Sequence (FCS)"

The "FCS" is a sequence that checks whether there are any transmission errors in the frame. FCS is a 2-byte code.
The following briefly describes how the FCS operates.

(1) During transmission of frames, a specific computation is performed on the content from A (address field) through to FIF (facsimile information field) at the transmitting side. The results of that computation is always expressed as a 2-byte code.

(2) The result of (1) is inserted in FCS (Frame Check Sequence) and transmitted.

(3) On the receiving side, the reverse computation to that in (1) is executed from the address field to the FCS during frame reception.

(4) If the result is equal to a certain value, it can be known that the frame is free of transmission errors.

This kind of transmission error detection method is called the Cyclic Redundancy Check (CRC).

6.9 Example of G3 Procedures

6.9.1 Polling (reception on calling side)

“Polling” refers to the reception of the document currently loaded on the called side by the calling side.

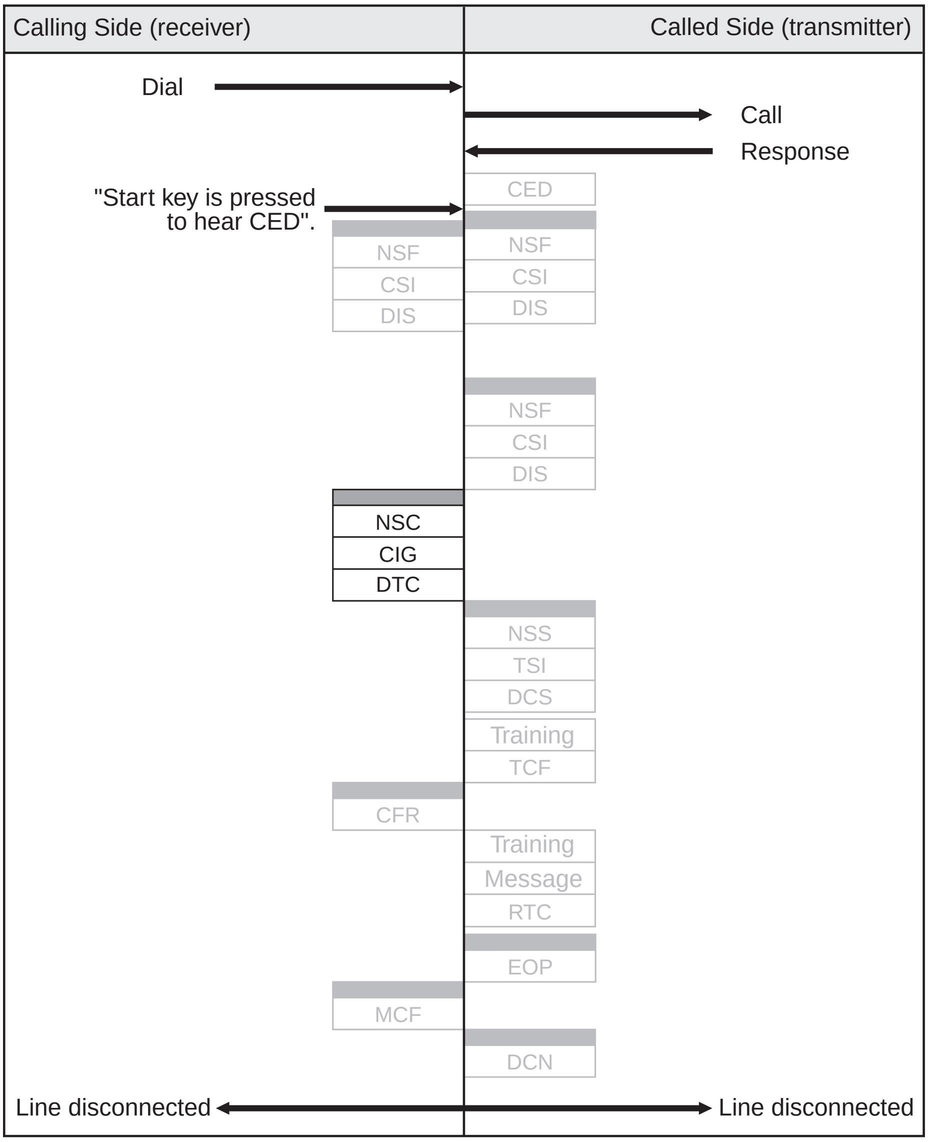


Fig. 5-84 Example of Polling Procedure

The called side performs the regular reception procedure. The calling side, too, performs the reception procedure. Then, it outputs the polling signal.

NSC	Calling side → Called side	Binary signal
Signal for communicating functions other than ITU-T recommendations (function unique to manufacturer not contained in DIS) and the maker code for requesting the other party to transmit the document (option)		

CIG	Calling side → Called side	Binary signal
Signal for communicating the telephone number of the calling side to the called side. (option)		

DTC	Calling side → Called side	Binary signal
Command for instructing transmission after receiving the DIS from the called side and verifying that there is a document loaded at the other party.		
As the calling side from then on becomes the receiver, the same information as DIS is contained in the signal.		

6.10 ECM Communications

ECM stands for Error Correction Mode. ECM enables transmission and reception of images without any omitted lines. It achieves this by re-transmitting image data containing omissions caused by noise, for example, on the telephone line. ECM partitions image data in block units, and divides these data blocks into several frames to be transmitted to the other party. The receiving side performs error judgment as each single frame is received, and this judgment is repeated until reception of a single block is completed. If there is an error frame at the moment that reception of a single block ends, the transmitting side is requested to re-transmit the error frame. After the transmitting side has received this re-transmit request, only the frame on which the error occurred is re-transmitted, and transmission of the next data block is restarted at the moment that it has been verified that the image data has been transmitted and received successfully.
On facsimiles that do not support ECM communications, an error occurs on each single line when an error occurs during communications of the image signal, and the line is omitted. Though error control has been performed to correct this shortcoming, ECM was appended as a G3 standard optional function in 1987 as an additional recommendation to ITU-T T.30 and T.4.

6.10.1 Error re-transmission mechanism

A half-duplex system by which the data communications direction is switched alternately is currently adopted for ECM communications on a G3 facsimile. First of all, it is verified that both the transmitter and the receiver have an ECM function by the pre-procedure. The transmitter reads the image to memory to configure a block of data. A data block is a group of 256 frames that are in an HDLC structure, and partitions image data coded by the MH, MR, MMR or JBIG schemes into 256 bytes. Accordingly, a single data block is 64 kbytes. The content of the coded image is the same as in general G3 communications.

When the receiving side receives the image data of a single block, it checks for errors by each individual frame. Error detection is performed by verifying the continuity of the frame and the CRC check. The receiving side then performs a re-transmit request for error frames by PPR. After the transmitting side receives the re-transmit request, it transmits only the error frame as the re-transmit block. When the receiving side receives the re-transmit block, it checks for errors again by each individual frame, and returns the result by PPR. When block has finished being transmitted normally by this re-transmit processing, the receiving side returns the signal indicating that the block was received normally. Fig. 5-85 shows an example of a communications procedure using ECM.

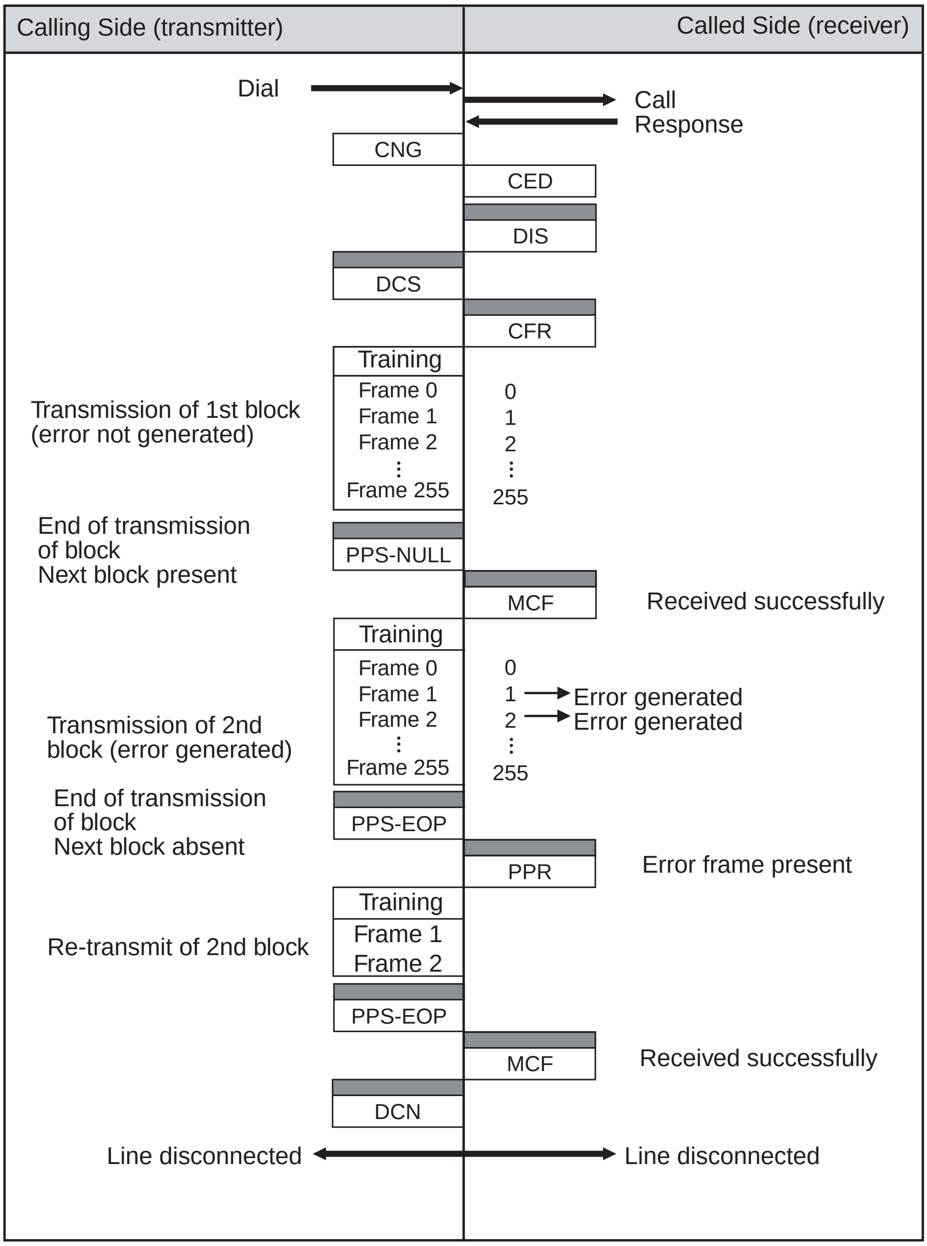


Fig. 5-85 Example of ECM Communications

6.10.2 Structure of ECM image signals

The content of coded images is the same as that in general G3 communications. Fills, however, are not required as the image data is basically communicated by memory transmission and reception. Each frames are numbered from 0 to 255.

- Frames

  A single frame comprises 256 bytes, and each frame is appended a number within the range 0 to 255.

- Partial page

  Documents containing little data can fit into a single block. However, documents that comprise data of 64 kbytes or more become multiple blocks. The single block of these multiple blocks are referred to as a “partial page.”

- Final frame

  A single block comprises up to 256 frames and is 64 kbytes. However, the final frame is sometimes a block that contains less than 256 frames. In cases where the final frame is 256 bytes or less in partial pages of less than 256 frames, 0’s are inserted in the section following RTC.

- RCP

  The end of each block is appended with the RCP frame. The end of partial pages midway during single pages and the end of frames to be re-transmit are also appended with RCP.

6.10.3 ECM error control procedure

- PPS-Q

  The transmitting side outputs PPS-Q when transmission of a single block ends. PPS-Q is the partial page Q signal, in other words, the end of the block. Different signals, however, are output for when there is a following block and for when the block is the final block.

PPS-NULL	Transmitted when the next block is present in multiple blocks
PPS-EOP PPS-EOM PPS-MPS	In the final block of a single page, EOP changes to EOM or MPS depending on state of next document.

- PPR

  The receiving side informs the transmitting side of error frames by PPR in response to PPS-Q. MCF is returned when there are no errors. As a single block of image data has 256 frames, frames are assigned a frame number within the range 0 to 255. The transmitting side is informed of the reception state of the 256 frames by PPR. “1” is set to error frames or frames that were not received for notifying the transmitting side. If the number of frames in the final block is 256 or less, “1” is set to non-existent frames.

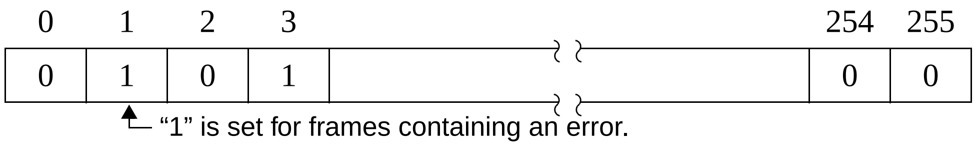


Fig. 5-86 Details of PPR

- CTC and CTR

When there is an error frame however many times the same block is transmitted, delaying the image transmission speed will reduce the rate (error rate) at which errors occur. For this reason, the transmitter outputs CTC when PPR is received four times in the same block to notify the receiver that it will transmit (fallback) at a delayed image transmission speed. After the receiver receives CTC, it outputs the CTR. The transmitter then re-transmit the same block at a lower transmission speed.
the rate (error rate) by which

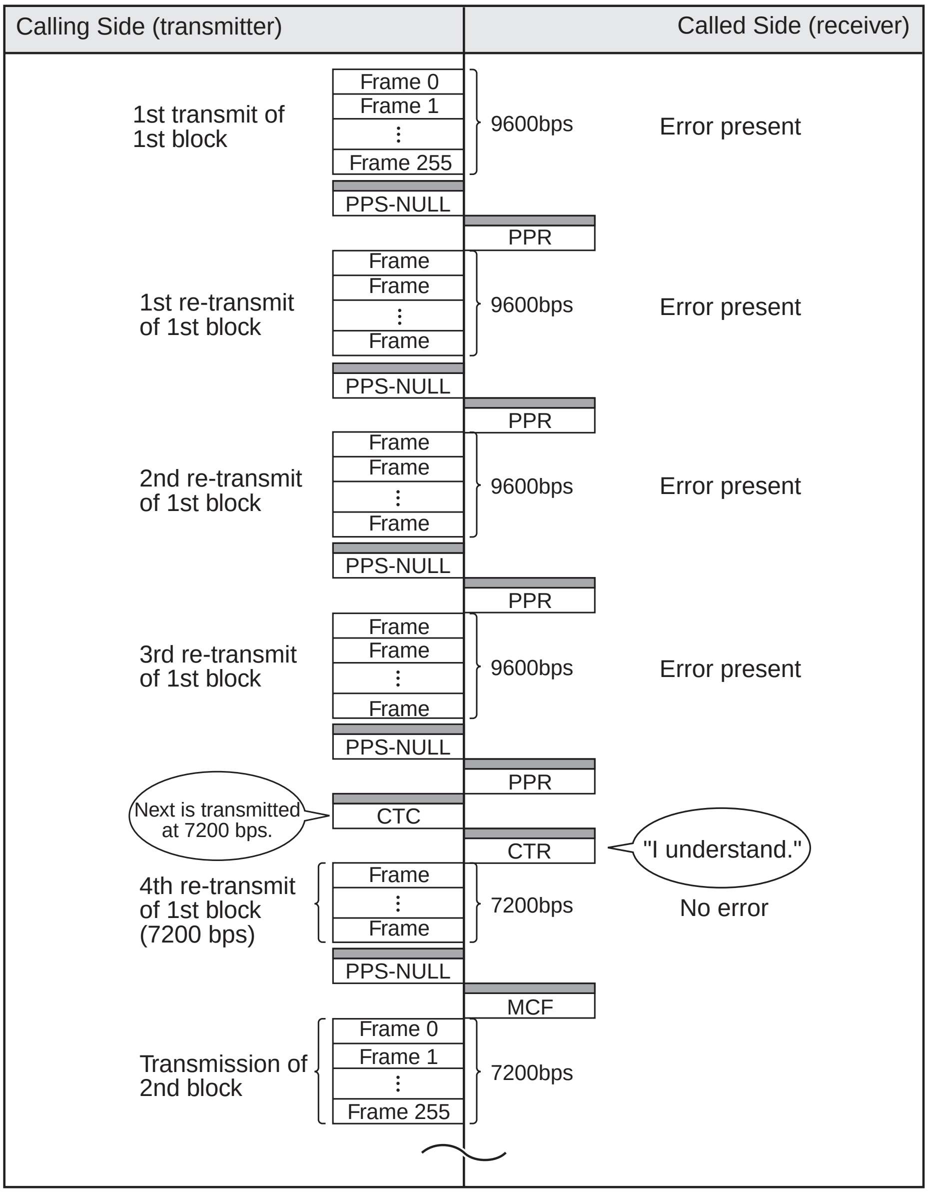


Fig. 5-87 CTC and CTR

- EOR and ERR

When there is an error frame however many times the same block is transmitted (when an error occurs even if the image transmission speed is delayed), the transmitter outputs the EOR to cancel re-transmitting of that block. Canon facsimiles do not output EOR until a fallback to 2400 bps is made. EOR is first output when the re-transmit is continued at 2400 bps and PPR is received. When the transmitter receives ERR, DCN is output to disconnect the telephone line as fallback beyond the current image transmission speed is impossible.

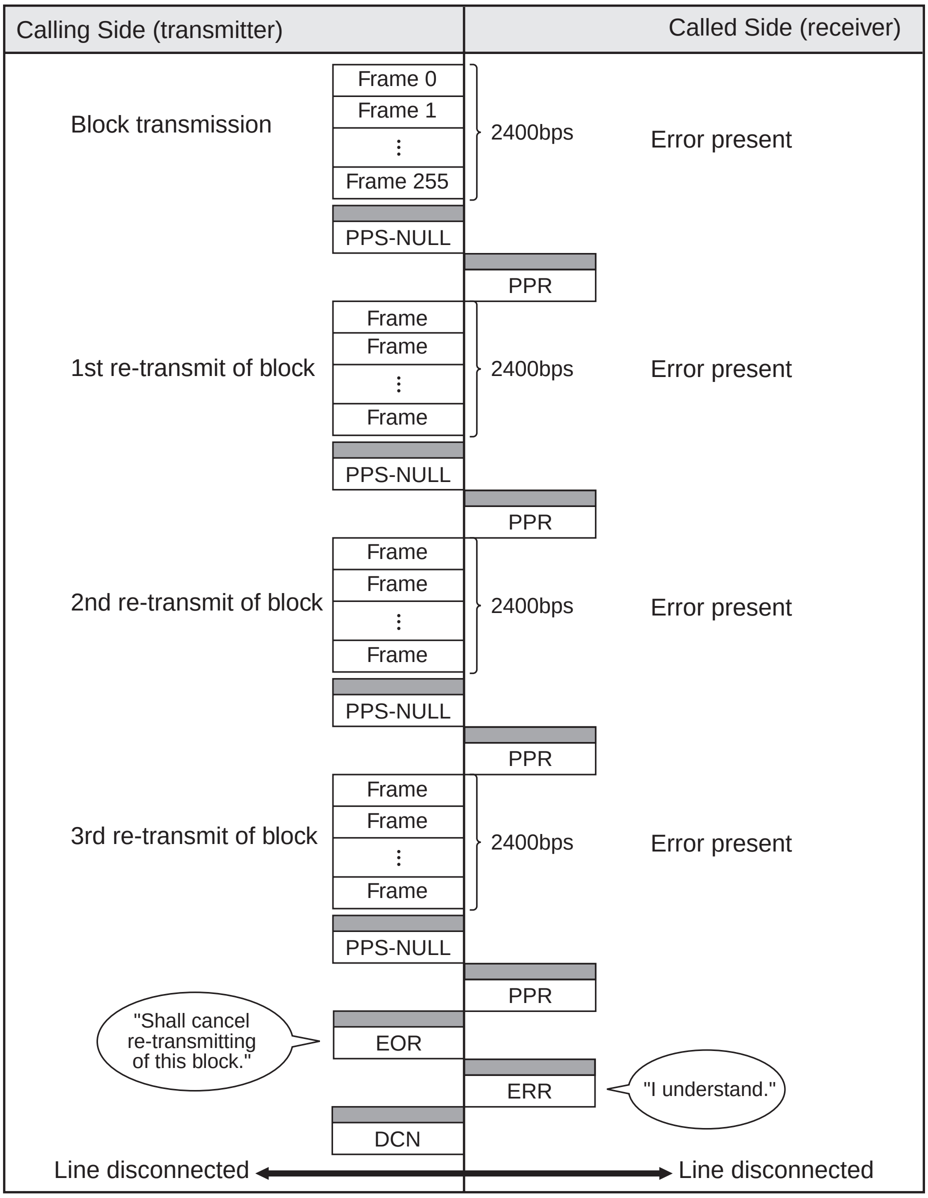


Fig. 5-88 EOR and ERR

- RNR and RR

  On receivers whose printing speed is slower than the data receive speed, the receive buffer sometimes becomes full or busy. In this case, reception of the next block is not possible until new free memory appears after printing of already received blocks has ended. If this happens, the receiver outputs RNR to communicate to the transmitter that the next blocks cannot be received temporarily (receiver is busy).

  When the transmitter receives RNR, RR is repeatedly output to inquire as to the state of the receiver. When the receiver receives RR, RNR is returned for the period that the receiver is busy. When the receiver no longer is busy due to end of printing, for example, MCF is output to communicate that the next block can be received. The transmission times of RNR and RR are determined by timer T5. On facsimiles having a small page buffer, instances where ##753, ##758 and ##783 errors frequently occur can be remedied by lengthening the timer T5 setting.

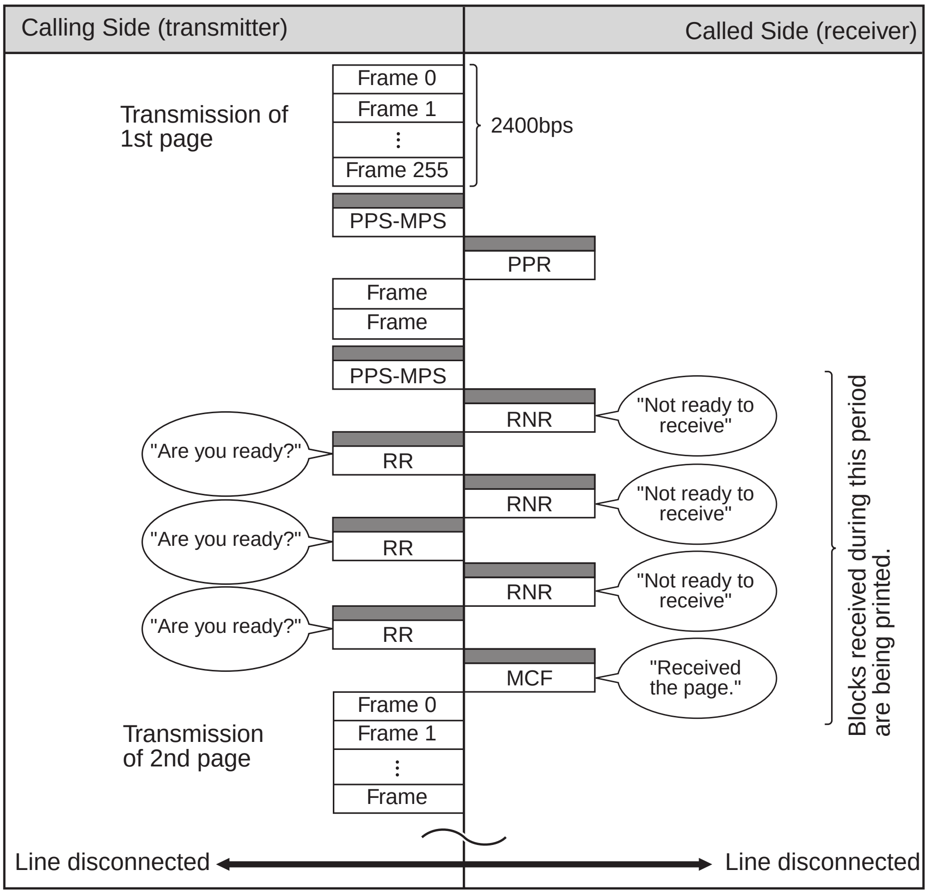


Fig. 5-89 RNR and RR

CHAPTER **6**

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6

1. INTRODUCTION

This chapter describes the functions of the main printed circuit boards used on a facsimile.

Mainly, the following printed circuit boards are used:

- SCNT board for controlling the entire facsimile system
- NCU board that acts as the facsimile's interface with the telephone line
- OPCNT board that performs detection of button operations or LCD display
- Power supply unit that supplies the required voltages to each of the printed circuit boards from the AC power supply for household use
- G4CNT board that controls the G4 facsimile communications system

Generally, these printed circuit boards are connected mainly to the SCNT board.

NOTE

In addition to these printed circuit boards, there are also the PCNT board and driver board. The PCNT board supplies high voltage for driving LBP printers, and the driver board groups together the driver ICs for driving the various motors on a BJ printer. These boards are sometimes integrated into a single board depending on the model of facsimile or sometimes not provided on the facsimile.

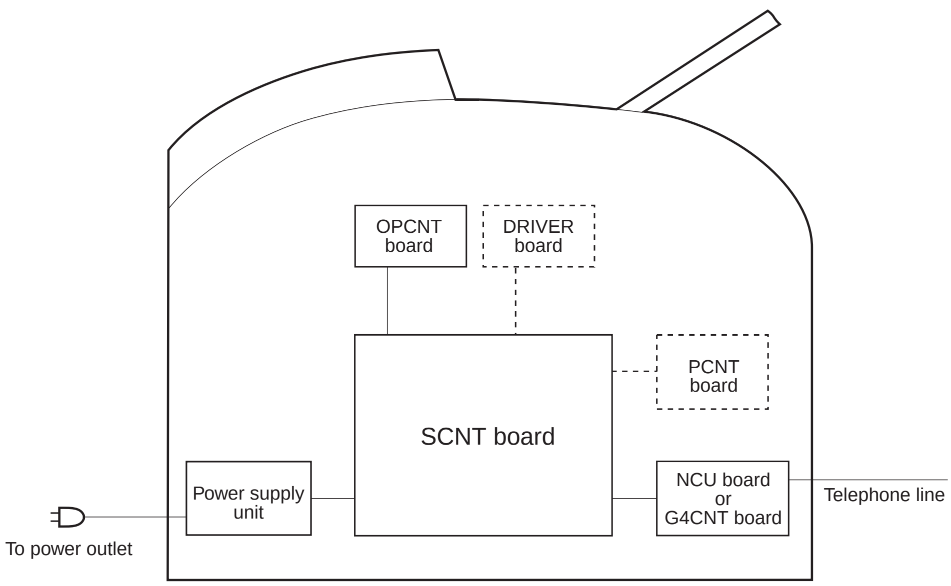
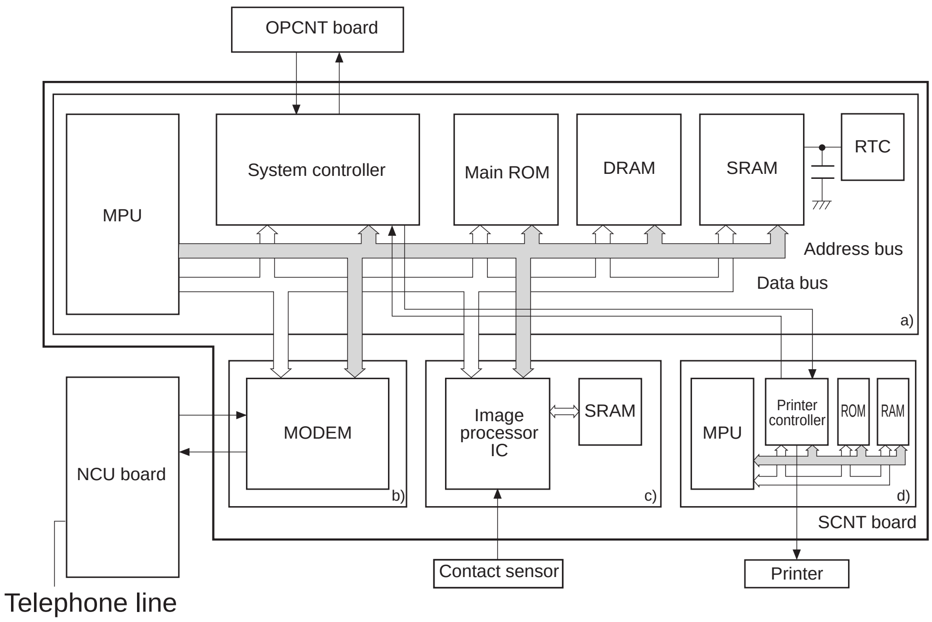


Fig. 6-1 Wiring Diagram

2. SCNT BOARD

"SCNT board" is an abbreviation of System CoNTroller board, and performs control of the entire facsimile system. The control functions of the SCNT board can be broadly classified into the following four control sections:

- System control section
- Communications control section
- Reading control section
- Printer control section



a) System control section
b) Communications control section
c) Reading control section
d) Printer control section

Fig. 6-2 System Block Diagram

2.1 System Control Section

This section comprises an MPU, system controller, memory (SRAM and DRAM), main ROM, real-time clock (RTC) and other components. A coding/decoding IC (CODEC IC) is sometimes used on some facsimile models. Each of the ICs in the system control section is connected by a bus excluding the RTC.

The MPU has a built-in DMA controller for increasing the efficiency of the CPU. The DMA controller performs DMA transfer between each of the ICs that require transfer of large amounts of data, for example, between

the DRAM and the MODEM, and between the system controller and the DRAM to reduce the load placed on the CPU.
The system controller is the IC that controls MPU peripheral devices. It converts the serial data that arrives from the reading section to parallel data and performs chip selection of peripheral ICs, amongst other operations.

2.2 Communications Control Section

This section comprises a MODEM, and is connected to the system control section by a bus. “MODEM” is an abbreviation of MOdulator/DEModulator. The MODEM on a facsimile performs modulation for transferring the image data to the telephone line, and demodulation of image data that has been received. The modulation/demodulation method used complies with ITU-T recommendations. Among its other functions, the MODEM also performs transmission of DTMF signals.

2.3 Reading Control Section

This section comprises an image processor IC and SRAM for buffering read data. The image processor IC is connected to the system control section via a bus.
After the document has been read by the contact sensor, the resulting image data undergoes A/D conversion by the image processor IC in the reading control section and image processing such as resolution conversion in the horizontal scanning direction, and the resulting image data is sent to the system controller in the system control section.

2.4 Printer Control Section

This section is functionally the same on both an LBP method or a BJ printer method, though slightly different in some respects. This section comprises an MPU, system control, DRAM and ROM independent of the system control section, and handles control of the entire printer. (On an LBP printer, this section is sometimes integrated as a one-chip microcomputer.) The printer control section merely transfers the printer status (status of printer-related sensors, error status, etc.) to the system control section. It is provided with an interface for receiving image data for printing, and communicates with the system control section. Facsimile image data is converted (resolution conversion, smoothing, etc.) to image data for printing at the system control section.

3. NCU BOARD

"NCU board" is an abbreviation for Network Control Unit board. This board is located at the telephone line - facsimile interface. This board functions to detect signals arriving from the telephone line to transfer them to the MODEM on the SCNT board, and to switch the line between the facsimile and telephone.

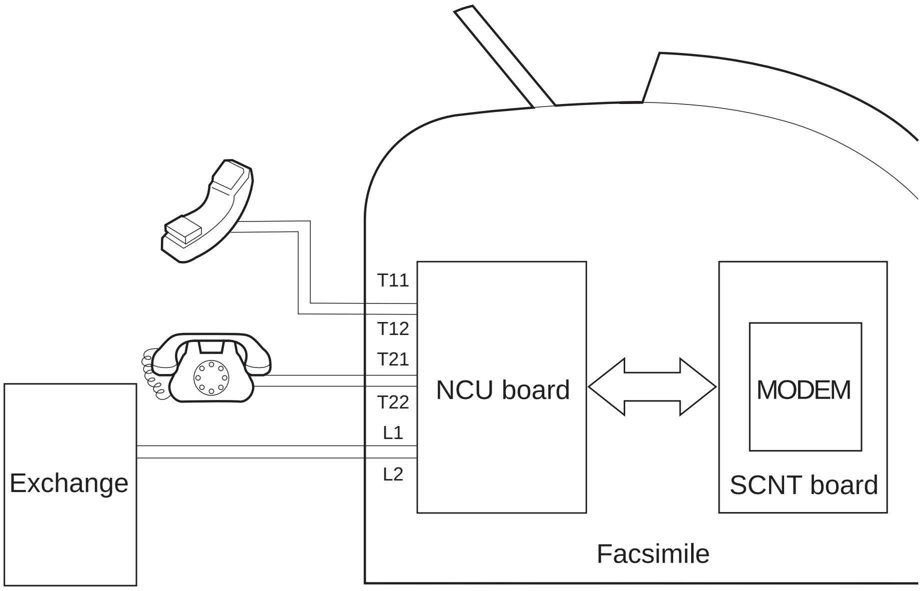


Fig. 6-3 Location of NCU Board

The main functions of the NCU board are as follows:

- Off-hook detection
- Formation of DC loop
- Detection of calling identification (CI)
- Line signal monitor
- Dial control
- 2-wire/4-wire conversion
- Protective circuits
- Telephone connection control

The following describes the functions of the NCU board divided into basic functions.

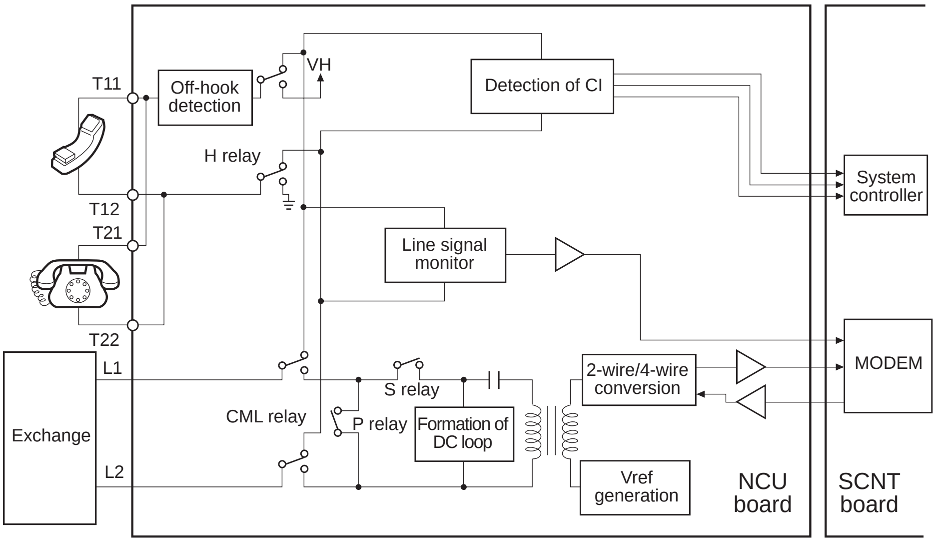


Fig. 6-4   Block Diagram of NCU Board Functions

3.1 Off-hook Detection

The off-hook of the telephone connected to the facsimile is detected when the telephone is in standby state or during facsimile communications. The circuit's built-in telephone set is designed so that terminals to be connected with the telephone line have an infinite (DC) resistance when the handset is placed down (on-hook) and several hundred ohms of DC resistance when it is lifted (off-hook).

3.2 Formation of DC Loop

As a DC voltage (0 to several tens of volts) is supplied across L1 and L2 at all times from the exchange, DC current flows between the facsimile and the exchange when the telephone becomes off-hook or when the CML relay turns ON. This current flow is called "formation of DC loop."

By formation of this DC loop, the exchange recognizes the response from the telephone (reception terminal), and performs connection of the telephone line to enable communications. For this reason, the DC loop must be retained during facsimile communications or during a conversation on the telephone.

In Fig. 6-5, DC voltage is supplied to the telephone as DC voltage is being supplied to terminals L1 and L2 on the facsimile from the exchange and L1 and L2 are connected internally on the NCU board. Yet, as the HS is

OFF within the telephone, DC current does not flow and the DC loop is not formed.

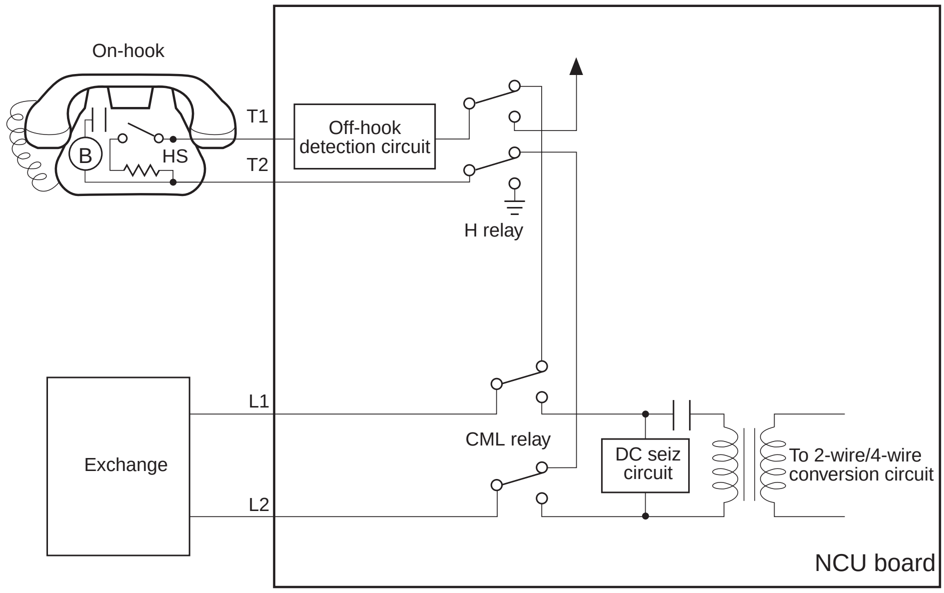


Fig. 6-5 Formation of DC Loop (in standby state)

DC current flows as the HS turns ON when the telephone is made off-hook, and a DC loop is formed between the exchange and the telephone.

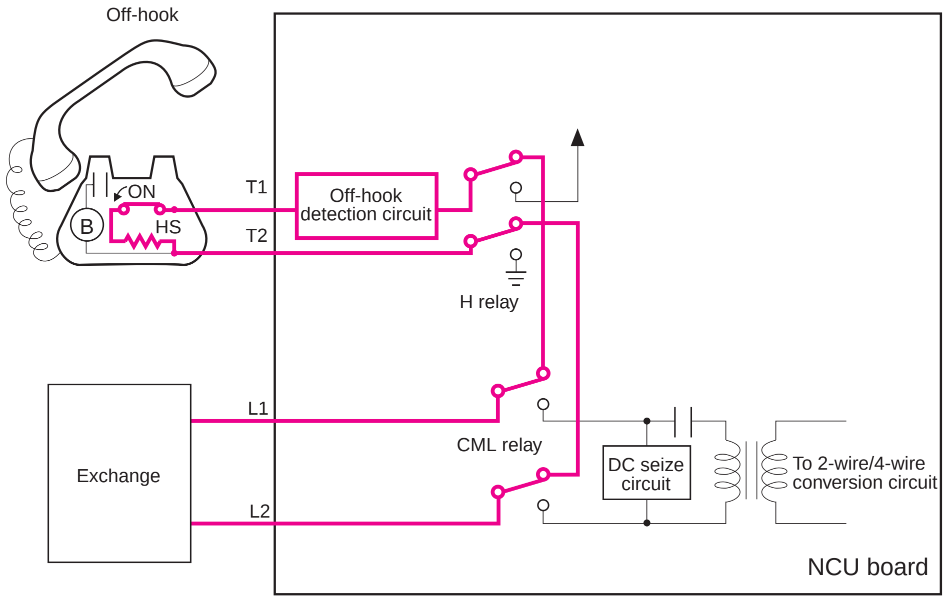


Fig. 6-6 Formation of DC Loop on Telephone Side

When the facsimile side is set to receive automatically, the CML relay turns ON when the calling identification (CI) is detected, and the DC loop is formed between the DC seize (RET) circuit and the exchange.

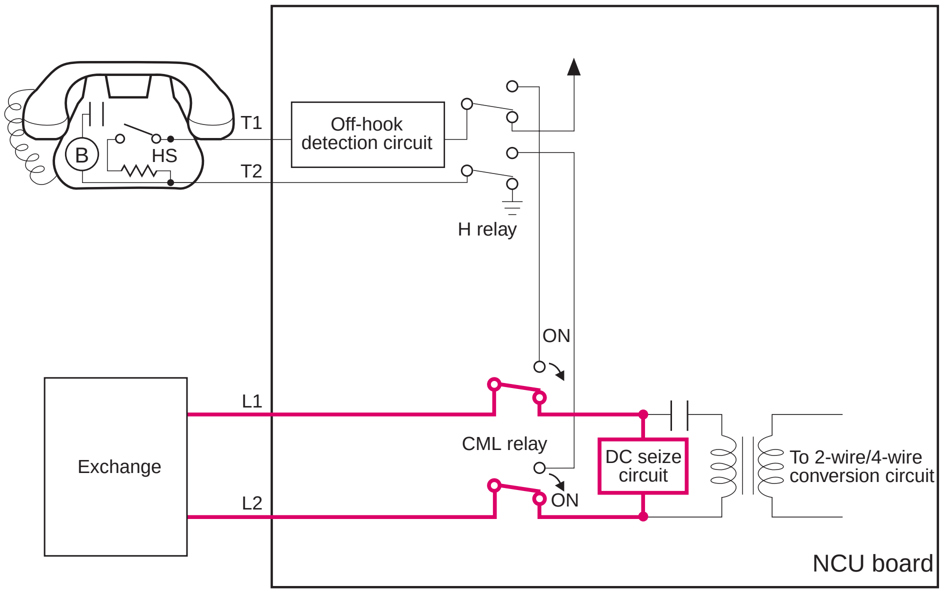


Fig. 6-7 Formation of DC Loop on Facsimile Side

3.3 Detection of Calling Identification (CI)

The CI detection function detects the calling identification (CI) sent from the exchange. Normally, when dialing is performed from the calling party, the bell of the telephone on the incoming call side rings according to the CI from the exchange.

The CI detection function is required for automatic reception by a facsimile. When CI is detected, the facsimile automatically receives the document.

The DC component of the CI arriving from the telephone line is cut by a capacitor (C1). The signal is then half-rectified by two photocouplers, PC1 and PC2, respectively, and the waveform is shaped by IC1 and IC2. The waveforms of each of these outputs (CI1 and CI2) are aligned by OR circuit IC3, and the resulting waveform is sent to the system controller on the SCNT board as CIOR together with CI1 and CI2.

The system controller distinguishes that the signal is CI by the waveform pattern of the arriving signal.

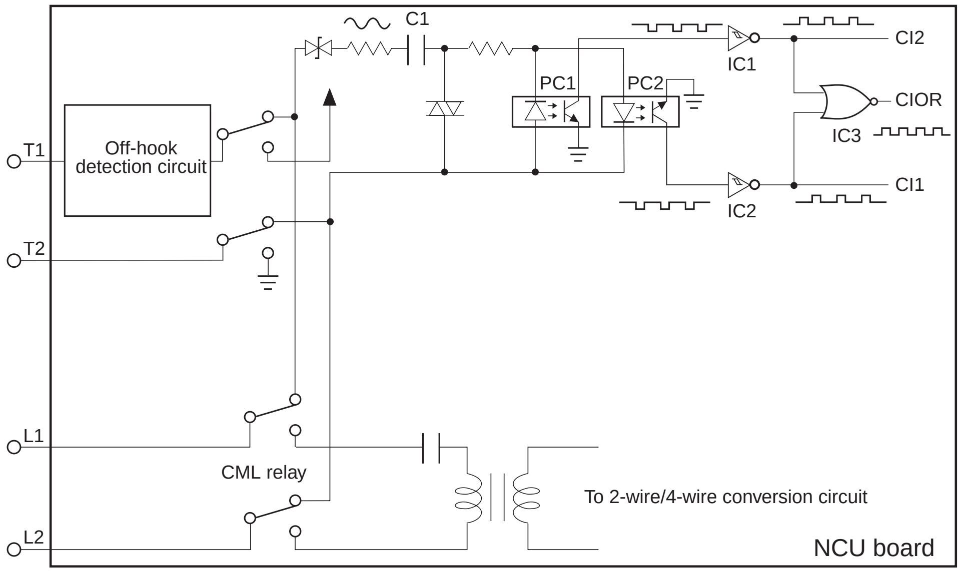


Fig. 6-8 CI Detection Circuit

3.4 Line Signal Monitor

In the answering machine connection mode, the CML relay is switched to the telephone side in the same way as in a standby state so that the telephone line is connected directly to the telephone. However, when the calling party is a facsimile, the CML relay must be switched to facsimile for reception, and so the CML relay is switched to the facsimile side according to the signals arriving from the telephone line.

For this reason, a circuit (line signal monitor circuit) is made between the CML relay and the H relay for monitoring the signals (CNG or DTMF) that arrive from the telephone line. In the answering machine connection mode, the signals are monitored to enable facsimile communications immediately when the other party is a facsimile.

The line signal monitor circuit is divided into a primary side and secondary side with a transformer provided as the boundary in the same way on the facsimile side.

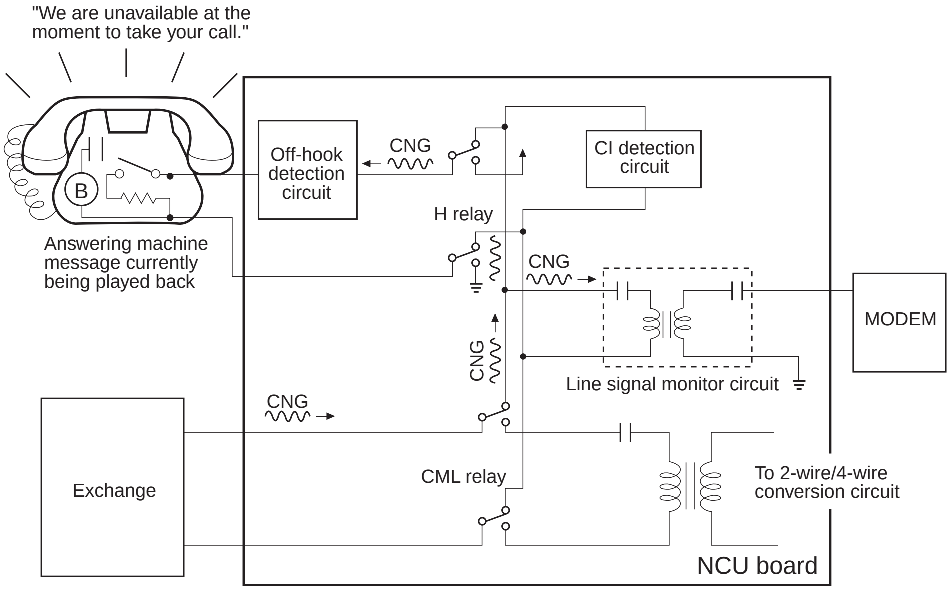


Fig. 6-9 Line Signal Monitor Circuit

3.5 Dial Control

The dial control function generates dial pulses (DP). Application of ON/OFF switching of relays is often adopted as a method of generating dial pulses. The following shows the basic configuration of the dial control circuit.

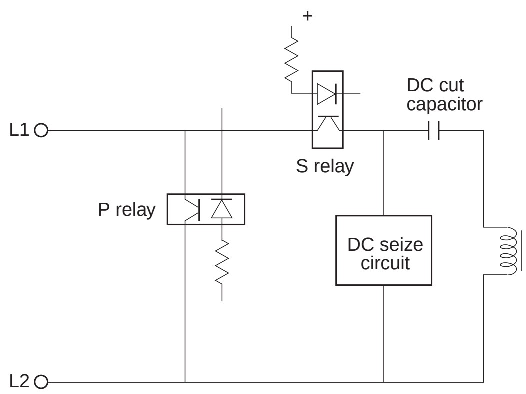


Fig. 6-10 Dial Control Circuit

To generate the dial pulse, the DC loop is formed by the P relay. The dial pulse is generated by turning this relay ON and OFF. If the S relay remains ON while the dial pulse is being generated, the pulse waveform is influenced by the DC seize circuit that is located after the S relay, and changes as follows.

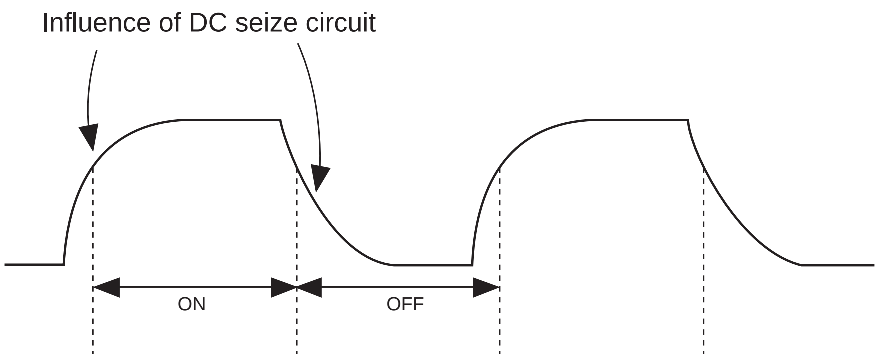


Fig. 6-11 Waveform of Weak Pulse

The waveform changes as follows when the S relay is turned OFF to indicate that it has been shaped.

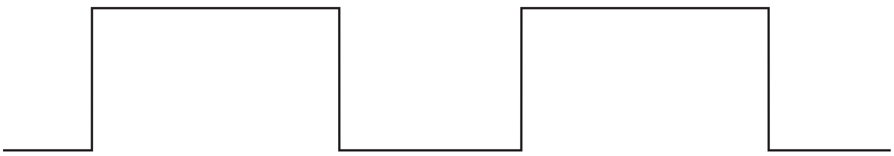


Fig. 6-12 Waveform of Clear Pulse

3.6 2-wire/4-wire Conversion

Normally, telephone lines are 2-wire. However, 2-wire must be converted to 4-wire so that the send data can be processed separately from the received data internally on the facsimile. The 2-wire/4-wire conversion circuit performs this conversion.

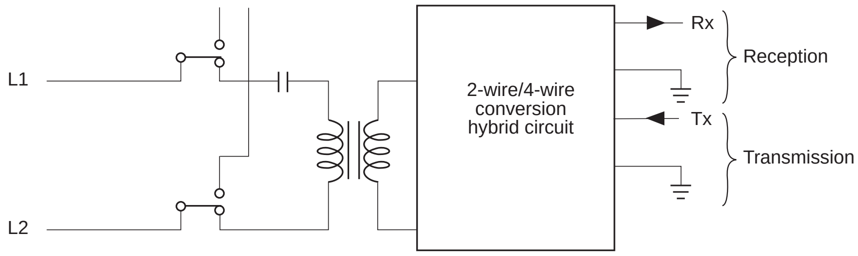


Fig. 6-13 2-wire/4-wire Conversion Circuit

3.7 Protective Circuits

An overvoltage protection function is provided for protecting elements on the NCU board when lightning, for example, causes a high voltage to be applied from the telephone line or when something causes an overvoltage to be applied. An arrestor is provided as a countermeasure for lightning between L1 and L2 on the primary side, and between L1, L2 and the frame ground (FG). Though arrestors normally do not allow current to pass, when a high voltage is applied, they allow current to pass for the amount that the rated voltage is exceeded to lower the voltage across L1 and L2, and across L1, L2 and FG. The arrestor lowers the voltage to the rated voltage by converting electrical energy to optical energy.
In some countries, the arrestor between L1, L2 and FG is connected to an arrestor ground, and the arrestor ground is connected to the power supply unit and in some cases is earthed via the power supply outlet.

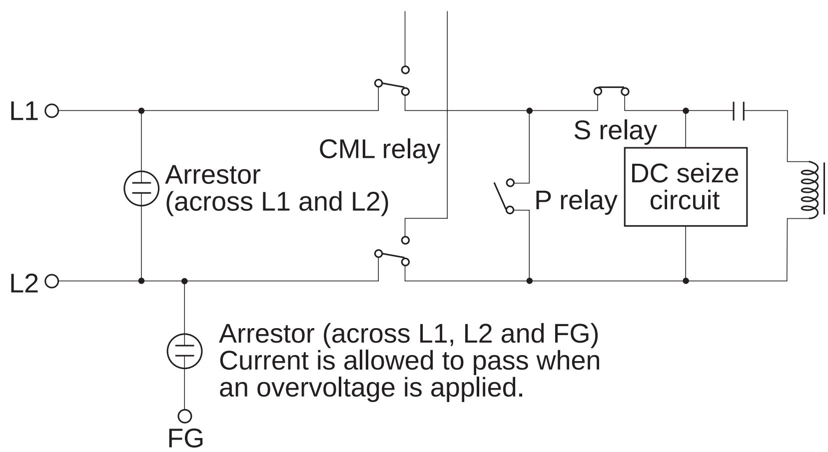


Fig. 6-14 Overvoltage Protection (arrestor)

NOTE

A varistor is used as the protective circuit for overcurrent.
Though varistors normally do not allow current to pass, they turn the CML relay ON when a high-voltage CI arrives from the telephone line, and so the current is allowed to escape to the line to protect the circuit elements from voltage rise.

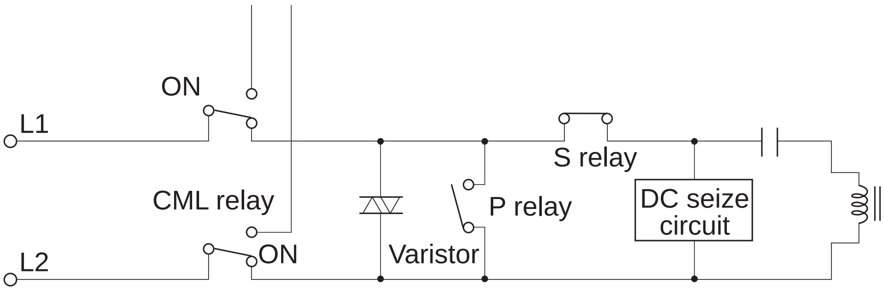


Fig. 6-15 Overcurrent Protection (varistor)

3.8 Telephone Connection Control

In European regions, there are some countries where the line connection of the handset and the extension telephone to be connected to the facsimile is prioritized, and must be connected in parallel in accordance with the communication standards of that country. These connection relationships are switched by means of the setting of the switches on the NCU board.
There are two control patterns as described below for the functions set by these switches.

- Prioritized connection

The connection relationship between the handset and the extension telephone is prioritized, and priority is given to the handset.
When this setting is made, the extension telephone can no longer be used when the handset is in use or is not connected. The extension telephone can be used when the handset is not in use.
Note, however, that when the handset is made off-hook while the extension telephone is in use, the line for the extension telephone will be cut as priority is given to the handset.

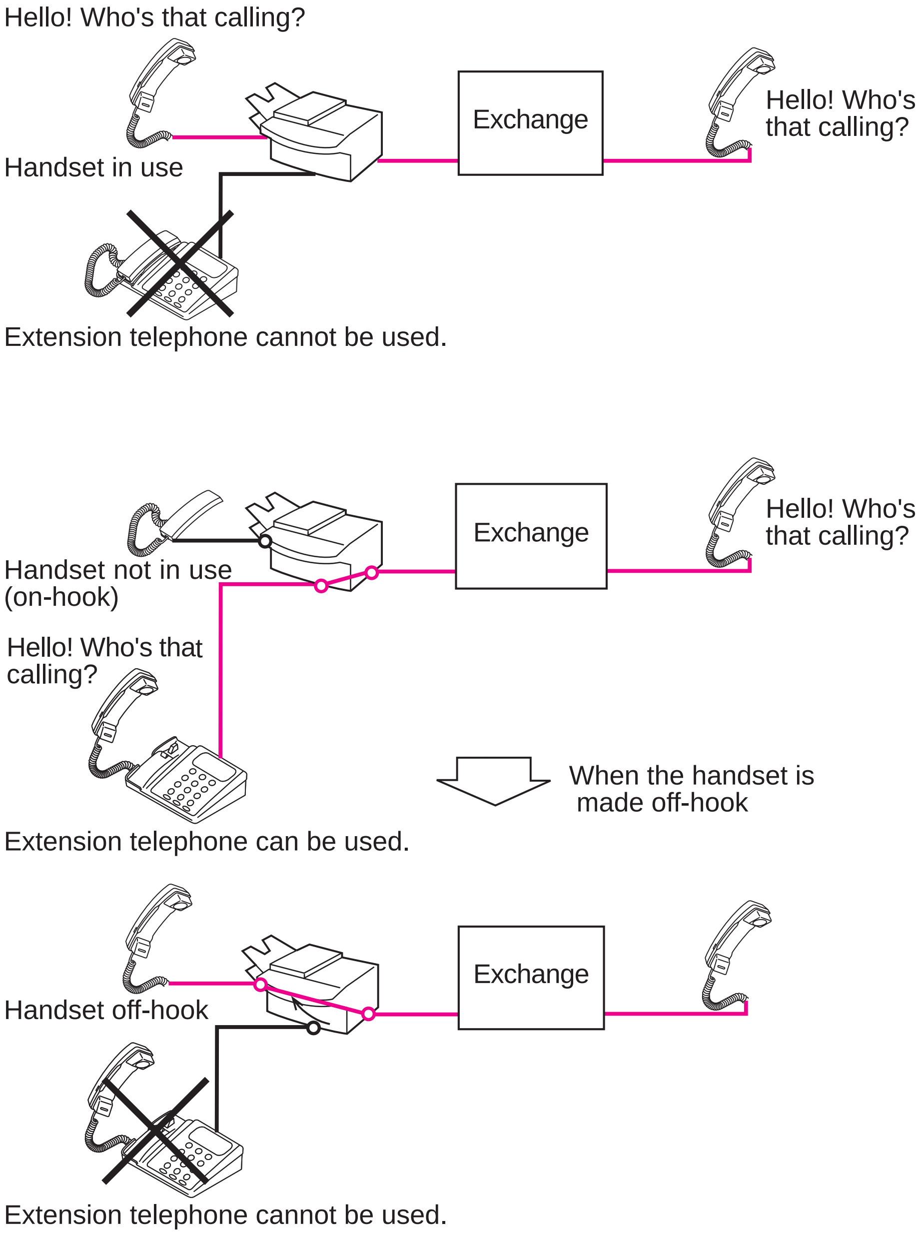


Fig. 6-16 Prioritized Connection

- Non-prioritized connection (parallel connection)

  The relationship between the handset and the extension telephone is not prioritized, allowing a three-way conference call.

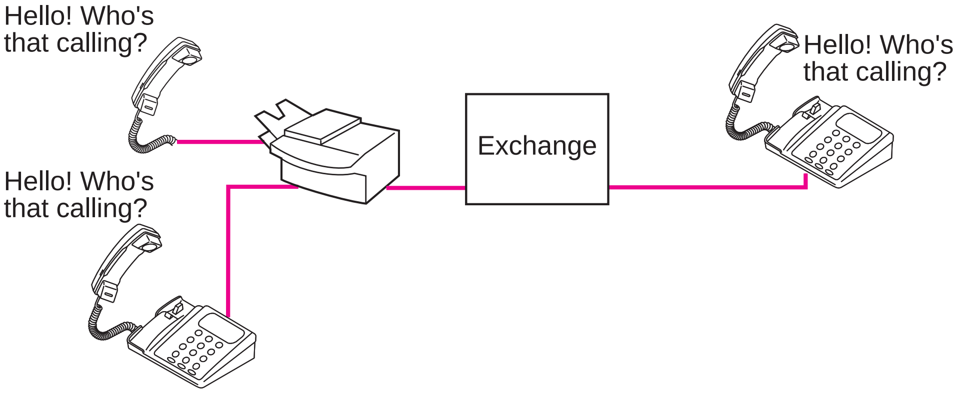


Fig. 6-17 Non-prioritized Connection

3.9 Relay Operations

The following describes operation of each of the relays.

- CML relay (Connect Modem to Line relay)

  This relay is for switching between the facsimile and the telephone (handset or extension telephone) that is the core function of the NCU board.

  With regular relays, an instantaneous circuit interruption occurs at switching. If a regular relay is used for the CML relay, there is the possibility that the exchange will malfunction because of this short break. For this reason, an early make break relay designed to prevent short breaks is used for the CML relay.

- H relay (Hook relay)

  This relay is for enabling detection of the off-hook state on the telephone (handset or extension telephone) during facsimile communications. As the CML relay switches to the facsimile side during facsimile communications, the voltage is not supplied to the off-hook detection circuit. When the H relay switches to the voltage terminal for off-hook detection, voltage is supplied to the off-hook detection circuit to enable detection of the off-hook state of the telephone even during facsimile communications.

- P relay (Pulse relay)

  This relay is for generating the dial pulse (DP). A relay is used for preventing chattering or sparks.

- S relay

  This relay is for shaping the pulse waveform that is generated by the P relay. A relay is used for preventing chattering or sparks.

- R relay

  This relay is exclusively for 230 V regions. It is used for sending signals to a private branch exchange when the R key is pressed. A photo-MOS relay is used for this relay.

4. OPCNT BOARD

As the operation panel is the part that the user must touch to operate the facsimile, the OPCNT board in the operation panel is powered ON at all times to enable use of buttons on the operation panel.
The OPCNT board is configured as follows:

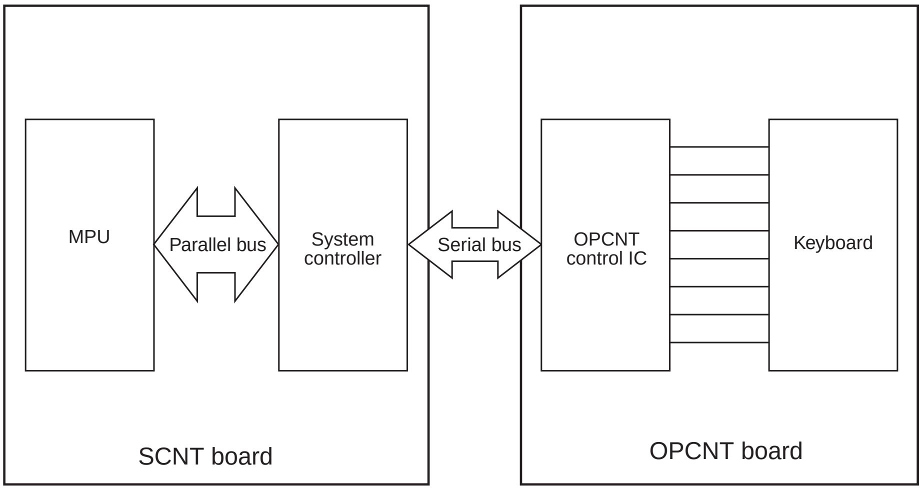


Fig. 6-18 Conceptual View of OPCNT Board

The OPCNT control IC on the OPCNT board performs serial communications with the system controller on the SCNT board. After this, serial/parallel conversion is performed by the system controller, and the signals are relayed to the MPU.
The following are the main functions of the OPCNT board:

- Detection of button input
- LED lighting control
- Display indication control

4.1 Detection of Button Input

The OPCNT board detects pressing of the buttons on the operation panel, and relays this to the SCNT board. Many buttons are provided on the top surface of the operation panel. If one switch were used for one button, many input ports would be required for the OPCNT control IC that is connected before the operation panel. For this reason, button input is detected using a matrix system to prevent an increase in the number of input ports.
The button detection circuit is configured as follows.

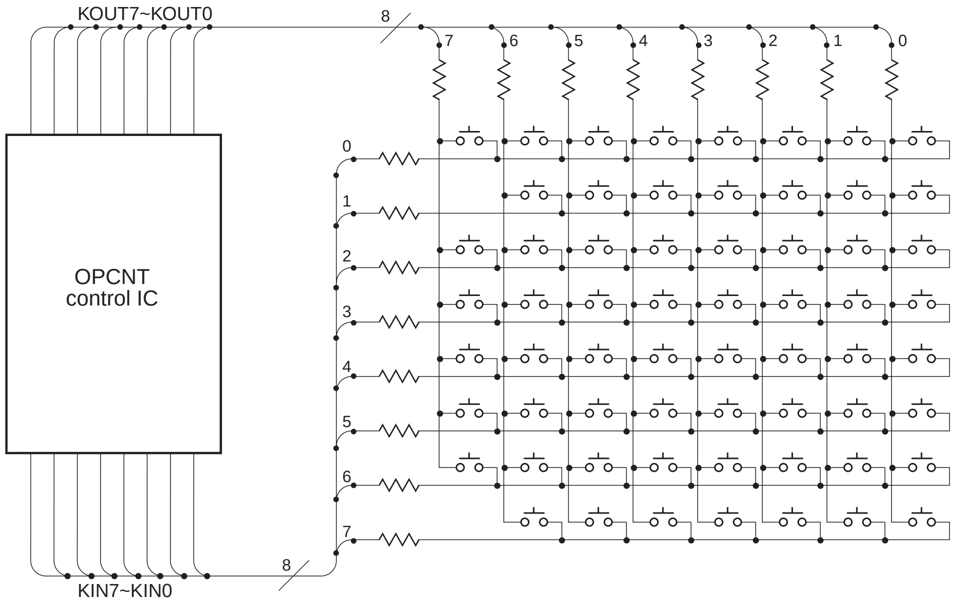


Fig. 6-19 Button Detection Matrix and Control IC

To detect button input, the reference clock from the OPCNT control IC is divided so that the state of outputs KOUT0 to KOUT7 is Low for a fixed period of time. The duration that these outputs are Low is shifted for each of the outputs. Inputs KIN0 to KIN7 are pulled up internally by the OPCNT control IC to be High at all times.

6

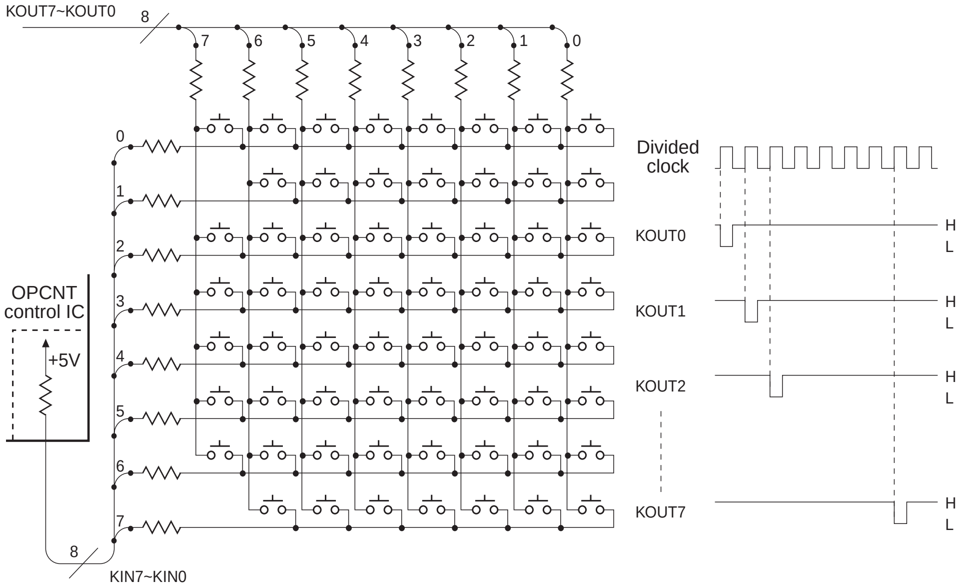


Fig. 6-20 Button Detection Timing Chart 1

When the KOUT0 to KOUT7 rows become Low, one of the KIN0 to KIN7 lines becomes Low when a button is held down, and the OPCNT control IC detects which button was pressed.

For example, if button 23 is held down when KOUT2 becomes Low, KIN3 also becomes Low, and the OPCNT control IC detects that the button of the KOUT2 row and the KIN3 line has been pressed.

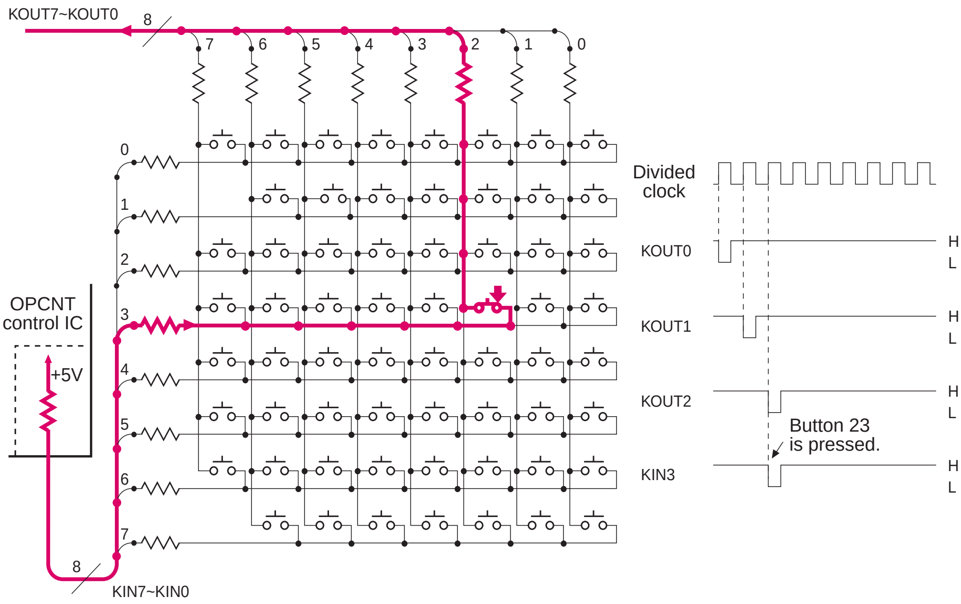


Fig. 6-21 Button Detection Timing Chart 2

When the OPCNT control IC detects button input, that information is relayed to the MPU by serial communications, and the command that instructs whether to perform LCD display or light the LEDs is returned from the MPU according to the button that was pressed.

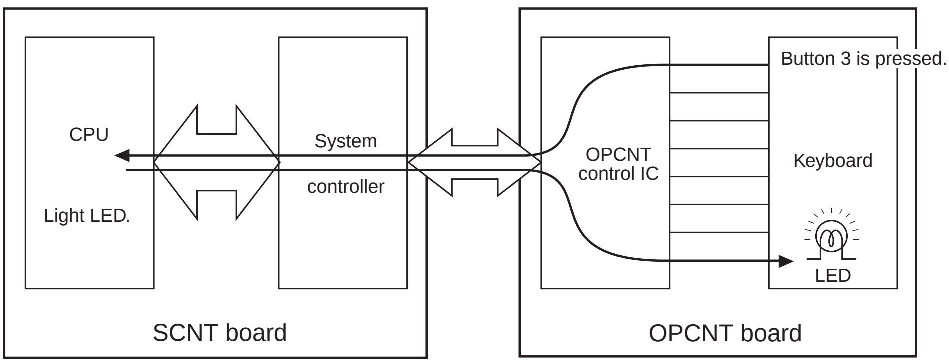


Fig. 6-22 Flow of Data

4.2 LED Lighting Control

The LEDs are connected to the ports on the OPCNT control IC as shown in the figure below. These ports are configured internally as drivers. When the LED lighting signal arrives from the MPU, the driver turns ON, and current flows to the LED to light the LED. Once an LED has lit, the lit state of the LED continues until the lighting OFF signal arrives from the MPU.

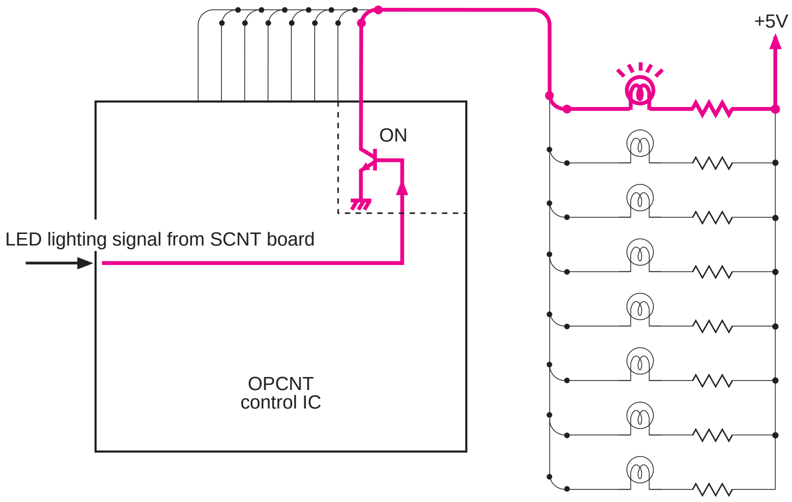


Fig. 6-23 LED Lighting Control

6

4.3 Display Indication Control

When LCD code data arrives from the MPU, this data is sent to the LCD module via the OPCNT control IC. The character generator (CG) of the LCD module converts the LCD code data to data for LCD display (data that indicates which pixel is to be output as black) based upon the code data that has arrived.

5. FLOW OF IMAGE SIGNALS

5.1 Transmission

(1) Images are read by the contact sensor, and the resulting analog image data is sent to the SCNT board.

(2) The analog image data that arrives from the contact sensor undergoes digital image data conversion, error diffusion processing or other processing on the image processor IC of the reading control section. The resulting image data is sent to the system controller by serial communications.

(3) The system controller converts the digital image data from serial to parallel and writes the data to DRAM.
In memory transmission mode, the MPU codes the digital image data in DRAM by the CODEC, and writes the resulting data to DRAM again.

(4) In the memory transmission mode, the coded digital image data is converted to raw data on the MPU. After this, coding according to the transmission mode is performed, and the resulting data is written to buffer area in DRAM.
In the direct transmission mode, the MPU codes the raw data in DRAM matched to the transmission mode, and writes the resulting data to buffer area in DRAM.

(5) The MPU transfers the data in DRAM buffer area to the MODEM one byte at a time in response to requests from the MODEM. When the data arrives, the MODEM performs modulation.

(6) After the data has been modulated, it is amplified by the 2-wire/4-wire conversion circuit on the NCU board, and is sent to the telephone line from L1 and L2.

5.2 Reception

(1) Received data that arrives from the telephone line is amplified by the NCU board, and then sent to the MODEM on the SCNT board.

(2) The MODEM demodulates the data, and writes the received data to DRAM.

(3) The MPU decodes the received data in DRAM by the CODEC, performs coding for storing the data in DRAM, and writes the data to DRAM again.

(4) The MPU decodes the data in DRAM to raw data and sends the data to the system controller.

(5) As the received raw data is the data for the facsimile, the system controller performs resolution conversion on the data to obtain data for printing, and sends the resulting data to the printer control section.

(6) At the printer control section, motors, rollers and other parts are controlled according to the data for printing, and printing is started.

6. POWER SUPPLY UNIT

The "power supply unit (regulator)" converts the alternating current (AC) for household use into a direct current (DC) constant voltage power source. A "constant voltage power source" refers to a power source whose output is maintained at a fixed output voltage even if the input voltage or output current fluctuate.

Series regulators and switching regulators are generally used as a DC constant voltage power supply. Facsimiles mainly use switching regulators.

The reason why a switching regular has been selected is that even though its circuit is more complicated than that of a series regulator, it is ideal for downsizing and allows the power supply unit itself to be made compact. Another reason why a switching regulator has been selected is that it demonstrates good stable power supply efficiency and generates little heat.

Table 6-1 Features of Switching Regulators and Series Regulators

Power Supply Type	Features
Switching regulator	• Compact size and light weight • High efficiency • Complicated circuit • Large noise
Series regulator	• Large size and heavy weight • Low efficiency • Simple circuit • Small noise

The following describes what sort of power supply a switching regulator is as switching regulators are used on almost all facsimiles.

6.1 Switching Regulator

Switching regulators supply only voltage that has dropped due to the load, and turn semiconductor switches ON and OFF ("switching") to control the supply voltage for maintaining a constant voltage. This is why this kind of regulator is called a "switching regulator."

Switching regulators compare fluctuations in the output voltage with the reference voltage, and change the time ratio (duty ratio) of the ON and OFF states of the input DC voltage switch according to the result of this comparison to control the output voltage to a constant voltage.

In other words, when the output voltage is higher than the reference voltage, the duty ratio is lowered (the OFF time is increased), and when it is lower than the reference voltage, the duty ratio is raised (the ON time is increased) so that the output voltage is equal to the reference voltage at all times.

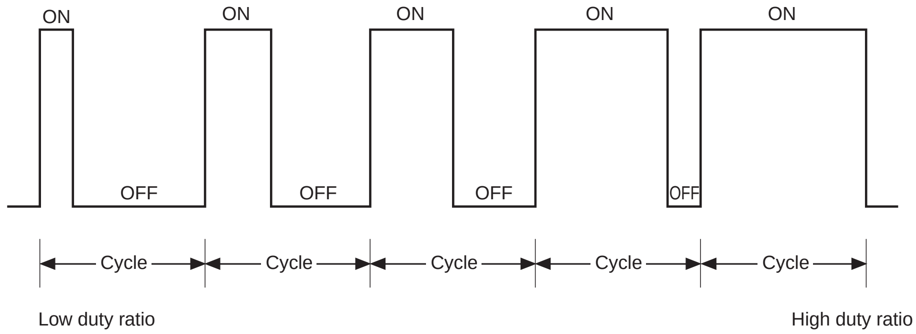


Fig. 6-24 Duty Ratio

The following diagram shows a function block diagram of a switching regulator. Let's describes the functions of each block. The AC input side is called the "primary side" and the DC output side the "secondary side" with a transformer provided as the boundary.

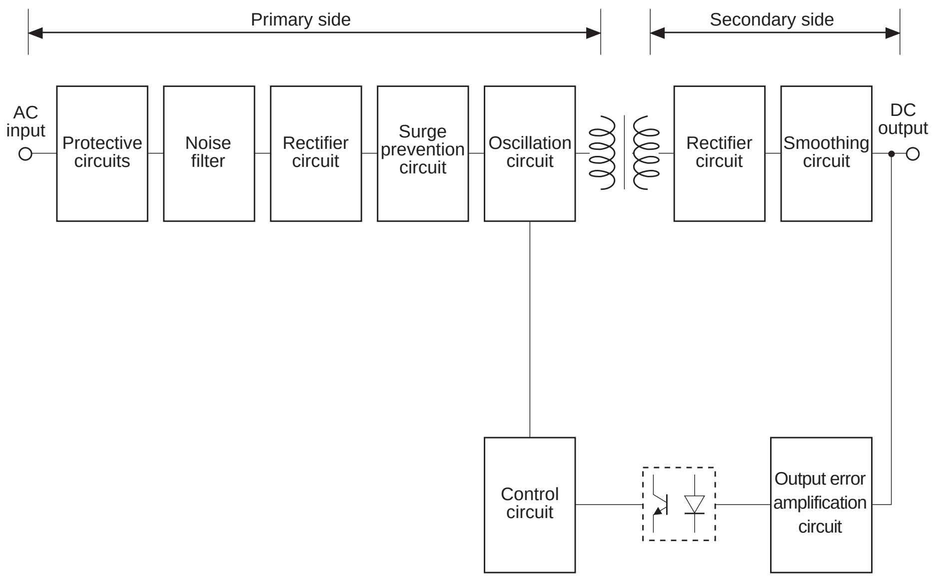


Fig. 6-25 Function Block Diagram

6.1.1 Protective circuit

The power supply circuit is provided with a protection function for over-current and overvoltage on the primary side.

As protection against overcurrent, the power supply circuit is provided with a current fuse. When an overcurrent flows, this fuse blows due to self-heating, preventing overcurrent from flowing to the circuit from then on.

As protection against overvoltage, the power supply circuit is provided with a varistor. When a voltage exceeding the rated voltage of the varistor is applied to the power supply line, the varistor causes a current to flow to prevent voltage of and above the rated voltage from being applied.

A phototransistor and photocoupler are also provided extending across the primary and secondary sides for detecting abnormal output voltage. When the photocoupler on the secondary side detects an abnormal output voltage, it relays this to the phototransistor on the primary side, and stops oscillation to stop supply of the power voltage.

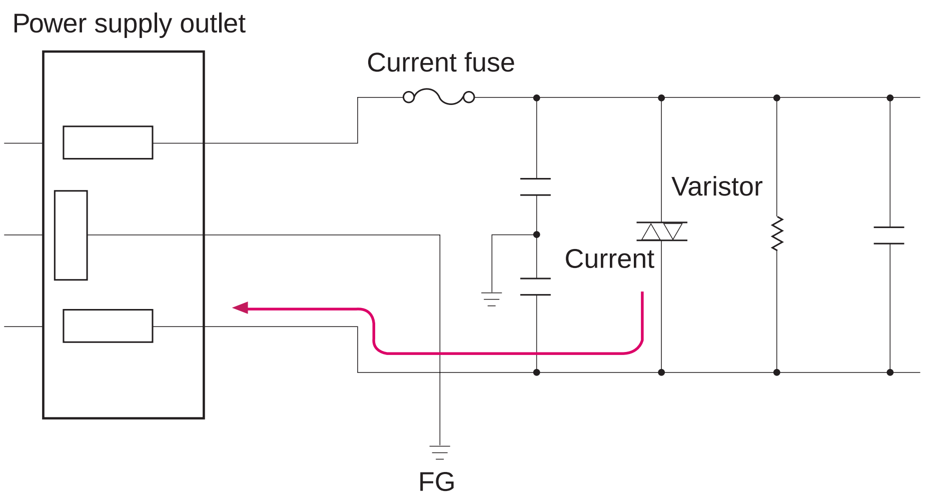


Fig. 6-26 Protective Circuit

6.1.2 Noise filter

The noise filter comprises coils and capacitors, and cuts noise generated at the input section (line noise, etc.) and prevents switching noise from escaping to the power supply line.

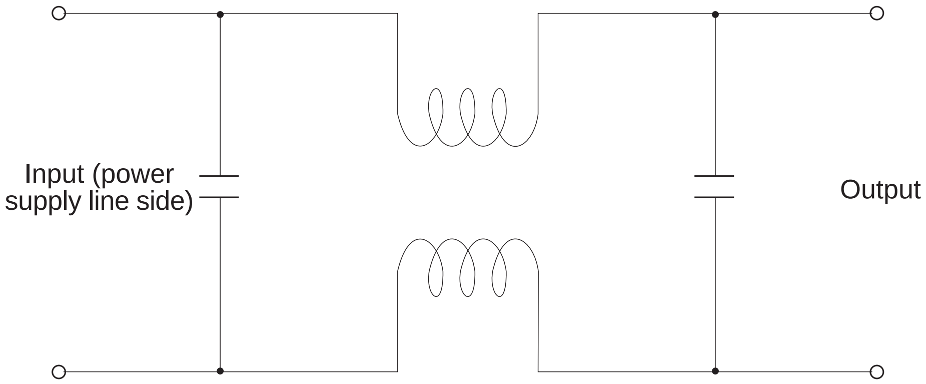


Fig. 6-27 Noise Filter

6.1.3 Rectifying circuit

6

The AC input signal is full-wave rectified by a diode bridge to convert the AC input to DC. The rectified voltage is made to have a shape like that of a mountain range, and is different from the constant voltage that is output from batteries. This kind of voltage is called a pulse wave.

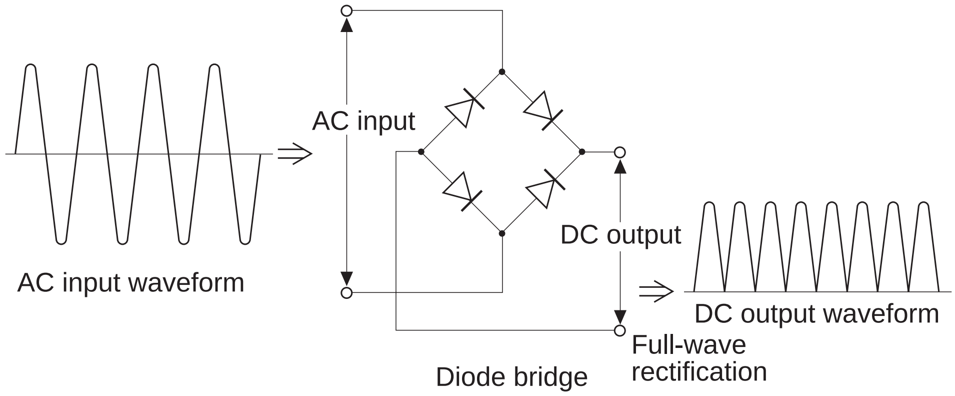


Fig. 6-28 Rectifier circuit

The diode bridge can also be represented as shown in Fig. 6-29.

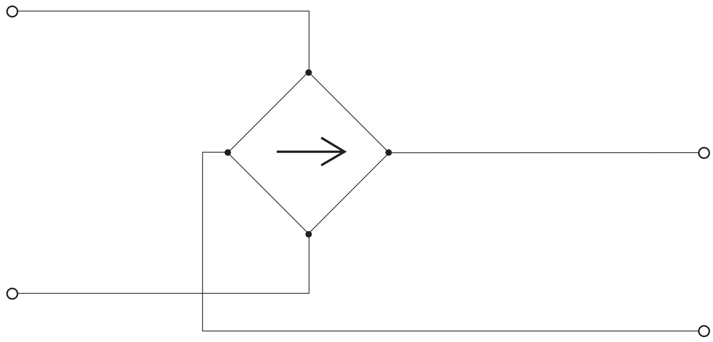


Fig. 6-29   Diode Bridge

6.1.4 Surge prevention circuit

AC input is rectified by the diode bridge, and is charged in capacitor C. For this reason, a large surge current flows when the power is turned ON. A thermistor is used to prevent surge current from flowing as there is the danger that elements on circuits may be destroyed when surge current flows. When the power is turned ON, the thermistor's resistance value is increased to limit surge current. After this, current flow causes the thermistor to self-heat which, in turn, lowers the resistance value, making it easier for current to flow.

NOTE

When the power is turned back ON immediately after it is turned OFF, the thermistor's temperature has not sufficiently fallen. So, current flows more easily, causing surge current to flow. For this reason, take care not to turn the power back ON immediately after turning it OFF.

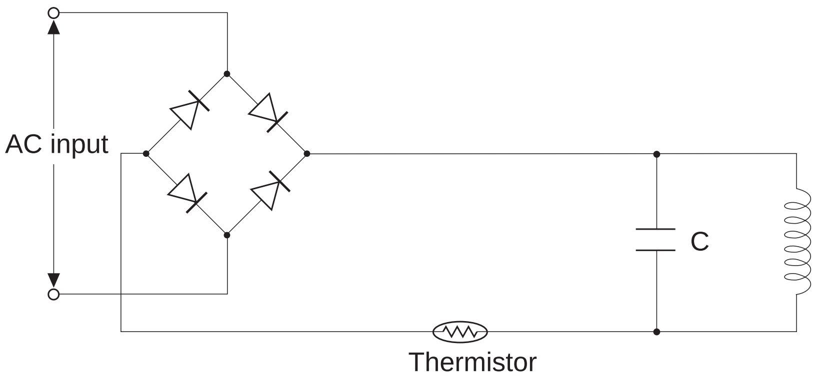


Fig. 6-30   Surge Prevention Circuit

6.1.5 Oscillation/Control and output error amplification circuits

The oscillation/control circuit (IC1) is located on the primary side, and the output error amplification circuit is located on the secondary side. The output error amplification circuit detects the error with the reference voltage according to the fluctuation in the output voltage. When the output voltage is higher than the reference voltage, the diode of PC1 lights. When it is lower, the diode goes out. This lighting ON/OFF information is relayed to the feedback port (FB) of the oscillation/control circuit (IC1) on the primary side via the phototransistor of PC1. The oscillation/control circuit outputs the transistor ON/OFF signal from the OUT port based upon this lighting ON/OFF information to control the input voltage to the transformer so that the output voltage is maintained at a fixed voltage.

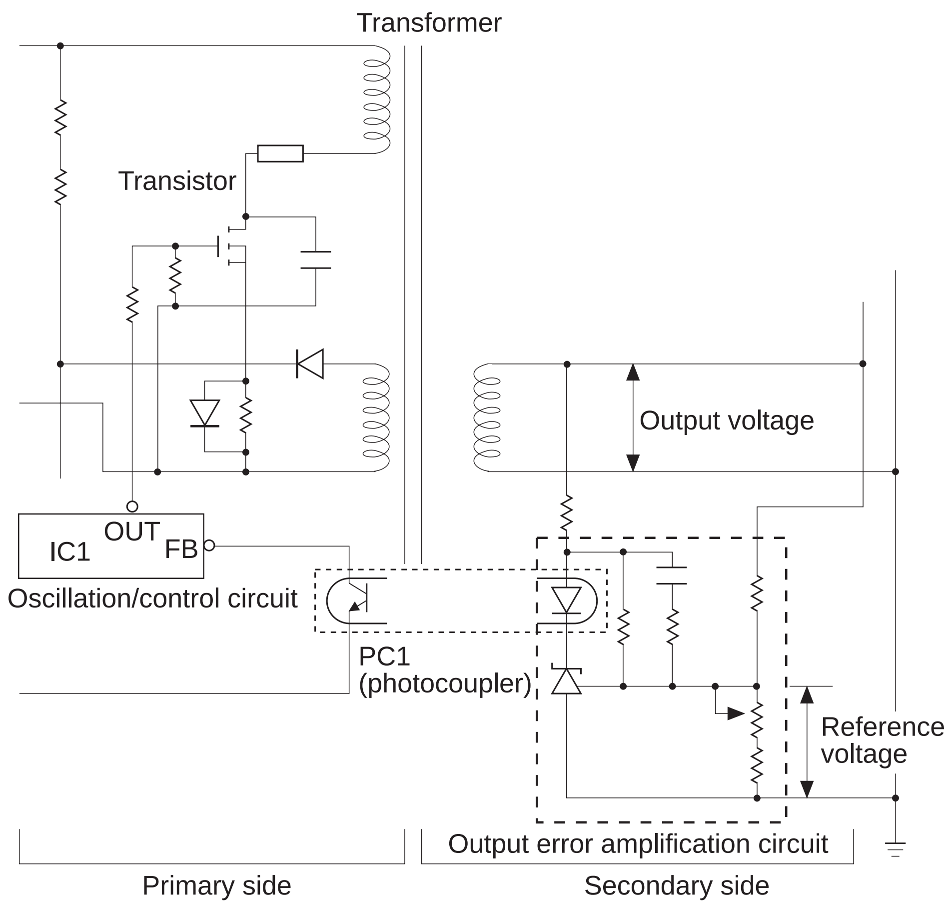


Fig. 6-31 Oscillation/Control/Output Error Amplification Circuit

6.1.6 Smoothing circuit

If AC is rectified using only a rectifier, the DC output contains a large pulsating component. The circuit used to reduce this pulsating current and provide smooth stable DC voltage is called a smoothing circuit.

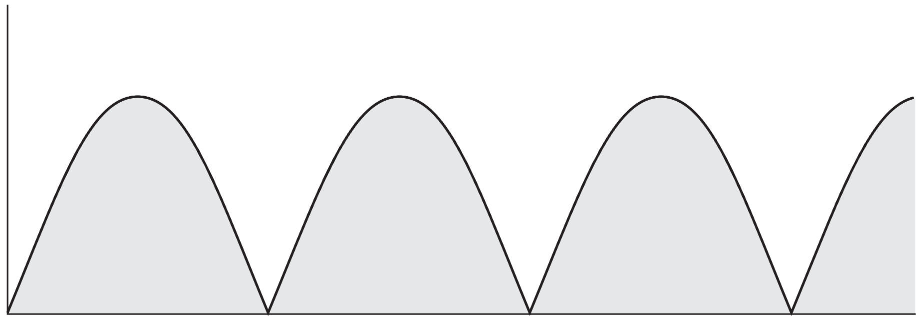


Fig. 6-32 Pulsating Component

Fig. 6-33 shows the smoothing circuit. This circuit uses a capacitor to complement the no-voltage component of the output in the above figure. When there is voltage, the capacitor is charged, and when there is a no-voltage component, the capacitor discharges to supply the voltage.
By this action, the smoothing circuit is able to smooth pulsating voltage that is output from the rectifying circuit to a DC constant voltage.

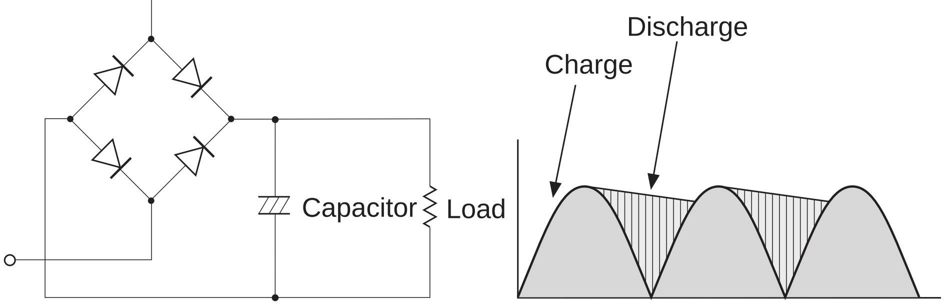


Fig. 6-33 Smoothing Circuit Using Capacitor

6.2 Configuration of Power Supply Unit on a Facsimile

The power supply unit on a facsimile, broadly speaking, supplies voltage to two or three power lines such as those below from the AC power for household use:

- +5V for IC drive
- +12V for operation panel and motor drive
- +24V for contact sensor and printer drive

7. G4CNT BOARD

The G4CNT board is provided on G4 facsimiles, and is the equivalent to the NCU board on a G3 facsimile. The G4CNT board performs connection with the ISDN line to perform digital communications. In the case of a G4 facsimile, G4 communications is performed. In the case of a G3 facsimile, digital signals are converted to analog signals at reception and analog signals are converted to digital signals at transmission by the PCM CODEC and MODEM on the G4CNT board to perform G3 communications.

- CPU

  The G4CNT board comprises the following ICs.
  As the block diagram below shows an example where two lines can be used simultaneously, two MODEMs are provided.
  The G4CNT board has a CPU (V821) for controlling the entire G4CNT and a slave CPU (V853). The slave CPU performs coding (MR, MMR or JBIG) on the MR data stored in DRAM matched to the functions of the machine at the other party, and during reception codes the coded data from the other party to MR data for storing on DRAM.

- ISDN interface

  As its name implies, this interfaces the facsimile with the ISDN line, and performs outgoing/incoming call control and layer 1 control (extraction of data and synchronization).

- HDLC controller

  This controller converts data to HDLC format and performs serial/parallel conversion to enable detection of data errors.

- SLIC

  This functions as an exchange when an analog telephone is connected to the facsimile. For this reason, it forms the DC loop with the analog telephone and detects the off-hook state of the telephone.

- Dual port RAM

  This RAM is for separating the V821CPU and V853 slave CPU systems.

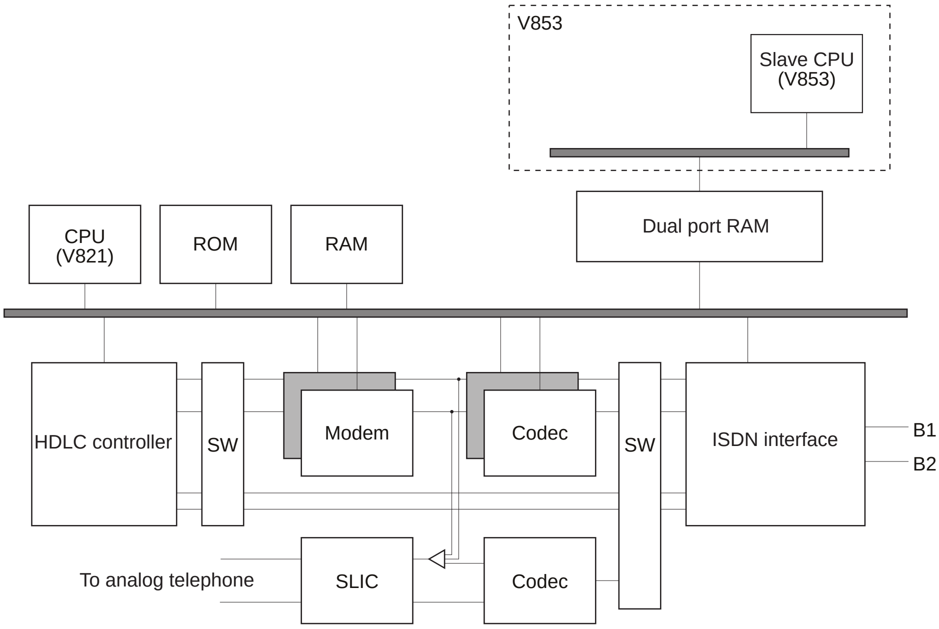


Fig. 6-34   System Block Diagram of G4CNT Board

6

Notes

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1. TRANSMISSION LINES OF TELEPHONE LINES

Let's take a look at what is used as the transmission lines of an actual telephone lines. Fig. A-1 shows the transmission lines of a hierarchical organization in Japan.

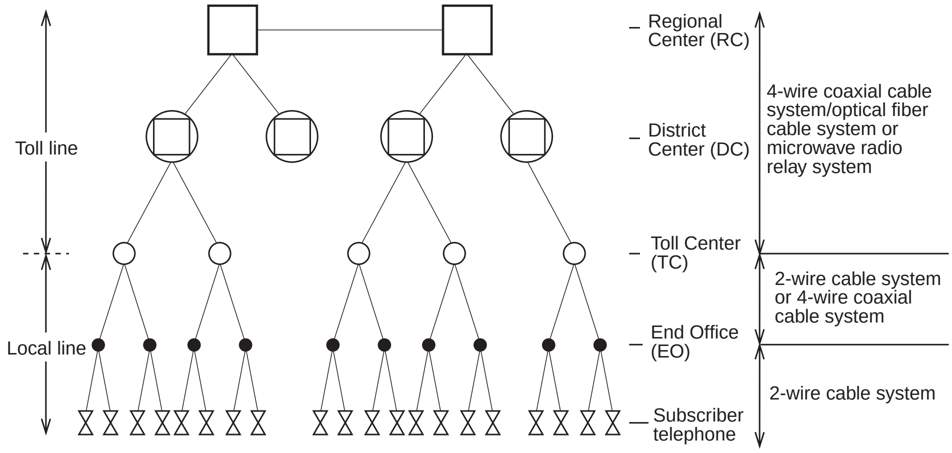

Fig. A-1 Transmission Lines of a Hierarchical Organization (example)

Fig. A-2 shows an organization and transmission lines of an international telephone network.

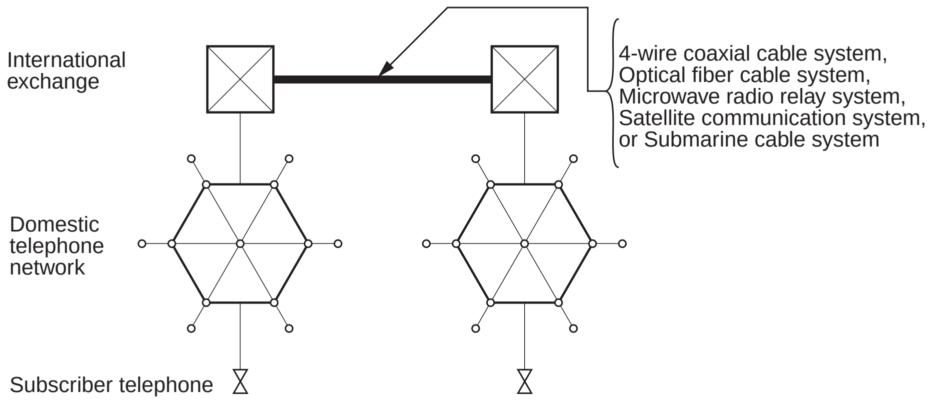

Fig. A-2 Organization and Transmission Lines of
an International Telephone Network

NOTE

Coaxial cable system

Coaxial cable, which is an assembly of coaxial pairs with relatively low attenuation and superior high-frequency characteristics compared to 2-wire cable, is used. Among its various methods, the FDM-FM method which provides 1000 to 10000 channels, is adopted.

Microwave radio relay system

This system uses microwave radio in the 1 to 10 GHz band for transmission. FDM-DM is used as the modulation method.

Satellite communication system

This system refers communications via communications satellites.

Submarine coaxial cable system

This system refers to the coaxial cable that is load on the ocean floor. The TASI (Time Assignment Speech Interpolation) system is used for efficient use of the cables. However, the tip of the leading section of the signal may be cut for the TASI system.

A

2. CHARACTERISTICS OF TELEPHONE LINE (ANALOG)

2.1 Telephone Line Band

A human voice spectrum has the characteristics shown in Fig. A-3.

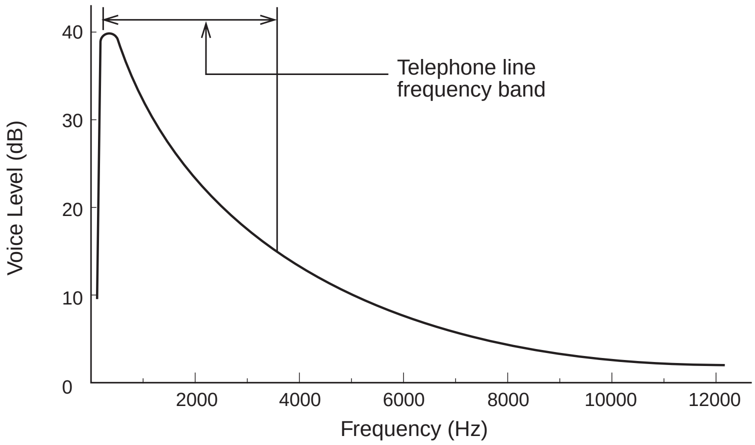

Fig. A-3 Voice Spectrum

The greater part of voice energy is concentrated between 0 to 4000 Hz as shown in the Fig. A-3. That is, if this frequency band is transmitted, the naturalness of the voice will be slightly lost. However, the content (information) of the telephone conversation can be satisfactorily transmitted.

For this reason, telephone lines are designed for voice transmission in a frequency bandwidth of 300 to 3400 Hz.

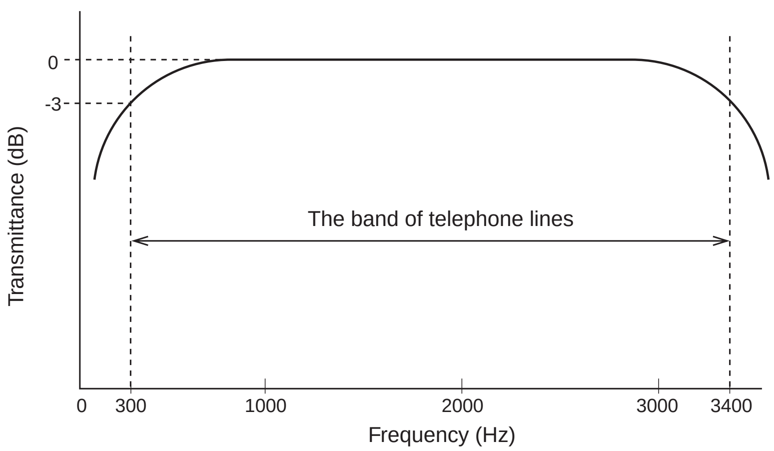

Fig. A-4 Ideal Frequency Characteristics of a Telephone Lines

However, this bandwidth is too narrow for data transmission which requires a broad bandwidth such as facsimile transmission.
So, coding and high-speed modulation technologies are used for facsimiles to transmit data at high speed in the limited narrow band.

2.2 Characteristics of Telephone Network Components

This item describes the characteristics of each component in a telephone network. Various trouble may occur in these components.

2.2.1 Characteristics of transmission line

(1) Half-duplex communication system

- 2-wire cable system

  External electrical noise can easily affect this system.
  The frequency characteristics deteriorate according to the material and length of the cable. Moreover, transmission loss may increase.

(2) Full-duplex communication system

- 4-wire cable system

  Same trouble as for a 2-wire cable system may occur.
- Microwave radio relay system

  The S/N may be affected by the weather.
- Satellite communication system

  Echo (approx. 0.6 to 1.0 sec. including return) is generated.
  The S/N may change due to the effect of the solar wind depending on the season.
- Submarine coaxial cable system

  Echo (approx. 0.3 sec. including return) is generated.
  The leading section of the signal may be cut and the band is narrow (upper limit 3 kHz).

NOTE

Half-duplex communication
When using two communication terminals, directional communication is performed alternately by this system.
Full-duplex communication
When using two communication terminals, directional communication is performed simultaneously by this system.

A

S/N

"S/N" stands for the signal-to-noise ratio. It is also called the SN ratio. (For details, see this chapter, 5. S/N.)

2.2.2 Characteristics of exchange

(1) Step-By-Step (SXS)

Noise or Short breaks are more likely to occur as these exchange has many mechanical contacts. This exchange is not suitable for facsimile transmission.

(2) Crossbar (XB) and Electronical Exchange (DEX)

These exchanges generate little noise or short breaks.

2.3 Factors of Telephone Line Deterioration

There are two main factors that cause the quality of facsimile transmissions via telephone lines to deteriorate: usual factors (which always present), unusual factors (which suddenly occurs), international communications and lightning. The following describes typical factors.

(For details, see this chapter, 7. Factors Which Cause Deterioration in Quality of Facsimile Transmission.)

(1) Usual factors

- Transmission loss
- Attenuation distortion
- Group delay distortion
- Level variation
- White noise
- Crosstalk
- Frequency offset
- Phase jitter

(2) Unusual factors

- Impulse noise
- Short break
- Sudden level variation
- Phase hit

(3) Factors in international communications

- Echo
- Time taken for establishing line connection

(4) Other factors

- Lightning

Though these factors do not cause major trouble in voice transmission, they sometimes are a problem in data transmissions such as facsimile transmission.

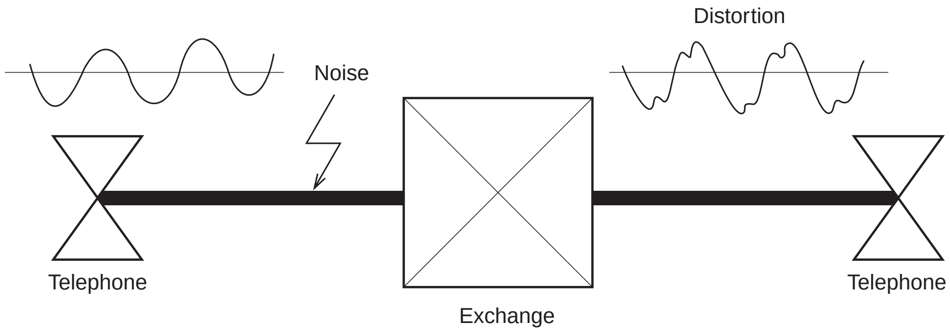

Fig. A-5 Deteriorating Factors

The following Table A-1 shows phenomenon that occur due to these deteriorating factors and countermeasures that can be taken to remedy these phenomenon.

Table A-1 Phenomenon Caused by Deteriorating Factors and Countermeasures

Deteriorating Factor	Phenomenon	Countermeasure
Transmission loss	An increase in transmission loss drops the signal level on the receiving facsimile. Transmission quality drops by deterioration of S/N.	Improve the S/N ratio. • Increase the transmission level on the ATT switch of the SSSW. • Slow down the transmission speed.
Attenuation distortion	Waveform distortion increases and image signals become more difficult to receive.	Adjust the NL equalizer of the SSSW. When black drops out in the image: → Turn NL ON. When the image is blurred: → Turn NL OFF.

A

Table A-1 Phenomenon Caused by Deteriorating Factors and Countermeasures

Deteriorating Factor	Phenomenon	Countermeasure
Group delay distortion	The image signals become more difficult to receive just like as in attenuation distortion.	—
Level variation	Lines are missed if the variation is significant.	Improve the S/N ratio. • Increase the transmission level on the ATT switch of the SSSW. • Slow down the transmission speed.
White noise	Lines are missed if the signal level is low.	Improve the S/N ratio. • Increase the transmission level on the ATT switch of the SSSW. • Slow down the transmission speed.
Frequency offset	Control procedure may be interrupted.	Improve the S/N ratio. • Increase the transmission level on the ATT switch of the SSSW. • Slow down the transmission speed.
Phase jitter	Lines may be missed if jitter is significant.	Improve the S/N ratio. • Increase the transmission level on the ATT switch of the SSSW. • Slow down the transmission speed.
Impulse noise	The same phenomenon as white noise and level variation occur.	Improve the S/N ratio. • Increase the transmission level on the ATT switch of the SSSW. • Slow down the transmission speed.
Short break	More conspicuous symptoms that level variation and impulse noise occur.	Countermeasures are difficult to implement.
Phase hit	Lines are missed.	Improve the S/N ratio. • Increase the transmission level on the ATT switch of the SSSW. • Slow down the transmission speed.

Table A-1 Phenomenon Caused by Deteriorating Factors and Countermeasures

Deteriorating Factor	Phenomenon	Countermeasure
Echo	Control procedure errors may occur.	Several countermeasures are available. (See this chapter, 7.3 Echo.)
Time taken for establishing line connection	In international communications, it may take a long time to connect lines. With automatic dialing, it may not be possible to connect.	Insert a pause in the registered telephone number.
Lightning	High voltage is conducted on telephone lines when lightning strikes. This voltage passes through the NCU board and may damage the inside of the facsimile.	• Take high-quality ground. • Unplug the power supply cord and telephone line during thunderstorms.

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3. FACSIMILE COMMUNICATION NETWORK SERVICES & MINIFAX (JAPAN ONLY)

In facsimile communications over telephone lines, there is a tendency towards increasing communications speeds to keep costs down. Facsimiles are also being provided more and more functions to make them more convenient. Alternatively, this is making facsimile machines more expensive.
For this reason, NTT (Nippon Telephone and Telegraph) views terminals and networks as an integrated system and is offering Facsimile communication network services (F-NET) as a network service and Minifax I (MF-I) and Minifax II (MF-II) as terminal services to satisfy the above user's needs and increase overall performance including communications costs.

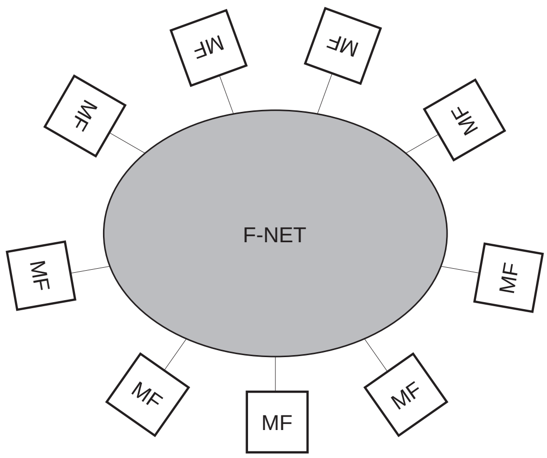

Fig. A-6   F-NET and Minifax

When you subscribe to a F-NET, normally your facsimile is shares a subscriber exchange on a PSTN as shown in the Fig. A-7 on which facsimile communications are performed.

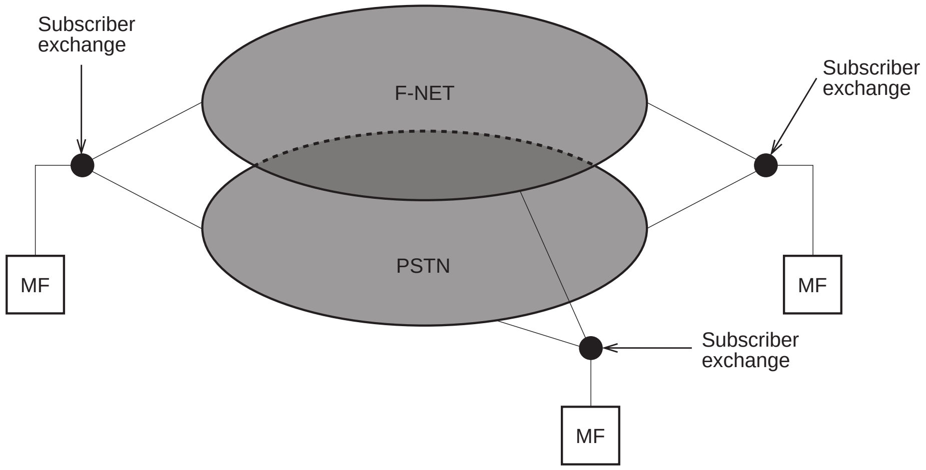

Fig. A-7   F-NET and PSTN

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3.1 F-NET

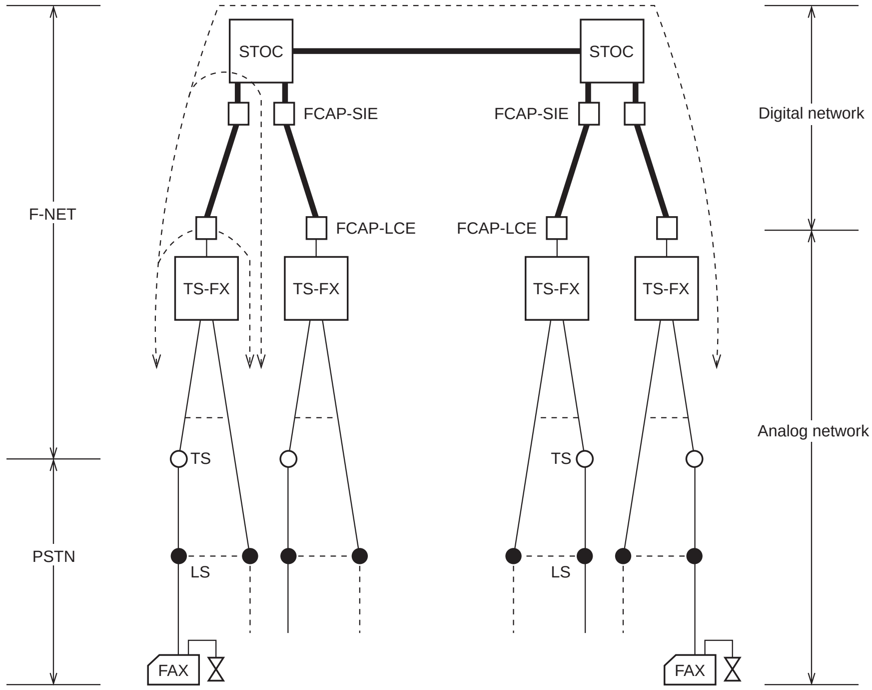
F-NET is organized as shown in the Fig. A-8 for the following reasons:

(1) Terminals and the network are considered to be integrated, and terminal functions are concentrated as far as possible on the network to improve terminal economy.

(2) Many services can be achieved and line usage efficiency improved by adopting a storage and conversion system.

(3) Adoption of digital transmission lines enables high-speed transmission of large volumes of data.

(4) Reasonable communications costs can be achieved by sharing existing subscriber telephone network facilities.



━━━ : Digital transmission line
─── : 4 kHz transmission line
- - - - : Flow of call (example)

TS-FX: Tandem trunk electronic exchange having facsimile communications functions
TS: Tandem trunk exchange
LS: Subscriber exchange
STOC: Storage and conversion equipment
FCAP: Facsimile signal conversion and control equipment
(LCE: line control equipment, SIE: Storage converter interface equipment)

Fig. A-8 Configuration of F-NET

3.1.1 Functions of facilities on F-NET

The following describes the facilities and functions of the component elements on F-NET.

(1) Storage and conversion equipment (STOC)

- Stores image signals.
- Transmits and receives image signals with other STOCs.
- Stands by and calls again when the incoming call terminal is busy.
- Generates messages such as non-delivery notices.
- Converts the size of A5- and A4-size documents.

(2) Facsimile signal conversion and control equipment (FCAP)

- Transmits and receives image signals with facsimile terminals.
- Performs A/D conversion on image signals.
- Codes image signals and suppresses redundancy.
- Multiplexes image signals, and transmits them to STOC. Alternatively, receives and separates digitized image signals from STOC.
- Appends the leading section of image signals with caller number before transmitting the image signals to the facsimile terminal.
- Monitors the digital transmission line between the STOC and TS-FX.

(3) Tandem trunk electronic exchange (TS-FX) having facsimile communications functions

- Switches and connects between the LS (or TS) and FCAP.
- Holds the subscriber data, and performs transmitter verification, charging and recording of communications.
- Transmits non-ringing alert signals to the facsimile terminal.

(4) Toll exchange (TS)

- Switches and connects between the LS and TS-FX.

(5) Local exchange (LS)

- Switches and connect between the facsimile terminal and TS-FX (or TS).
- Detects the caller number and transmits this information to the TS-FX.
- Connects to the facsimile terminal with the telephone bell in a non-ringing state.

(Note 1) LS and TS share the subscriber telephone network.

(Note 2) A crossbar exchange (XB) or electronic exchange (DEX) are used for LS and TS, and electronic exchange (DEX) is used for TS-FX.

Two types of terminal are stipulated as being connectable to F-NET: Class 1 connection arrangement terminal and Class 2 connection arrangement terminal.

Class 1 Connection Arrangement Terminal

Terminal supporting the Minifax I mode

Class 2 Connection Arrangement Terminal

Terminal having an F-NET compatible G3 mode

For details on the Minifax I mode, see this chapter, 3.2 Minifax I (MF-I).

3.1.2 General description of connection operation

The Fig. A-9 shows the basic connection operation on F-NET.

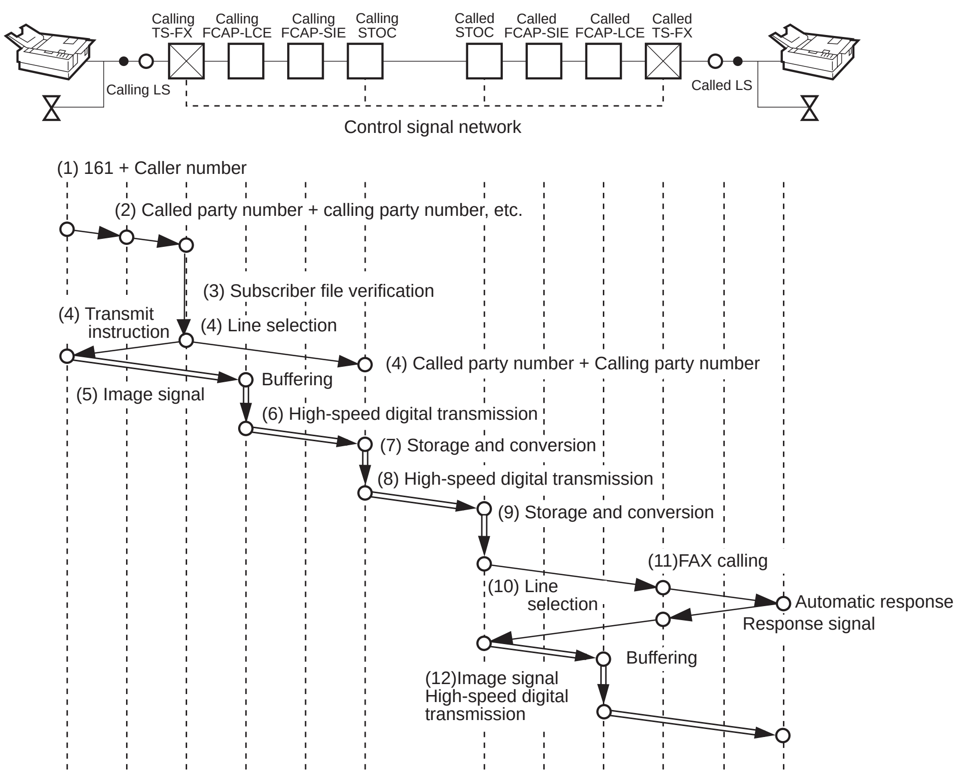


Fig. A-9 Connection Procedure
(Example of communications outside area)

3.1.3 Description of connection operation on F-NET

(1) When the caller dials the special number “161” on the telephone, the secondary dial tone (SDT) is returned from the LS. The caller then dials the called party number.

(2) LS detects the caller number, and transmits this to the TS-FX on the calling side together with the called party number.

(3) The calling TS-FX verifies and check whether or not the calling facsimile has an arrangement to use F-NET.

(4) The calling TS-FX sets the line up to the calling STOC, and instructs facsimile transmission operation to the calling facsimile by the facsimile switching instruction signal (2100 Hz).

(5) The calling facsimile and the calling FCAP-LCE are connected, and the image signals are transmitted from the calling facsimile after the selection of the communications mode and other communications control.

(6) The calling FCAP-LCE multiplexes the received image signals, and transmits them by high-speed digital transmission to the calling STOC.

(7) The calling STOC stores the image signals to memory. If the document size must be converted, it stores the image signals to memory after performing conversion.

(8) The calling STOC looks for free space on the digital transmission line, and transmits the calling party number, called party number, and image signals to the called STOC.

(9) The called STOC stores the image signals from the calling STOC to memory.

(10) The called TS-FX is started up by the called STOC. When it receives the called party number via the control signal network, the line up to the LS is set.

(11) If the called party is not busy, the facsimile alert signal (1300 Hz) for starting up the called facsimile with the telephone bell in a non-ringing state is sent from the called TS-FX. Response signals (primary response: DC loop, secondary response: 2100 Hz) are returned from the called facsimile.

(12) The called FCAP-LCE is connected to the called facsimile, and the image signals are transmitted from the called FCAP-LCE after com-

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munications control. Reception of the image signals by the called facsimile completes this series of communications operations.

3.2 Minifax I (MF-I)

“Minifax I” originally is the name of Class 1 connection arrangement terminals for F-NET. The transmission method used on these terminals is also called “Minifax I (MF-I)”. Any simple mention of Minifax refers to Minifax I.

Recent Canon facsimiles do not support communications with Minifax I.

3.3 Minifax II (MF-II)

Facsimile machines called “Minifax II (MF-II)” are produced as Class 2 connection arrangement terminals for facsimile communications. The mode used here is the mode called “F-NET compatible G3” and is almost the same as ITU-T’s G3 standard.

(1) Control procedure of G3 facsimiles supporting F-NET

The Fig. A-10 shows the procedure for transmitting to F-NET from a facsimile terminal.

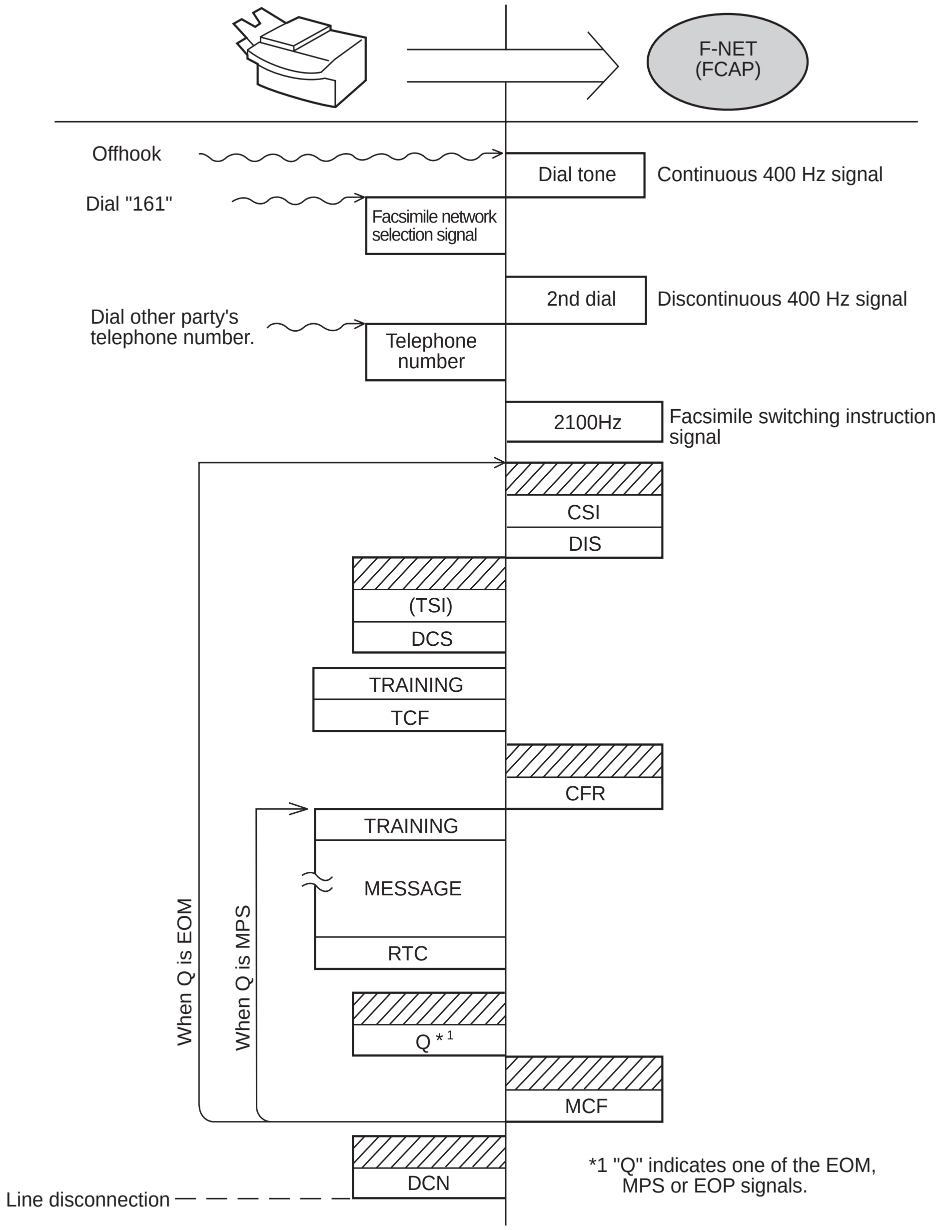

Fig. A-10 Control Procedure of F-NET Compatible G3 (Facsimile terminal to F-NET)

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The Fig. A-11 shows the procedure for sending to the terminal from F-NET.

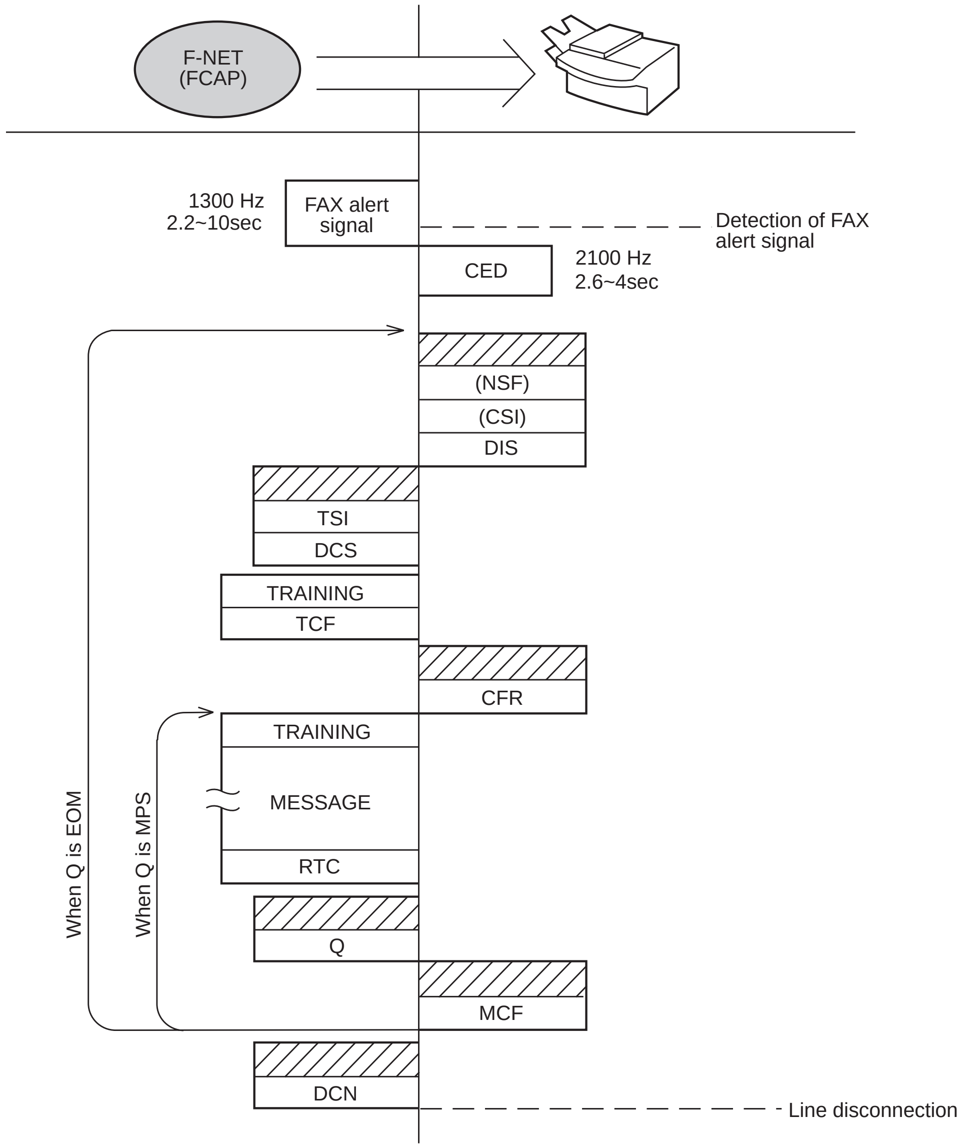


Fig. A-11 Control Procedure of F-NET Compatible G3
(F-NET to facsimile terminal)

4. TELEPHONE LINE BAND & SIGNAL SPECTRUM

Although the bandwidth of regular telephone lines is 300 to 3400 Hz, the upper limit is 3000 Hz for submarine coaxial cables for international communications. This is for the efficient use of high-cost cables.

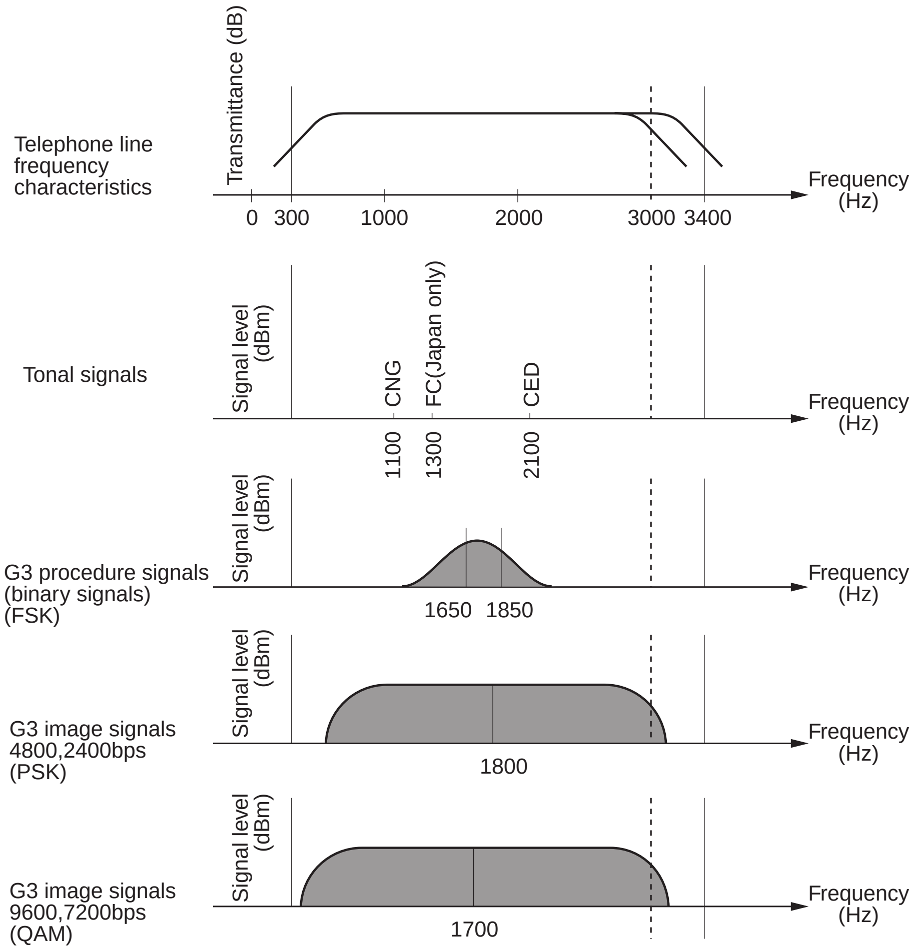


Fig. A-12 Telephone Line Bandwidth and Signal Spectrum

5. S/N

S/N (Signal to Noise) is the ratio of the signal power level to the noise power level at optional point on a telephone line.

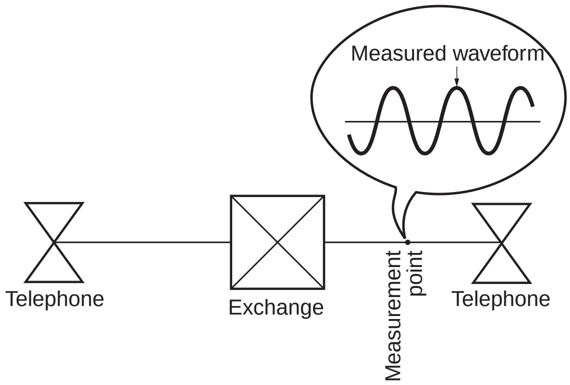


Fig. A-13 S/N

Generally, S/N can be calculated by the following formula:

$$S/N = 10 \log_{10} \frac{\text{Signal power[mW]}}{\text{Noise power[mW]}} \text{ [dB]}$$

Fig. A-14 S/N Calculation Formula

As can be known from the formula, a "good S/N" is a large S/N. That is, the signal power level is large compared to the noise power level. A "poor S/N" is when the above condition is reversed.

It can be said that the performance of the receiving facsimile is high if it can receive image signals at a small S/N. If signals can be received properly from large noise, this is a clear indication that performance is high. The Fig. A-15 shows the relationship between the signal level and noise level.

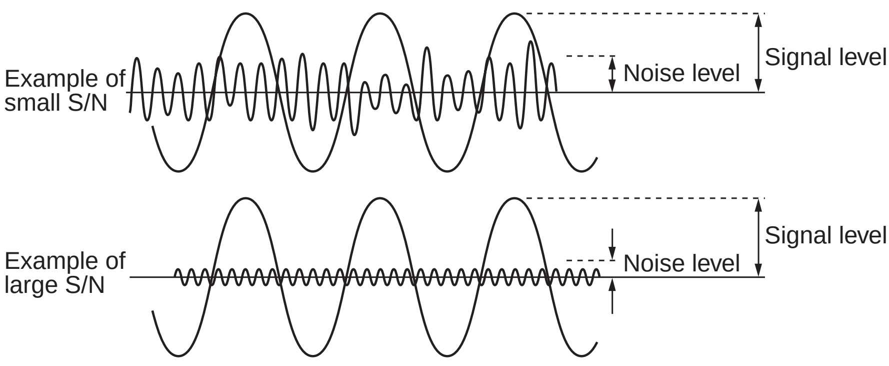


Fig. A-15 Relationship between Signal Level and Noise Level

6. POLARITY INVERSION ON EXCHANGE

The Fig. A-16 shows the standard operation of an exchange in order to explain polarity inversion. This example is for an exchange operating in Japan. The polarity on the calling side is reversed simultaneously with the called party becoming offhook. The original polarity is restored simultaneously with the end of the telephone conversation and the called party becoming onhook.

On some facsimiles, the characteristics of the telephone line are used when to perform auto-dialing.

Polarity is not reversed on some exchanges overseas and some private branch exchanges.

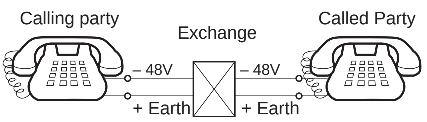
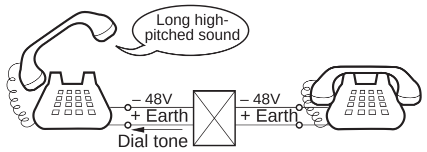
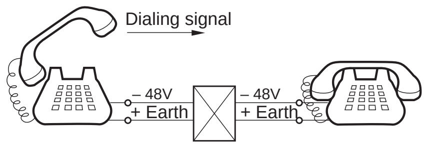
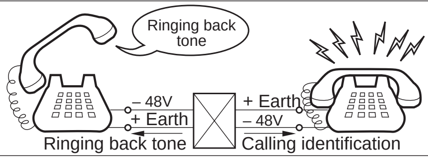
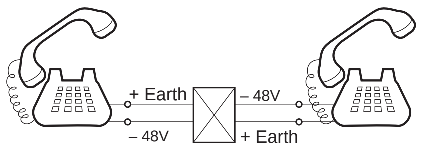
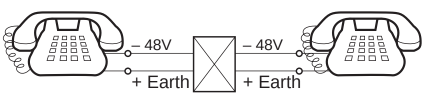
Telephone State	Operation of Exchange	Telephone Line State
① Both onhook (normal state)	Monitors states of terminals.	
② Calling party offhook (loop closed)	Exchange is started up. Dial tone is sent to calling party.	
③ Transmission of dialing signal	Operation of exchange Selects the called party.	
④ Calling called party in progress	Selects the called party, inverts the polarity and sends the calling identification. Sends the ringing back tone to the calling party.	
⑤ Called party offhook (loop closed)	Restores original polarity after response from called party. Deactivates the calling identification. Inverts the polarity on the calling party and deactivates the ringing back tone.	
⑥ Voice transmission		
⑦ End of call Both onhook	Restores all lines to their original states.	

Fig. A-16 Example of Standard Operation of Exchange in Japan

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7. FACTORS WHICH CAUSE DETERIO-RATION IN QUALITY OF FACSIMILE TRANSMISSION

7.1 Usual Factors

(1) Transmission loss

"Transmission loss" is the amount that a signal transmitted from the transmitting terminal attenuates until it arrives at the receiving terminal. Transmission loss is expressed in dB.

Transmission loss has the greatest influence on the quality of telephone conversations. So, a loaded cable is added to subscriber lines, and for long-distance lines a digital transmission line comprising coaxial cable and a microwave radio relay system are used. As a result, most of the transmission loss occurs on the subscriber line.

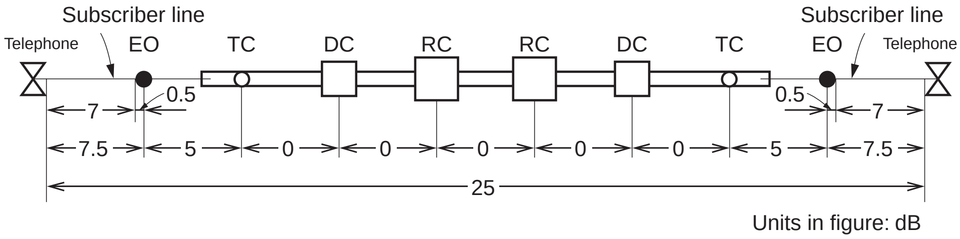


Fig. A-17 Example of Loss Distribution on a Toll Line

NOTE

Loaded Line

In the past, when there were no suitable amplifiers, excessive attenuation prevented telephone conversations from being conducted when long-distance calls were made. However, as you can tell from the Fig. A-18, the amount of attenuation is reduced by self-induction action if coils are inserted in the line at fixed intervals. These coils are called "Loading coils" and insertion of these coils is called "load". A line equipped with loading coils is called a "loading cable" and a line without loading coils a "Non-Loading cable (NL)". Loading cables, however, cause group delay distortion.

Currently, all newly installed subscriber lines are non-loading cables.

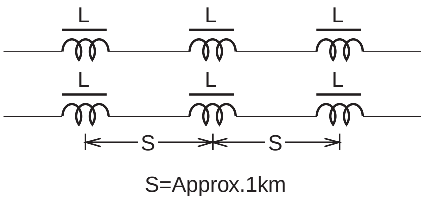


Fig. A-18 Loading cable

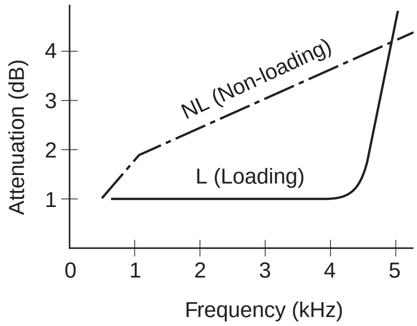


Fig. A-19 Attenuation Characteristics of Non-loading Cable

(2) Attenuation distortion

"Attenuation distortion" is the distortion that occurs as a result of inconsistent transmission loss in the required frequency band.

Attenuation distortion occurs between EOs (end offices) and on non-loaded subscriber lines. Humps may occur in the attenuation characteristics of the subscriber line due to impedance mismatching.

Attenuation distortion occurs does not cause special problems in telephone conversations. However, in the case of G3 facsimile transmission, image signals can no longer be received properly and errors occur frequently if the distortion is significant.

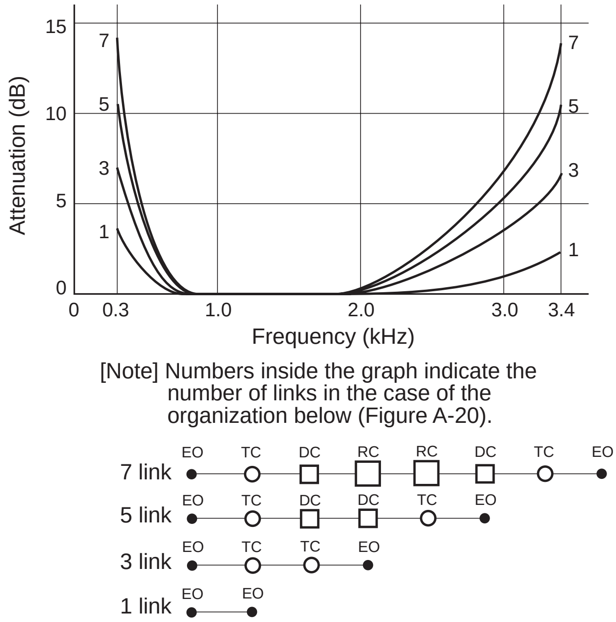


Fig. A-20 Attenuation Characteristics between EOs

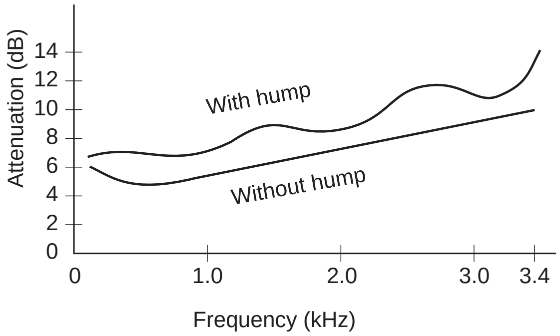


Fig. A-21 Attenuation Characteristics of Subscriber Lines

NOTE

Number of links

The “number of links” is the number of times that modulation (multiplex) is performed between exchanges in the telephone hierarchy at or above the EO stage. You can also think of this as the number of transit trunks between exchanges that a telephone conversation passes through.

(3) Group delay distortion

It takes a certain amount of time to transmit voice or data signals from a transmitting terminal to a receiving terminal over a telephone line. This is called “delay”. Distortion occurs in the waveform if the delay is inconsistent within the required frequency band. This is called “group delay distortion”.

Group delay distortion occurs due to multiplexing that is performed at exchange in the telephone hierarchy at or above the EO stage.

Group delay distortion does not cause any problems during telephone conversations as the sensitivity of the human ear is not so sharp. However, in G3 facsimile transmission, this prevents image signals from being received properly and errors occur frequently just like attenuation distortion.

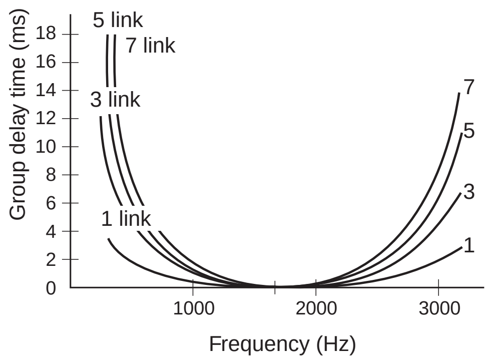


Fig. A-22 Group Delay Characteristics between EOs

(4) Level variation

"Level variation" refers to the signal level change according to time.

(5) White noise

"White noise" occurs in amplifier vacuum tubes, transistors and resistors, and is uniformly distributed among all frequencies.

(6) Crosstalk

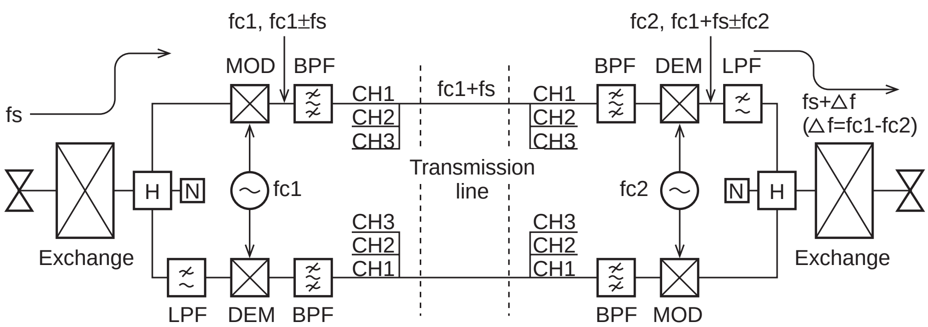
"Crosstalk" is the voice signals you can hear on other lines that is caused by electromagnetic or inductive coupling. Crosstalk occurs when the level at an EO is -15 dBm or more, and is the equivalent to white noise.

(7) Frequency offset

"Frequency offset" is the difference between the input signal frequency and the output signal frequency.

As SSB (Single Side Band) transmission is used in FDM, the carrier wave (fc1) is not transmitted from the transmitter to the receiver. Instead, the receiver uses its own carrier (fc2) to regenerate the signal. Generally, a slight frequency difference (Δf) between fc1 and fc2. The Fig. A-23 shows its generation procedure.

Frequency offset does not cause any special problems in telephone conversations. In G3 facsimile transmission, however, waveforms may be distorted and the S/N deteriorates.



fs : Signal frequency
fc1, fc2 : Carrier frequency
MOD : Modulator
DEM : Demodulator

H : Hybrid circuit
N : Balancing network
BPF : Band pass filter
LPF : Low pass filter

Fig. A-23 FDM and Frequency offset

FDM

FDM stands for Frequency Division Multiplex.

This is a multiplex system in which the available transmission bandwidth of a transmission line is divided by frequency into narrow bands. By this method, carrier waves of differing frequencies are modulated on the signal wave, and their single sidebands are arranged along the frequency axis.

There is another multiplex method TDM (Time Division Multiplex) in which one transmission line is used alternately for time sharing.

(8) Phase jitter

"Phase jitter" presents the fluctuation of the signal phase. Phase jitter occurs when the signal is modulated with phase modulation (PM) or frequency modulation (FM) by some cause.

Phase jitter does not cause any special problems in telephone conversations. In G3 facsimile transmission, however, lines may be missed.

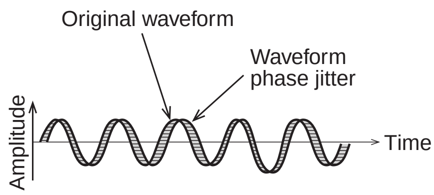


Fig. A-24 Phase Jitter

7.2 Unusual Factors

(1) Impulse noise

"Impulse noise" is the irregular noise that occurs because of the contact points at an exchange.

This noise is easily generated by step-by-step exchange that operate by mechanical contacts.

Impulse noise is no problem in telephone conversations, except that it can be a little offensive to the human ear when it occurs. In G3 facsimile transmission, however, the same image defects that occur with white noise and level variation occur.

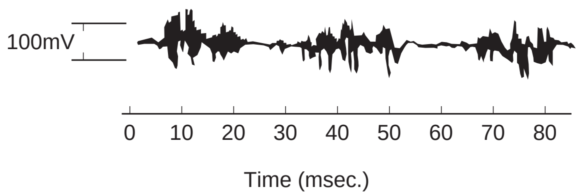


Fig. A-25 Impulse Noise Caused by a Step-By-Step Exchange

(2) Short breaks

A "short break" is a sudden drop in the reception signal level of 6 dB or more for 1 msec to 60 sec continuous. Short breaks are caused by fading in microwave radio ralay and satellite communications system zones or by faulty contacts on equipment and cables.

Short breaks do not cause any special problems in telephone conversations as long as the break is not continuous. However, in G3 facsimile transmission, the same phenomenon as in level variation and impulse noise occur significantly.

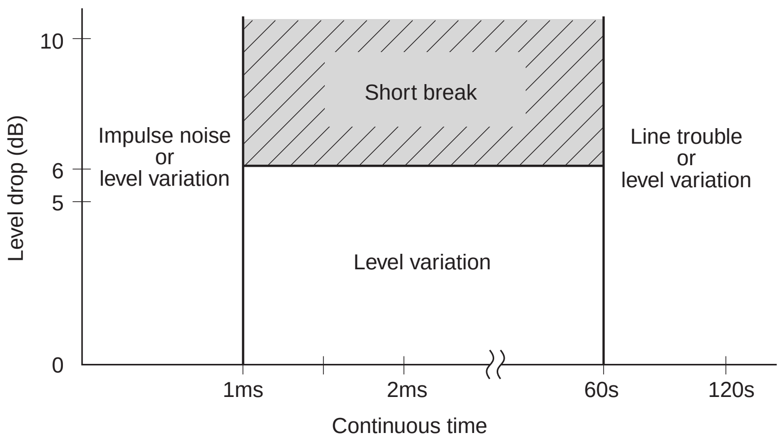


Fig. A-26 Short Break Area

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(3) Phase hit

"Phase hit" is the sudden phase fluctuation caused by fading on carrier equipment and on microwave transmission zones, or by the switching of the transmission line on a multiplex transmission line.

Phase hit does not cause any special problems in telephone conversations. However, in G3 facsimile transmission, the same phenomenon as in phase jitter occur significantly.

7.3 Echo

"Echo" is the phenomenon where one's own voice is reflected at the other party and returns after a certain time to be heard.

Echo mainly occurs in international communications.

7.3.1 Causes of echo

Generally, some of the power in electrical signals is reflected between the line and load (such as the exchange), between lines of differing characteristics impedance, and in hybrid circuits (see figure Fig. A-29 for details of a 2-wire/4-wire conversion circuit). It is very difficult to eliminate this reflection. This difference in characteristic impedances is sometimes called "impedance mismatching."

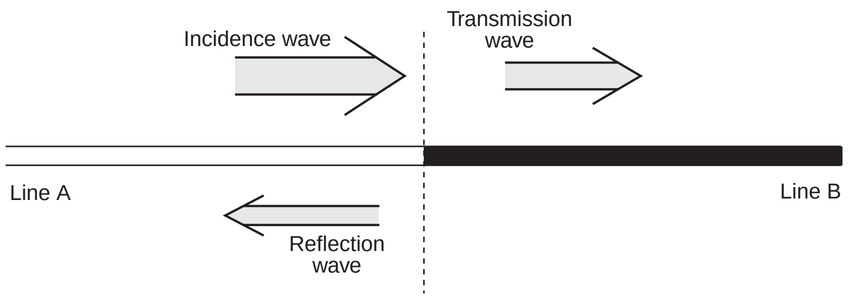

Fig. A-27 Reflection of Signal Energy

Communication satellites and submarine cables are used as the transmission lines in international communications.

Since communications satellites are in stationary orbit at a height of 35,800 km over the equator, the one-way distance extends about 100,000 km. Submarine cables are shorter than that, though the distance still reaches several thousands of kilometers.

Due to these distances, the propagation delay time will be 0.3 sec and 0.1 sec, respectively, even at the speed of electric current or radio waves (approx. 300,000 km per second). Because of this signal propagation delay

time, such phenomenon occur. That is, one's own voice is reflected at the other party, and is heard after 0.6 sec and 0.2 sec, respectively.
The time for the echo to return may reach 1.2 sec in the case of satellite communications.

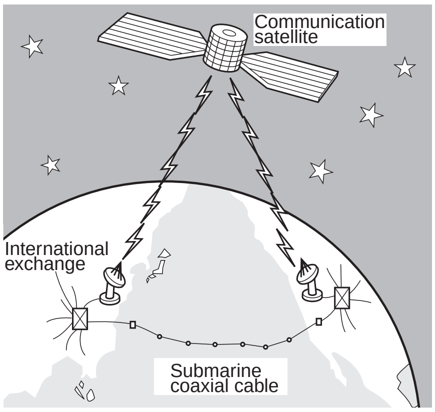

Fig. A-28 Transmission Lines for International Communications

7.3.2 Echo control devices on telephone line networks

(1) Echo suppressor (Standardized in ITU-T G.164)

Since echo is annoying to the person making the telephone call, a device called an "echo suppressor" is attached on international telephone lines and domestic long-distance transmission lines where delay exceeds 45 msec. Echo suppressors are equipped with special switches for eliminating voice signals that are reflected on the other party while the speaker is still talking. Each suppressors are equipped on each channel. The Fig. A-29 shows the operation of switches when the voice of the speaker on the right reaches the other party on the left.

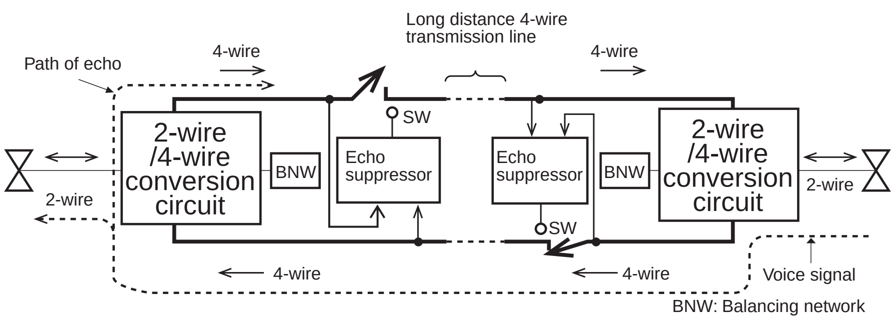

Fig. A-29 Echo Suppressor

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(2) Echo suppressor disabler (Standardized in ITU-T G.164)

Problems may arise with the echo suppresor which is necessary for general telephone calls when carrying out data communication using the full-duplex system. For this reason, a device called a “disabler” for disabling the echo suppressor is built into the echo suppressor.

A disabler turns of the echo suppressor by a tone (echo suppressor disable tone) of 2100±21 Hz that lasts for 300±100msec or longer so that echo occurs.

The echo suppressor is turned back on when a no-signal state lasts for 100 msec or more.

The CED that appears at the start of the facsimile procedure disables the echo suppressor functions as its frequency is 2100 Hz. This causes echo to occur as shown in the Fig. A-30. Since this causes an inconvenience in facsimile transmission, adopt countermeasures described in this chapter, 7.3.3 Echo countermeasures.

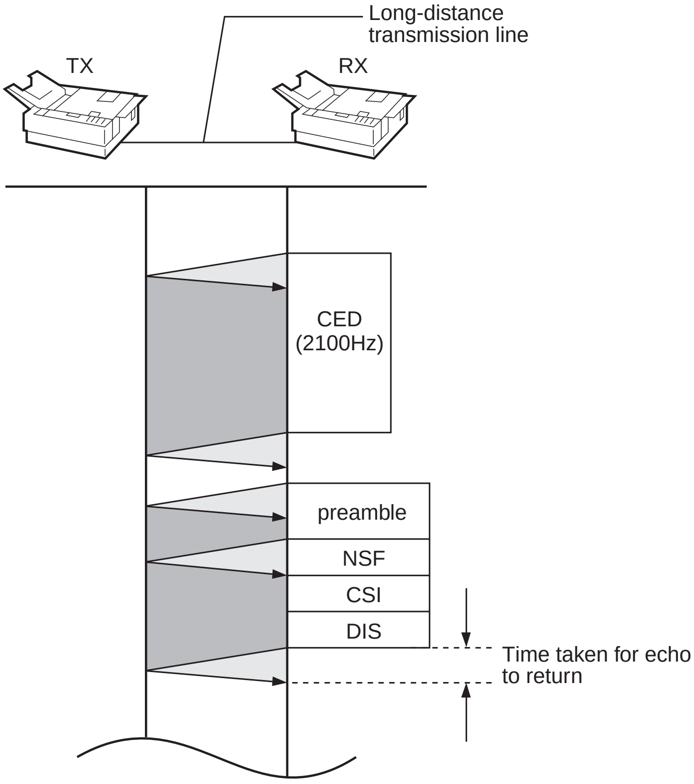

Fig. A-30 Example of Echo Occurrence by Echo Suppressor Disabler

(3) Echo Canceller (Standardized in ITU-T G.165)

If the signal propagation delay time were not too long, if the echo return loss was not too low, and if the speakers would not frequently interrupt each other, then an echo suppressor would be sufficient. However, the echo return loss varies considerably from connection to connection. The echo canceller has been made using advances in digital circuit technology to provide satisfactory service under such adverse conditions.

As shown in the Fig. A-31, an echo canceller contains complex signal processing circuits. These circuits compare the signals in both directions of the transmission line and synthesize a replica of the echo, and subtract that from the actual echo. Equipped on every 120 telephone lines, echo cancellers completely eliminate echo while allowing telephone conversations to pass through unimpaired, thus allowing full duplex transmission.

Though the performance of echo cancellers is superior to that of echo suppressors, echo cancellers are more complex and expensive. The percentage of equipment on which echo cancellers are equipped is increasing. Currently, echo cancellers are equipped on 100% of equipment in the USA and Japan.

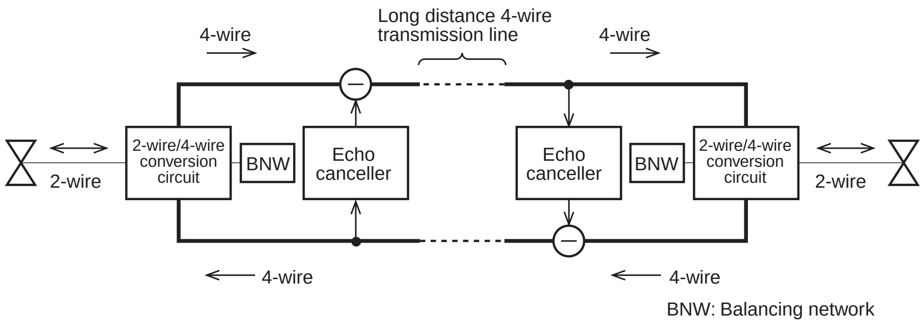

Fig. A-31 Echo Canceller

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Return Loss

NOTE

"Return loss" is a ratio expressed in decibels (dB) of how much reflected power that occurs due to impedance mismatching attenuates with respect to the incidence power. In the following formula, the amount of attenuation caused by mismatching of two impedances Z1 and Z2 is calculated. Balancing on a hybrid circuit (2-wire/4-wire conversion circuit) is also expressed as return loss.

$$L_R(\text{Return Loss})=10\log_{10}\frac{[\text{Incidence power}]}{[\text{Reflection power}]}[\text{dB}]=20\log_{10}\left|\frac{Z_1+Z_2}{Z_1-Z_2}\right|[\text{dB}]$$

Fig. A-32 Return Loss

7.3.3 Echo countermeasures

The following describes the main countermeasures against echo that are adopted on Canon facsimiles.

(1) Countermeasure on Receiver

Add a tonal signal (1080 Hz, 0.5 sec) before the CED tone (selected by the SSSW).

By adding a tone other than 2100±21 Hz before CED, disabling of the echo suppressor can be prevented.

A tone of 1080 Hz is added on Canon facsimiles.

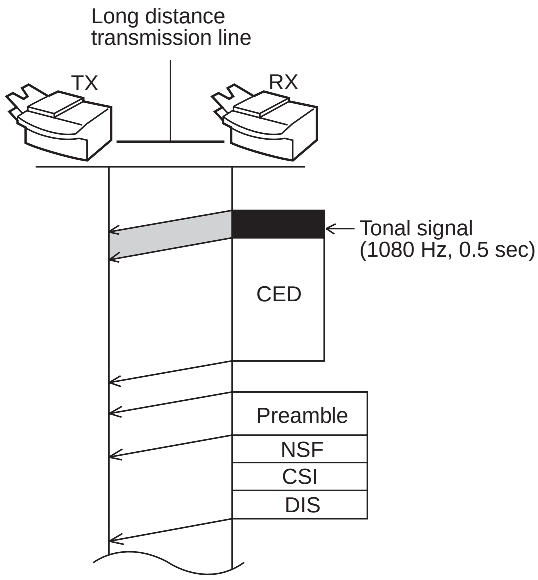


Fig. A-33 Echo Countermeasure on Receiver

(2) Countermeasures on Transmitter

Ignore the first DIS from the called party and respond to the second DIS.

By ignoring the first DIS, a no-signal state lasting for 0.1 sec or more can be created on the telephone line.

This turns the echo suppressor back on, and echo is not generated from then on.

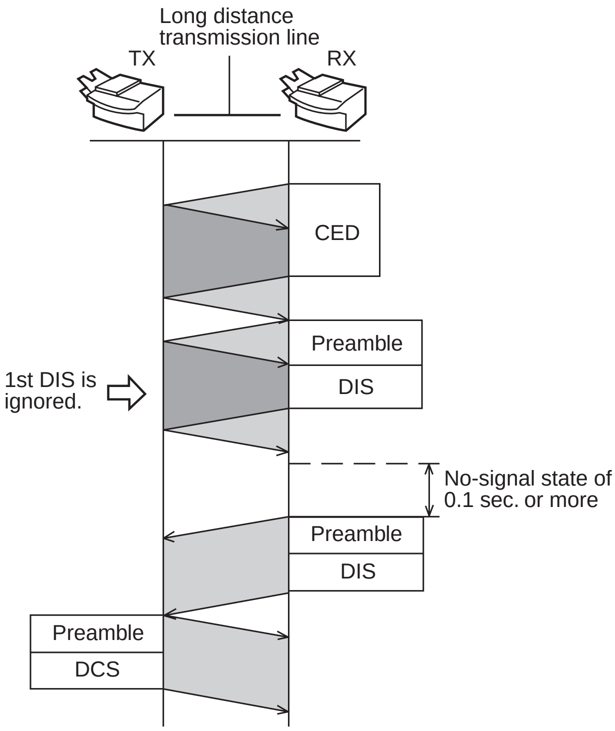


Fig. A-34 Echo Countermeasure on Transmitter

(3) Countermeasures on both transmitter and receiver

After transmitting binary signals, ignore the binary signals from the other party for 0.6 to 0.7 sec. (This function is provided on all Canon facsimiles.)

After transmitting each binary signal, ignore binary signals from the other party for 0.6 to 0.7 sec (differs according to model of facsimile) as shown in the Fig. A-35.

This is because the regular echo delay is within 0.6 sec. By performing this process, the facsimile is not likely to be deceived by its own signals.

Moreover, since the preamble time is 1.0 sec, a preamble of 0.3 to 0.4 sec can be received even in the case of domestic communications with a short propagation delay. This countermeasure does not cause any problems.

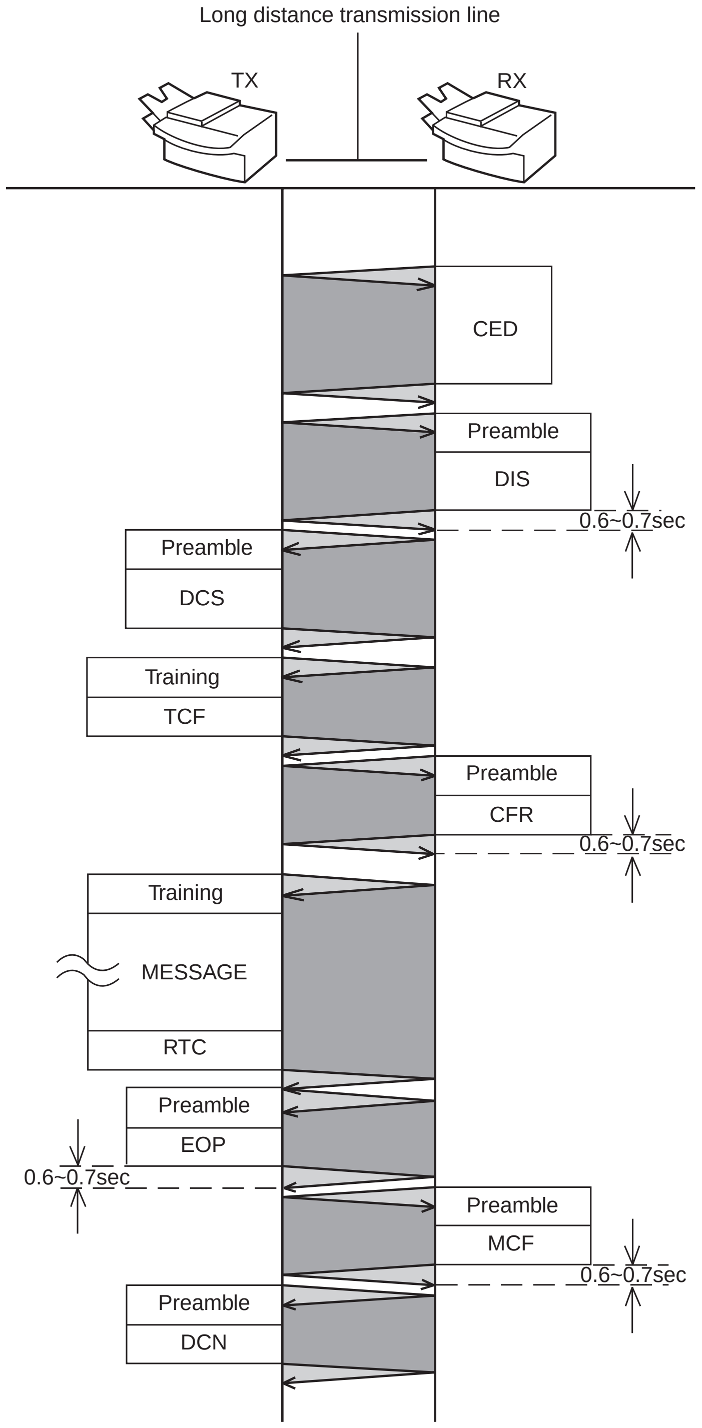
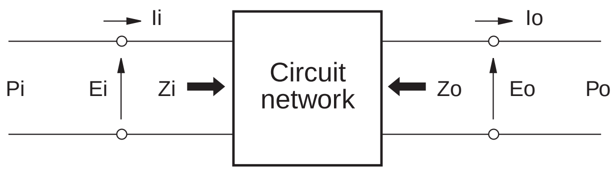


Fig. A-35 Countermeasures on Both Transmitter and Receiver

8. RATIO, dB, dBm & dBV

(1) Ratio and dB

There are two ways of comparing values: by ratio and by dB indication (logarithm indication).



where Pi : Input power
Ei : Input voltage
Ii : Input current
Zi : Input impedance
Po : Output power
Eo : Output voltage
Io : Output current
Zo : Output impedance

Fig. A-36 Input and Output

When the power is compared on a circuit such as the above (Fig. A-36), the ratio becomes

$$\frac{Po}{Pi} \text{ [times]}$$

Take the common logarithm of this ratio and multiple it by 10 times:

$$10 \log_{10} \frac{Po}{Pi} \text{ [dB]}$$

This is called dB (decibel). Transforming the above equation results in the following:

$$10\log_{10} \frac{Eo^2/Zo}{Ei^2/Zi} \text{ [dB]}$$

If the input and output impedance are equal, then the above equation changes as follows:

$$10 \log_{10} \left(\frac{Eo}{Ei}\right)^2 \text{ [dB]} \quad = \quad 20 \log_{10} \frac{Eo}{Ei} \text{ [dB]}$$

The same applies to the current ratio

$$20 \log_{10} \frac{Io}{Ii} \text{ [dB]}$$

When these ratios of power, voltage and current are greater than 1, the dB value is a positive value. When they are smaller, the dB value is a negative value. So, a positive dB value expresses gain while a nagative dB value expresses attenuation.

- Practical dB values

The following advantages are obtained from the logarithmic characteristics.

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- A very wide range of numerical values can be expressed as small numerical values by using dB. Small ratios can also be expressed conveniently.

  Example:

  When the power ratio is 1, 0 dB is used; when 10, 10 dB is used, and when 100, 20 dB is used. Even at 1,000,000, only 60 dB is used. So, a smaller numerical value range is sufficient.
- When expressed as a ratio, the total gain and total attenuation must be calculated by the product of each gain and each attenuation, respectively. Whereas, the calculation is simpler if total gain and total attenuation area expressed as dB. The total gain and total attenuation can be calculated by simply adding each gain and each attenuation, respectively.

(2) dBm

dB described above is based upon the power ratio between the input terminal and the output terminal. In effect, this is a relative indication.

Absolute indication can be achieved provided that the reference for comparison is fixed to a certain value. Generally, the following is supposed:

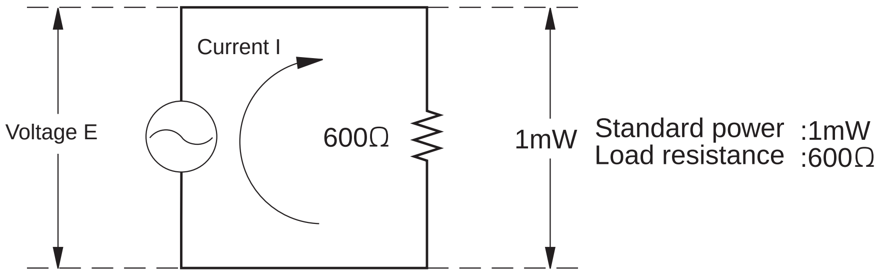

Fig. A-37 Assumption in 600 ohm impedance series

As a result

$$P = \frac{E^2}{R}$$

Therefore

$$E^2 = P \times R$$

$$E = \sqrt{P \times R} = \sqrt{1 \times 10^{-3} \times 600} \fallingdotseq 0.775[V]$$

$$I = \frac{E}{R} \fallingdotseq 1.29[mA]$$

If we assume that 1 mW is taken to be the standard power, then 0.775 V becomes the standard voltage for voltage conversion. The absolute indication is as follows and is expressed in units of dBm.

$$\text{Power} \quad 10 \log_{10} \frac{P}{1mW} \text{ [dBm]}$$

Voltage $20 \log_{10} \frac{E}{0.775V}$ [dBm] (where impedance of the measurement point is 600 ohm)

Let's look at how dB and dBm are actually used. As shown in the Fig. A-38, if we assume the presence of attenuation on the transmission line and the exchange, then the signal that is transmitted from the transmitter at a level of -13 dBm becomes -27.5 dBm at the receiver.

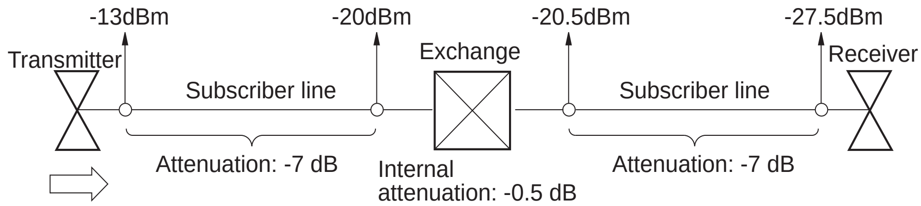

Fig. A-38 How dB and dBm are used

For reference, Table A-2 shows the conversion table for ratio and dB.
Table A-3 shows the conversion table for dBm and power/voltage on a 600 ohm impedance system.

Table A-2 Conversion Table for Ratio and dB

dB	Power	Voltage
+20	100.0	10.0
+10	10.0	3.2
0	1.0	1.0
-10	0.1	0.3
-20	0.01	0.1

Table A-3 Conversion Table for dBm and Power/Voltage on a 600 ohm Impedance System

dBm	Power	Voltage
0	1.0mW	0.775V
-10	0.1	0.245
-20	0.01	0.0775
-30	0.001	0.0245
-40	0.0001	0.00775

(3) dBV

dBV is the absolute indication of the voltage when the standard voltage is taken to 1 V. If the voltage of the measurement point is taken to be E V, then dBV is defined in the following equation:

$$20 \log_{10} \frac{E}{1} \text{ [dBV]}$$

The dBm indication of the voltage on a 600 ohm impedance system is described as:

$$20 \log_{10} \frac{E}{0.775} \text{ [dBm]}$$

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Here, let us try calculating the relationship between dBm indication and dBV indication:

$$20 \log_{10} \frac{E}{0.775} - 20 \log_{10} \frac{E}{1}$$

$$= 20 \left(\log_{10} \frac{E}{0.775} - \log_{10} E\right)$$

$$= 20 \log_{10} \left(\frac{E}{0.775} \times \frac{1}{E}\right) = 20 \log_{10} \frac{1}{0.775}$$

That is, if we added 2.2 dB to the value of the dBV indication, the result is the dBm indication.

$$\text{dBm} \fallingdotseq \text{dBV} + 2.2\text{dB}$$

9. BINARY SIGNALS TABLE

Table A-4 Signal Table

	Abbreviation (* indicates option.)	Function	Format (B: binary signal, T: tonal signal) On facsimile that first receives DIS X=0 On opposite facsimile X=1
Signals transmitted by transmitter	CNG	Calling Tone	T: 1100 Hz
	DCS	Digital Command Signal	B: FCF1=X100 0001
	EOM	End of Message	B: FCF1=X111 0001
	EOP	End of Procedure	B: FCF1=X111 0100
	MPS	Multiple-Page Signal	B: FCF1=X111 0010
	NSS*	Non-Standard Facilities Setup	B: FCF1=X100 0100
	PRI-EOM*	Procedure Interrupt - End of Message	B: FCF1=X111 1001
	PRI-EOP*	Procedure Interrupt - End of Procedure	B: FCF1=X111 1100
	PRI-MPS*	Procedure Interrupt - Multiple-Page Signal	B: FCF1=X111 1010
	TCF	Training Check	“0” continuous for 1.5 seconds
	TSI*	Transmitting Subscriber Identification	B: FCF1=X100 0010
	PWD*	Password	B: FCF1=1000 0011
	SEP*	Selective Polling Address	B: FCF1=1000 0101

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Table A-4 Signal Table

	Abbreviation (* indicates option.)	Function	Format (B: binary signal, T: tonal signal) On facsimile that first receives DIS X=0 On opposite facsimile X=1
Signals transmitted by receiver	CED*	Called Station Identification	T: 2100 Hz
	CFR	Confirmation to Receive	B: FCF1=X010 0001
	CIG*	Calling Subscriber Identification	B: FCF1=1000 0010
	CSI*	Called Subscriber Identification	B: FCF1=0000 0010
	DIS	Digital Identification Signal	B: FCF1=0000 0001
	DTC	Digital Transmit Command	B: FCF1=1000 0001
	FTT	Failure to Train	B: FCF1=X010 0010
	MCF	Message Confirmation	B: FCF1=X011 0001
	NSC*	Non-Standard Facilities Command	B: FCF1=1000 0100
	NSF*	Non-Standard Facilities	B: FCF1=0000 0100
	PIN	Procedure Interrupt Negative	B: FCF1=X011 0100
	PIP	Procedure Interrupt Positive	B: FCF1=X011 0101
	RTN	Retrain Negative	B: FCF1=X011 0010
	RTP	Retrain Positive	B: FCF1=X011 0011
	SUB*	Subaddress:	B: FCF1=X100 0011
	PWD*	Password:	B: FCF1=X100 0101
Common signals	CRP*	Command Repeat	B: FCF1=X101 1000
	DCN	Disconnect	B: FCF1=X101 1111
Image signals	EOL	End Of Line	B: 0000 0000 0001 (=001H)
	RTC	Return To Control:	6 continuous EOLs
	RCP	Return To Control for Partial page:	For details of HDLC Configuration, see page 5-108 6.8.2 Structure of binary coded information.

Table A-4 Signal Table

	Abbreviation (* indicates option.)	Function	Format (B: binary signal, T: tonal signal) On facsimile that first receives DIS X=0 On opposite facsimile X=1
Error correction mode (ECM) exclusive signals	CTC	Continue To Correct:	B: FCF1=X100 1000
	CTR	Response to Continue to Correct:	B: FCF1=X010 0011
	EOR	End of Retransmission EOR-NULL EOR-EOM EOR-MPS EOR-EOP EOR-PRI-EOM EOR-PRI-MPS EOR-PRI-EOP	B: FCF1=X111 0011 FCF2=0000 0000 FCF2=1111 0001 FCF2=1111 0010 FCF2=1111 0100 FCF2=1111 1001 FCF2=1111 1010 FCF2=1111 1100
	ERR	Response to End Of Retransmission	B: FCF1=X011 1000
	PPR	Partial Page Request	B: FCF1=X011 1101
	PPS	Partial Page Signal PPS-NULL PPS-EOM PPS-MPS PPS-EOP PPS-PRI-EOM PPS-PRI-MPS PPS-PRI-EOP	B: FCF1=X111 1101 FCF2=0000 0000 FCF2=1111 0001 FCF2=1111 0010 FCF2=1111 0100 FCF2=1111 1001 FCF2=1111 1010 FCF2=1111 1100
	RNR	Receive Not Ready	B: FCF1=X011 0111
	RR	Receive Ready	B: FCF1=X111 0110

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10.MAKER CODES TABLE

Maker codes are included in the NSS/NSF/NSC signals of the FIF. While each maker is indicated within the three bytes of the FIF, when the third byte is 00, the maker is indicated in the fourth byte. The codes included in the maker code are indicated as shown below.

Table A-5 Maker Codes

Hexadecimal	Binary		Company Name
00 01	0000 0000	0000 0001	KANDA TSUSHIN KOGYO
00 03	0000 0000	0000 0011	TOHOKU PIONEER
00 04	0000 0000	0000 0100	YGREC SYSTEMS
00 05	0000 0000	0000 0101	NAKAJIMA ALL
00 06	0000 0000	0000 0110	JRC
00 07	0000 0000	0000 0111	
00 08	0000 0000	0000 1000	FUNAI
00 09	0000 0000	0000 1001	ALTECH
00 0A	0000 0000	0000 1010	ORION ELECTRIC
00 0B	0000 0000	0000 1011	USC
00 0C	0000 0000	0000 1100	JBS
00 0D	0000 0000	0000 1101	MINOLTA
00 0E	0000 0000	0000 1110	KYOCERA
40 **	0100 0000	**** ****	NTT
50 **	0101 0000	**** ****	KDD
60 **	0110 0000	**** ****	MASTER NET
62 **	0110 0010	**** ****	PHOENIX
64 **	0110 0100	**** ****	KONICA
66 **	0110 0110	**** ****	MITA
6A **	0110 1010	**** ****	BROTHER
6C **	0110 1100	**** ****	TELECOMET
6E **	0110 1110	**** ****	ADVANCE
70 **	0111 0000	**** ****	KYUSHU MATSUSHITA ELECTRIC
80 **	1000 0000	**** ****	ANRITSU
82 **	1000 0010	**** ****	IWATSU ELECTRIC
84 **	1000 0100	**** ****	OKI
86 **	1000 0110	**** ****	CASIO

Table A-5 Maker Codes

Hexadecimal	Binary		Company Name
88 **	1000 1000	**** ****	CANON
8A **	1000 1010	**** ****	SANYO
8C **	1000 1100	**** ****	SHARP
8E **	1000 1110	**** ****	TAMURA
90 **	1001 0000	**** ****	TOSHIBA
92 **	1001 0010	**** ****	NEC
94 **	1001 0100	**** ****	JRC
96 **	1001 0110	**** ****	HITACHI
98 **	1001 1000	**** ****	FUJIXEROX
9A **	1001 1010	**** ****	FUJITSU
9D **	1001 1101	**** ****	MATSUSHITA ELECTRIC
9E **	1001 1110	**** ****	PANASONIC MATSUSHITA
A0 **	1010 0000	**** ****	MITSUBISHI
A2 **	1010 0010	**** ****	MURATA
A4 **	1010 0100	**** ****	RICOH
A6 **	1010 0110	**** ****	OMRON
A8 **	1010 1000	**** ****	TOYOCOM
AA **	1010 1010	**** ****	NITSUKO
AD **	1010 1101	**** ****	MATSUSHITA COMMUNICATION
AE **	1010 1110	**** ****	TEC
B0 **	1011 0000	**** ****	LOGIC SYSTEM INTER.
B2 **	1011 0010	**** ****	OHKURA ELECTRIC
B4 **	1011 0100	**** ****	SONY
B6 **	1011 0110	**** ****	HITACHI TELECOM TECH.
B8 **	1011 1000	**** ****	HITACHI SOFTWARE
BA **	1011 1010	**** ****	KUONI
BC **	1011 1100	**** ****	IBM JAPAN
BE **	1011 1110	**** ****	SILVER SEIKO

11.STANDARD DOCUMENT SIZES

Table A-6 and Table A-7 shows ISO standard document sizes.

Table A-6　ISO A-series Document Sizes

	Size (mm x mm)	Remarks
A0	841×1189	
A1	594×841	Size of an opened out newspaper
A2	420×594	
A3	297×420	
A4	210×297	
A5	148×210	
A6	105×148	

Table A-7　ISO B-series Document Sizes

	Size (mm x mm)	Remarks
B0	1030×1456	
B1	728×1030	
B2	515×728	
B3	364×515	
B4	257×364	
B5	182×257	
B6	128×182	

The table below shows the standard document sizes widely used in North America.

Table A-8　Standard Document Sizes Widely Used in North America

Name	Size (inches)	Size (mm)	Remarks
Letter	8½×11	216×279	
Legal	8½×14	216×356	
Ledger	11×17	279×432	Double letter size

12.G3 FACSIMILE TRANSMISSION CONTROL PROCEDURES

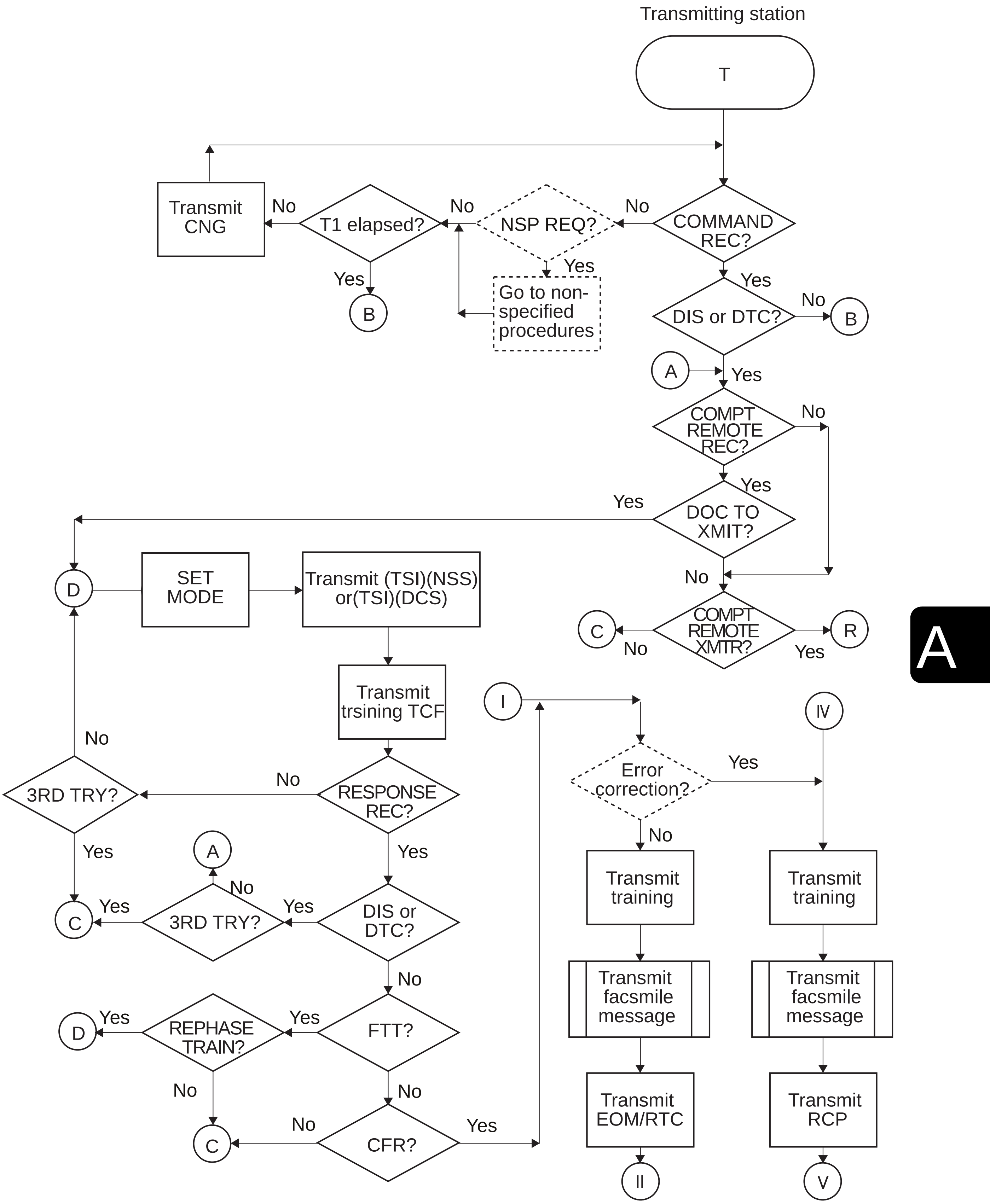


Fig. A-39 Transmitting Station Procedure 1

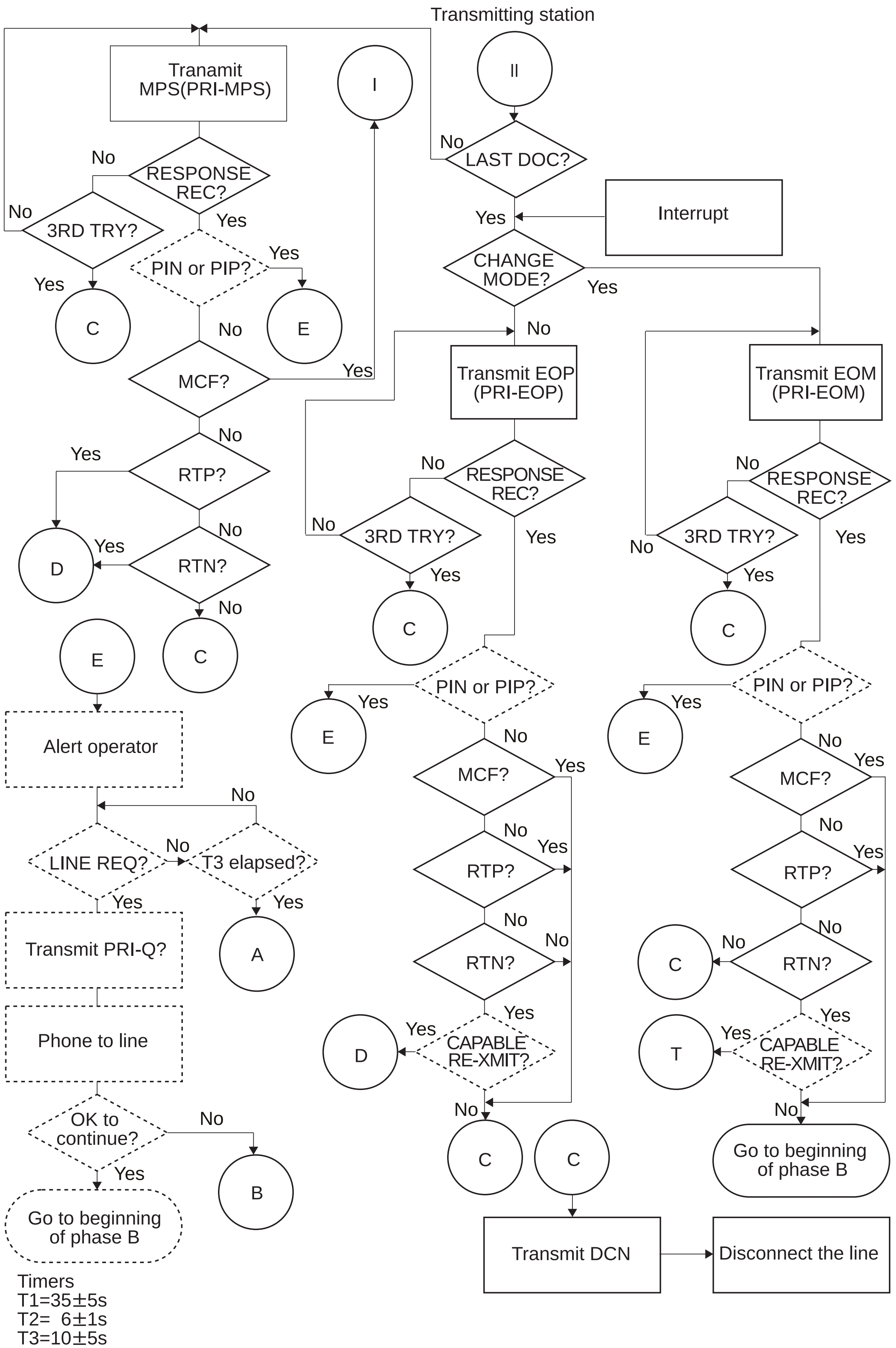


Fig. A-40 Transmitting Station Procedure 2

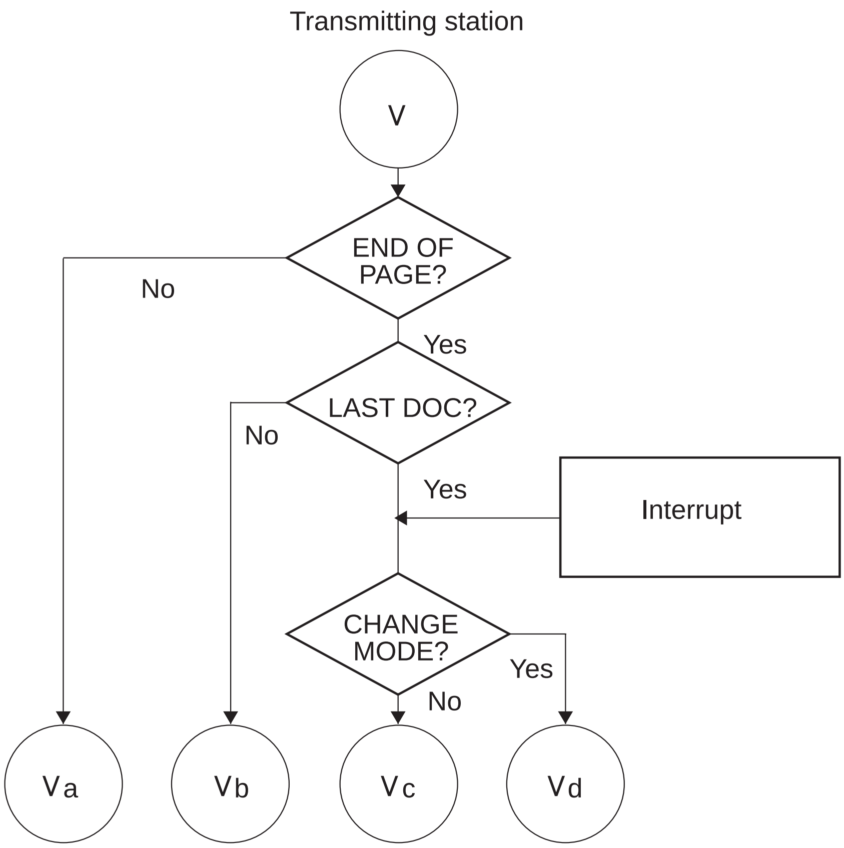


Fig. A-41 Transmitting Station Procedure 3

A

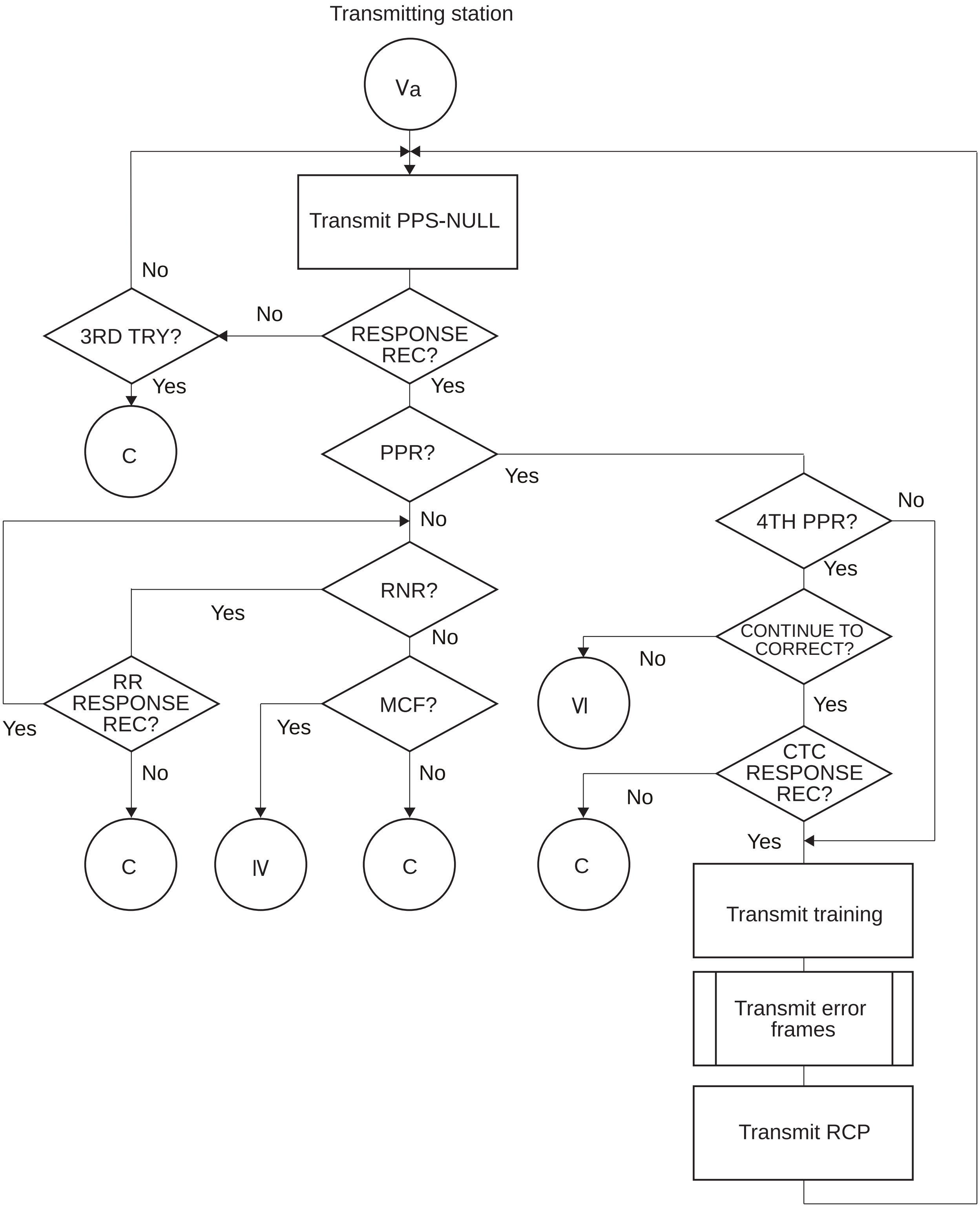


Fig. A-42 Transmitting Station Procedure 4

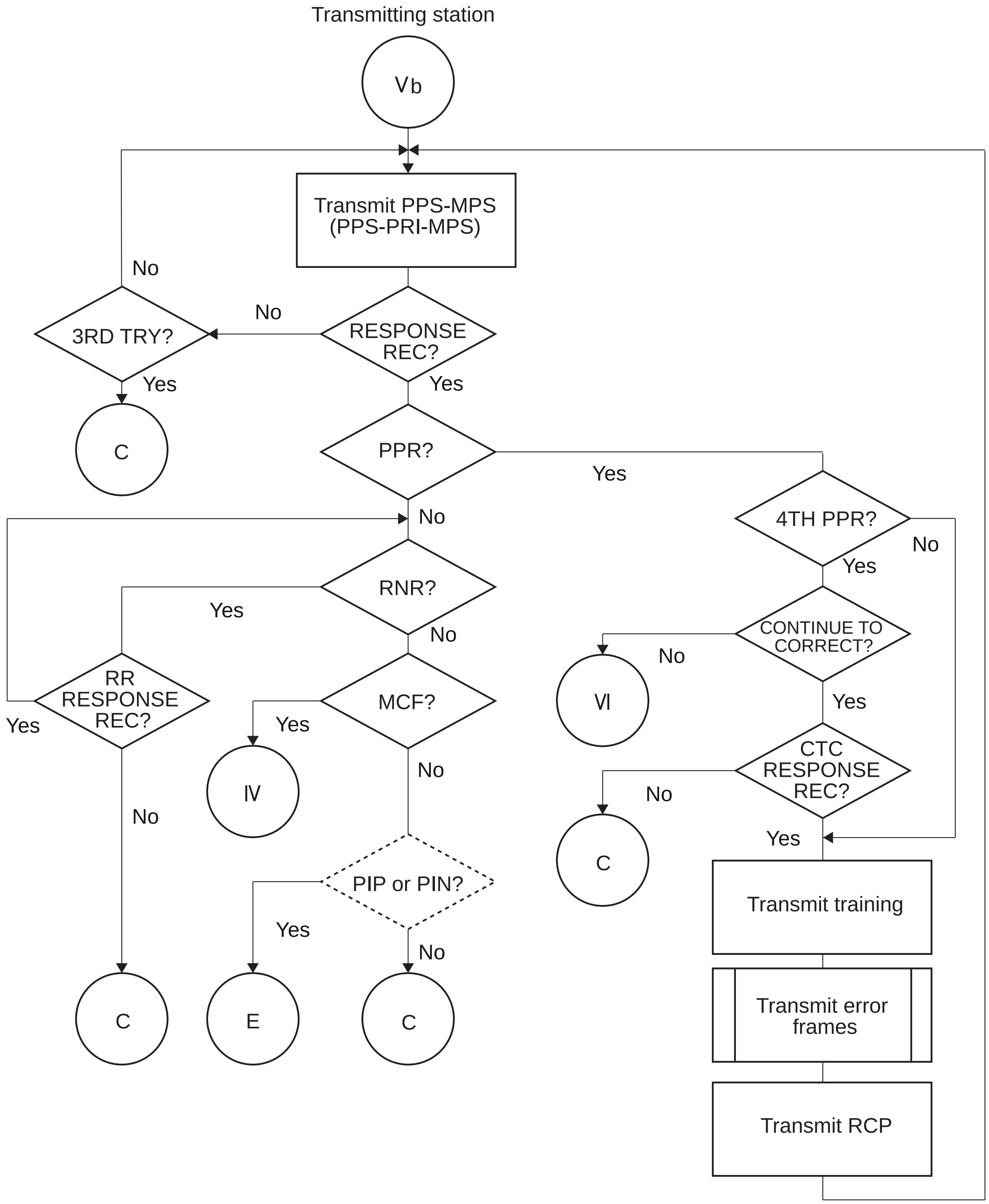


Fig. A-43 Transmitting Station Procedure 5

A

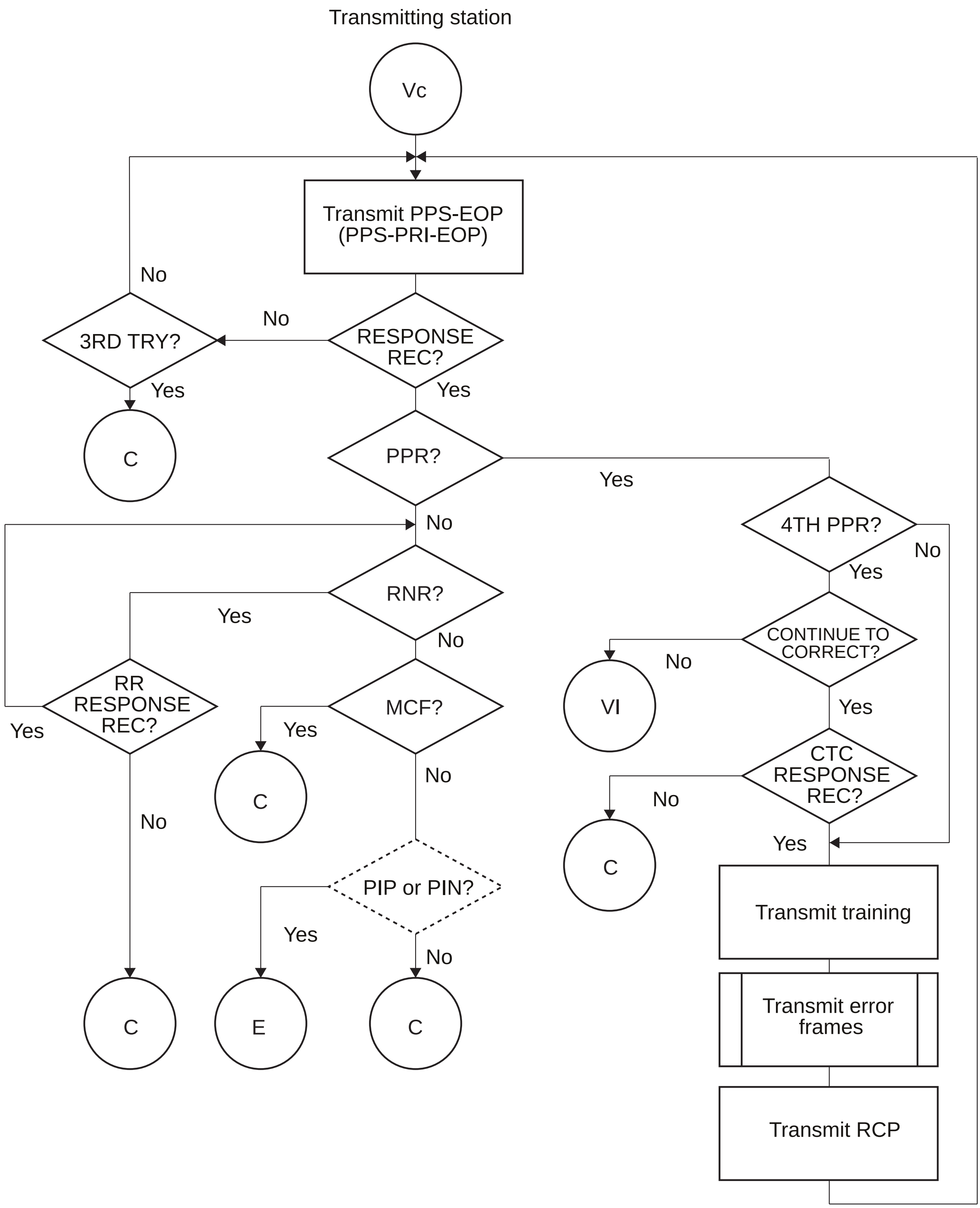


Fig. A-44 Transmitting Station Procedure 6

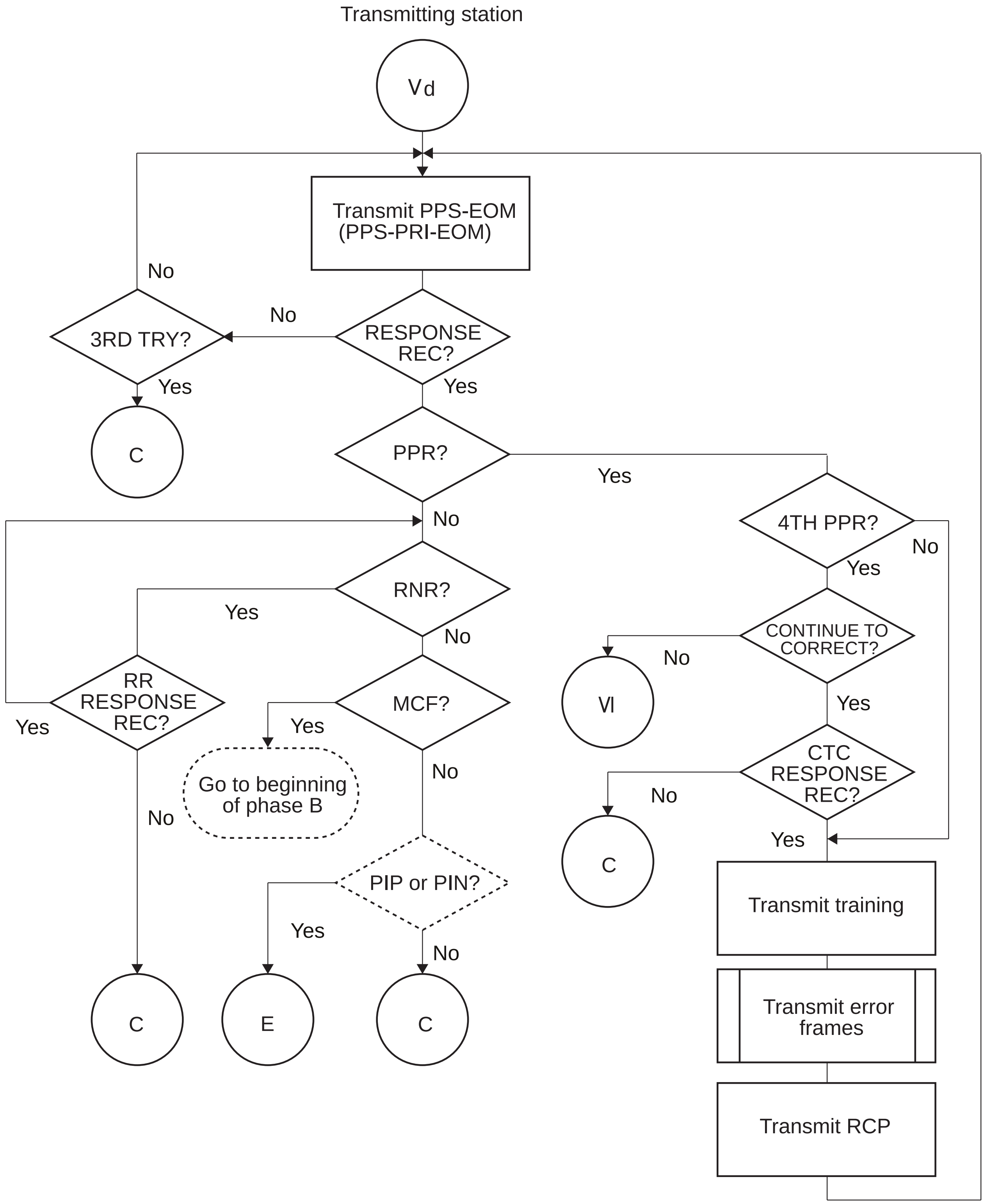


Fig. A-45 Transmitting Station Procedure 7

A

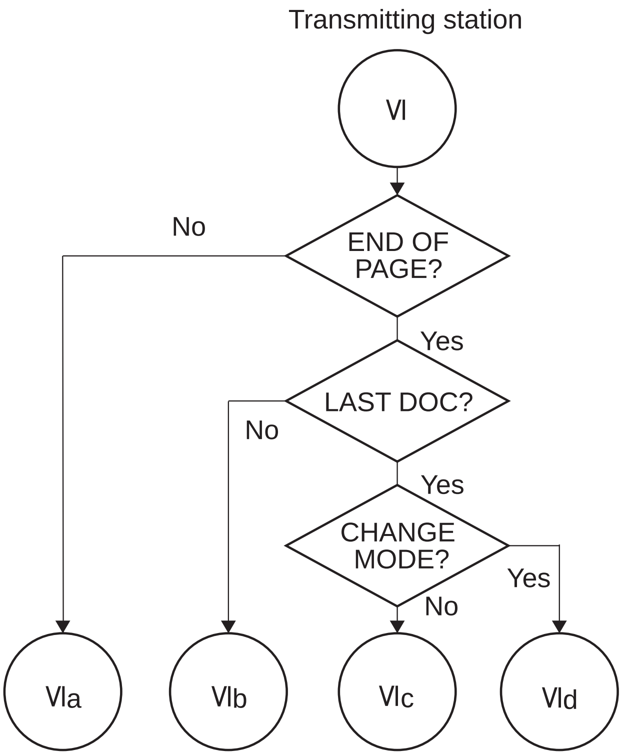


Fig. A-46 Transmitting Station Procedure 8

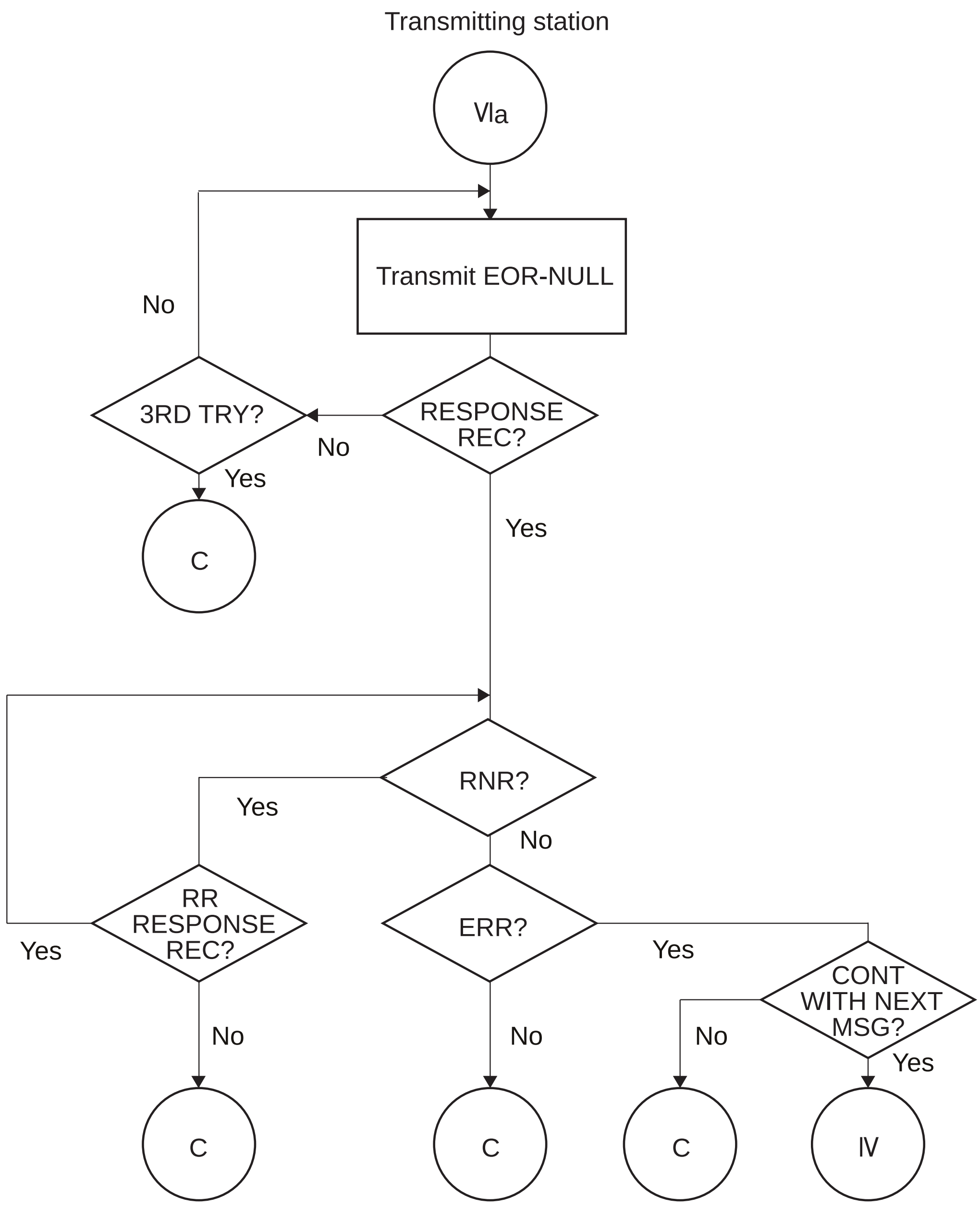


Fig. A-47   Transmitting Station Procedure 9

A

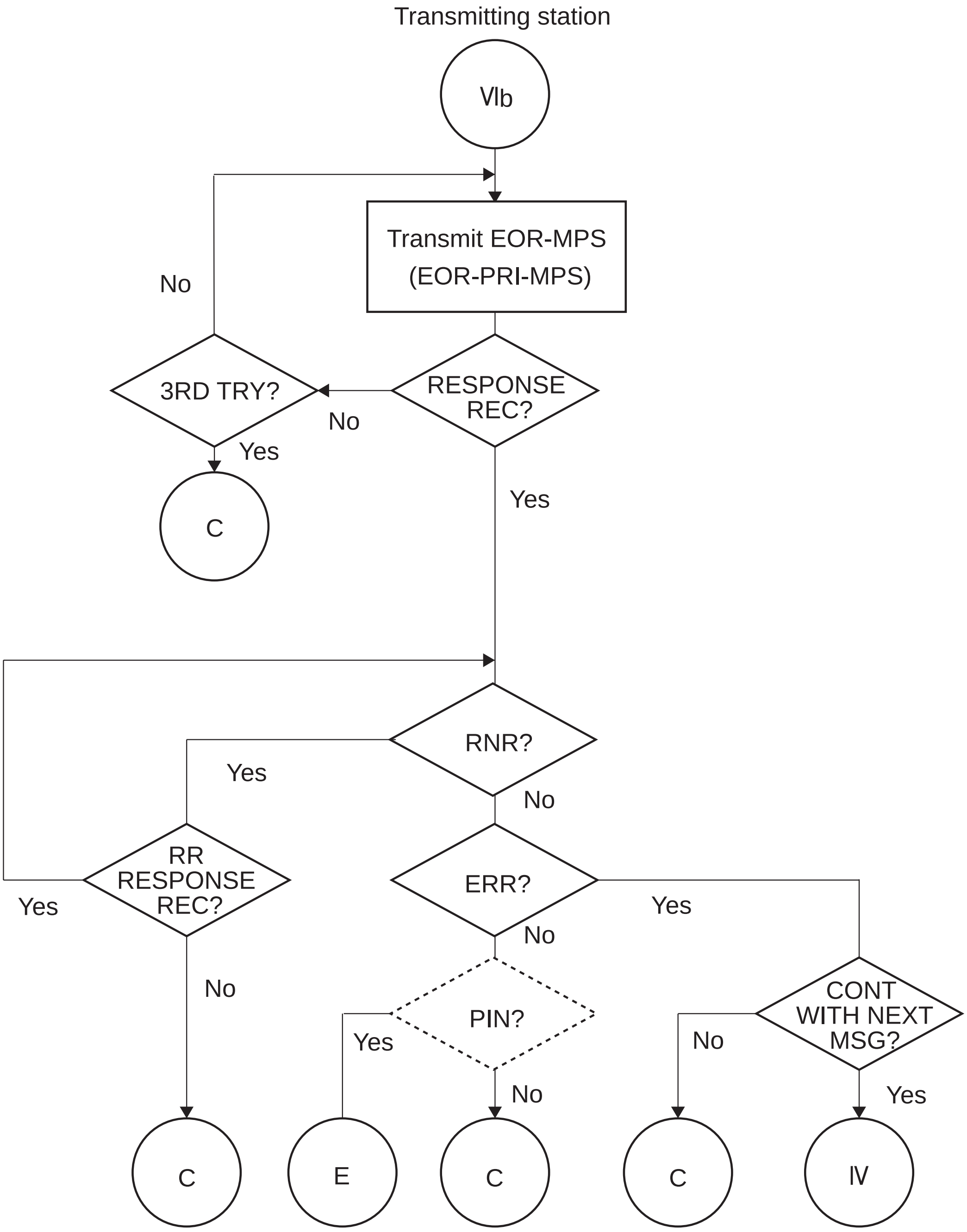


Fig. A-48 Transmitting Station Procedure 10

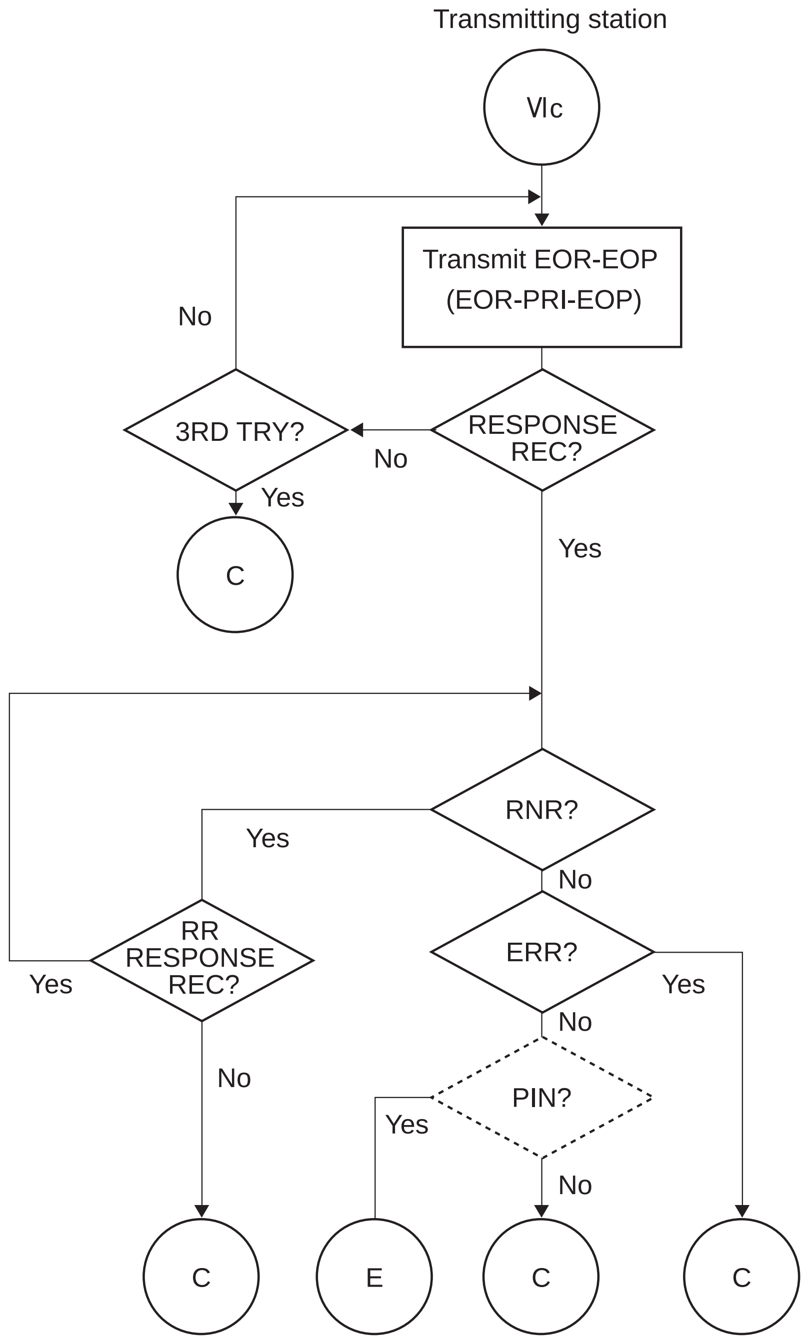


Fig. A-49 Transmitting Station Procedure 11

A

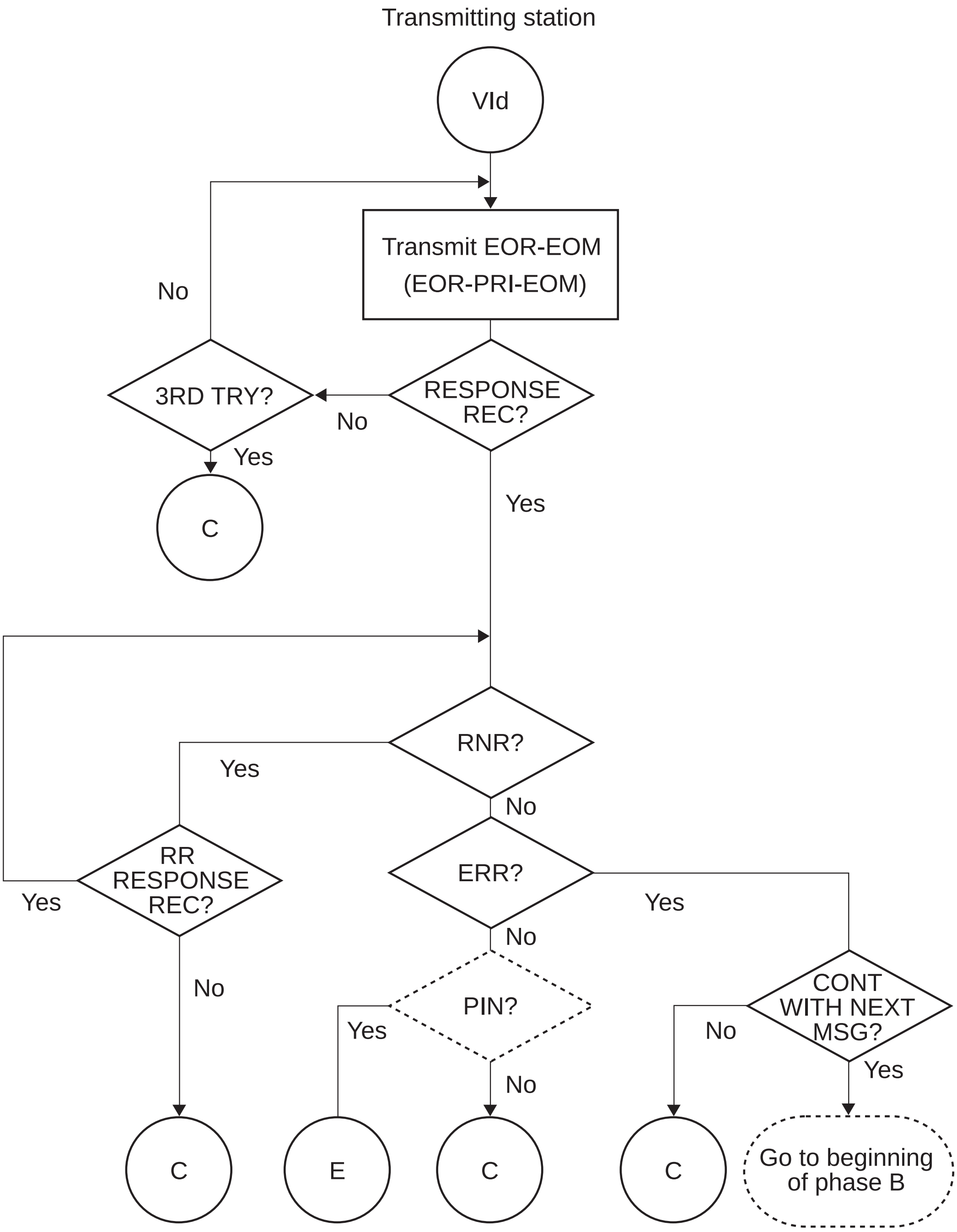


Fig. A-50 Transmitting Station Procedure 12

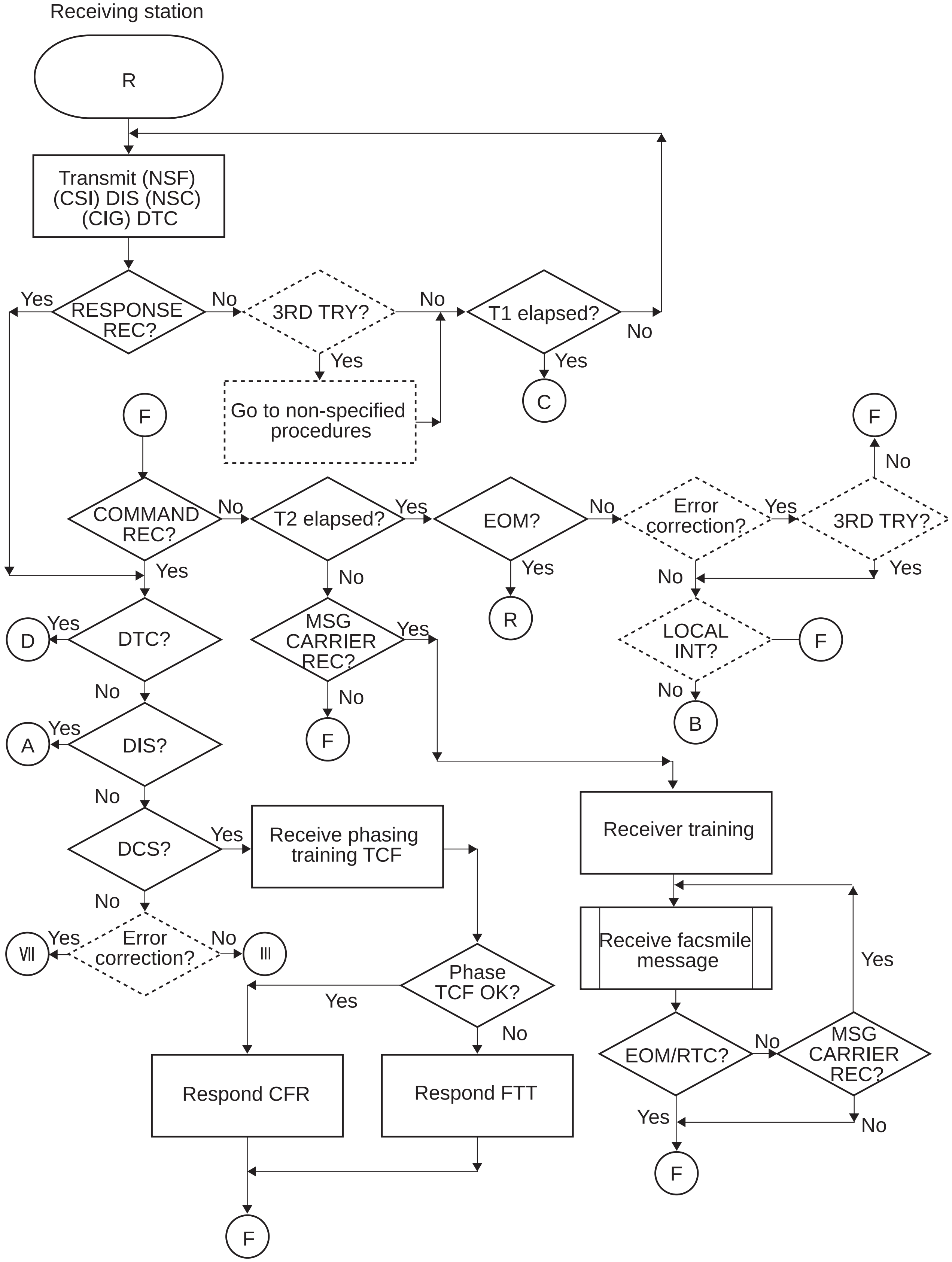


Fig. A-51 Receiving Station Procedure 1

A

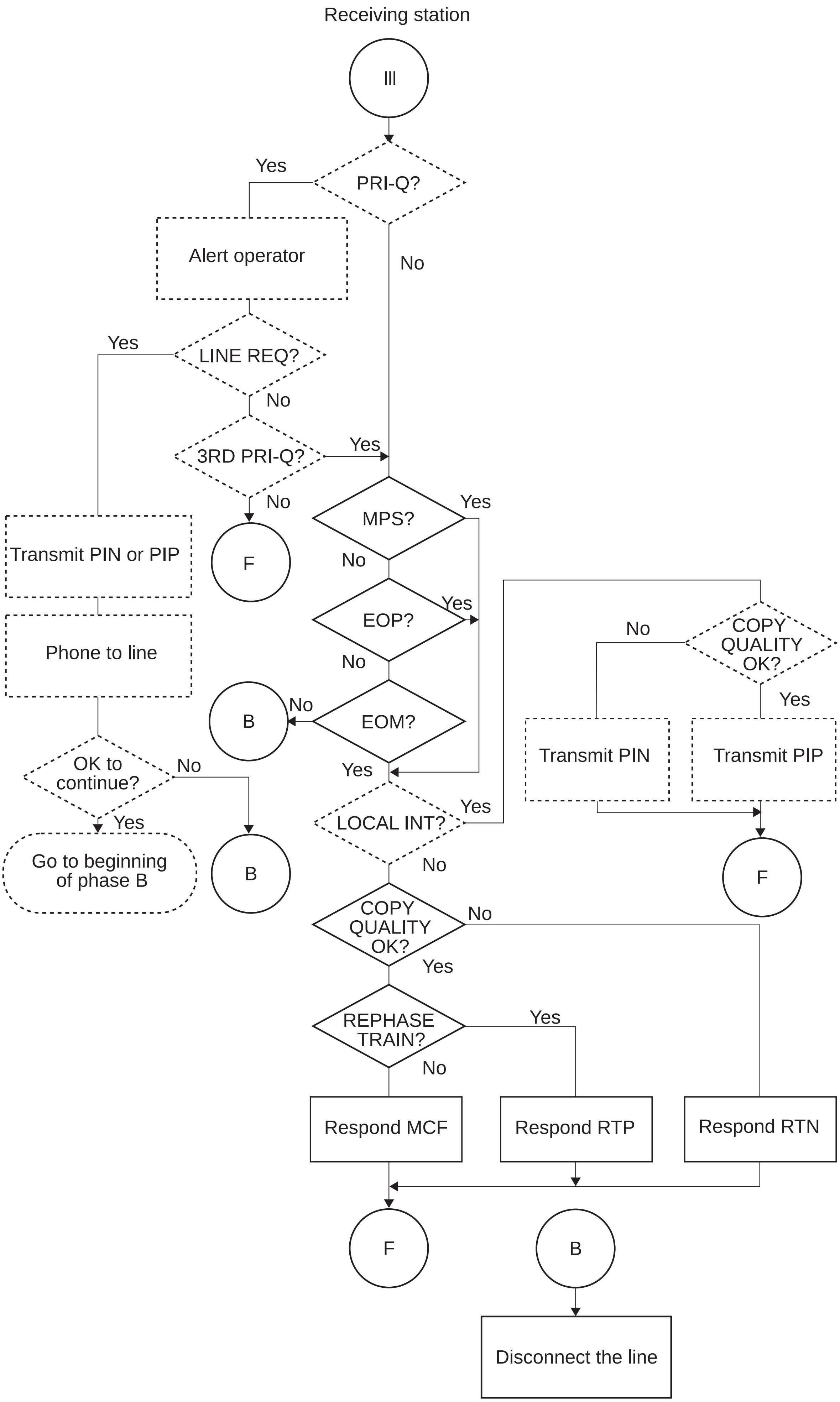


Fig. A-52 Receiving Station Procedure 2

Receiving station

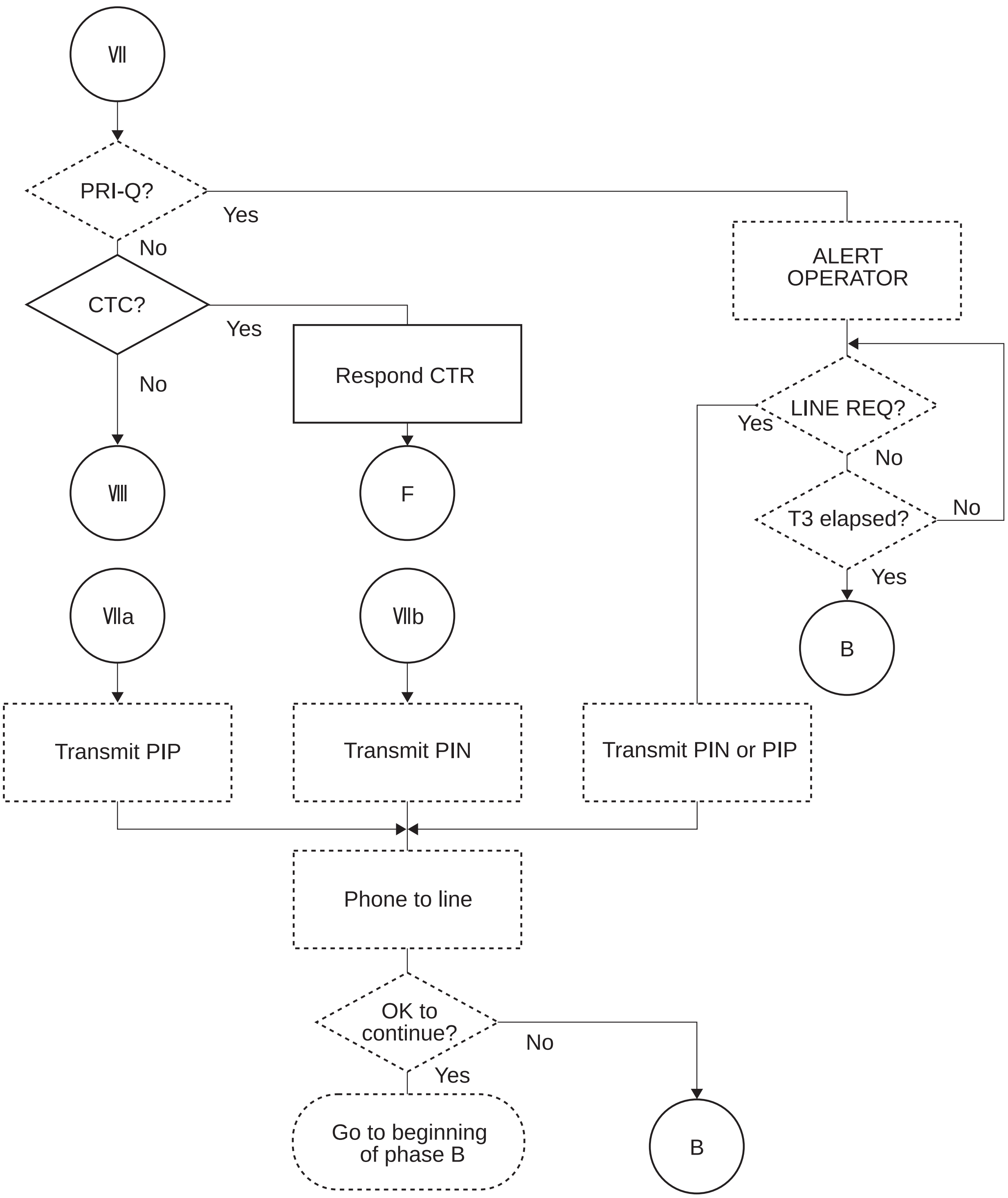


Fig. A-53 Receiving Station Procedure 3

A

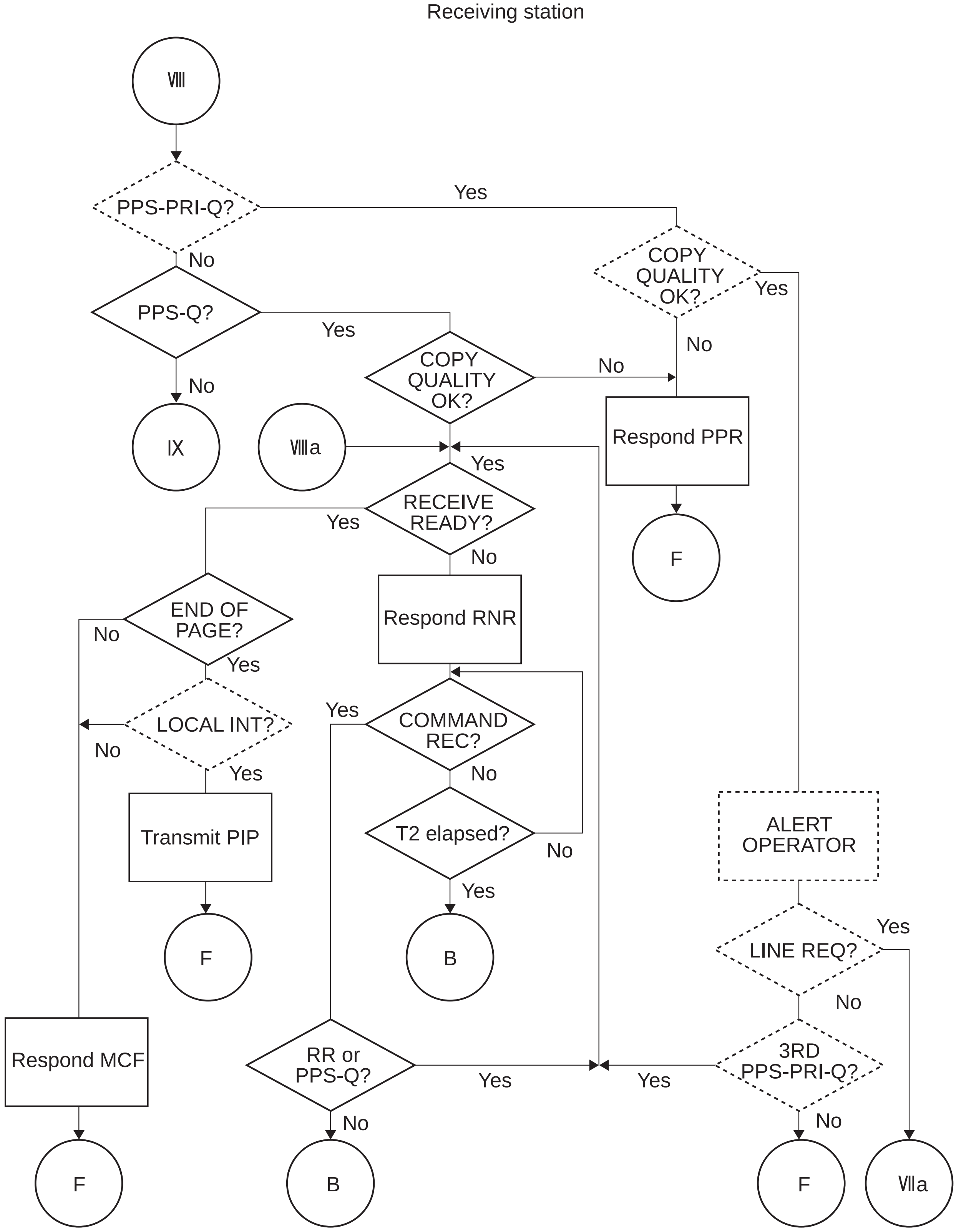


Fig. A-54 Receiving Station Procedure 4

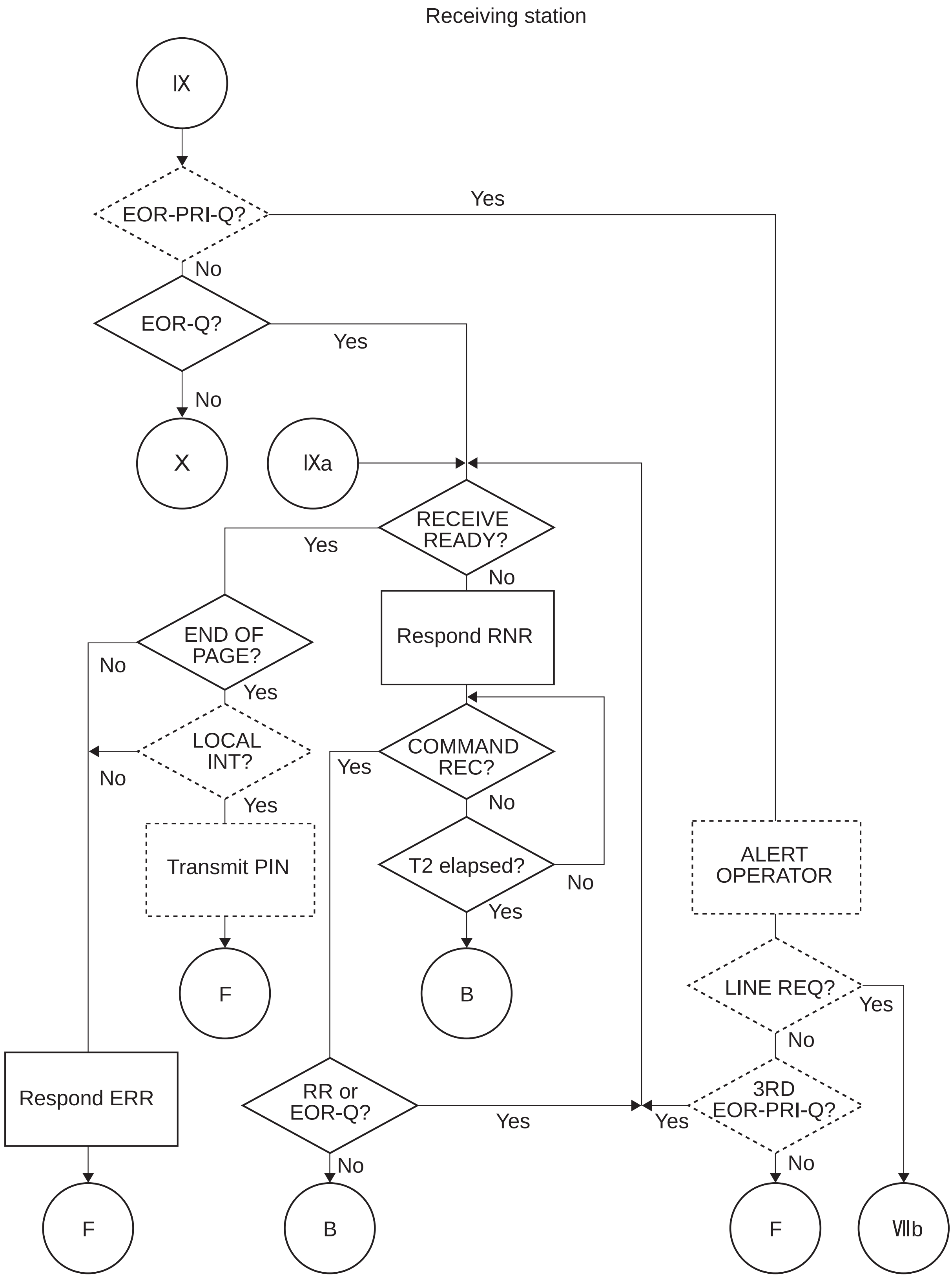


Fig. A-55 Receiving Station Procedure 5

Receiving station

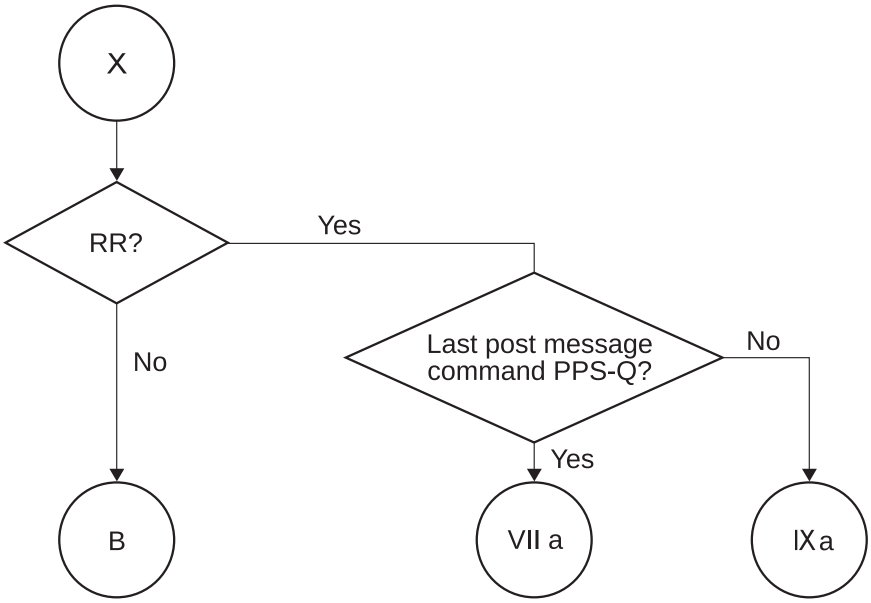
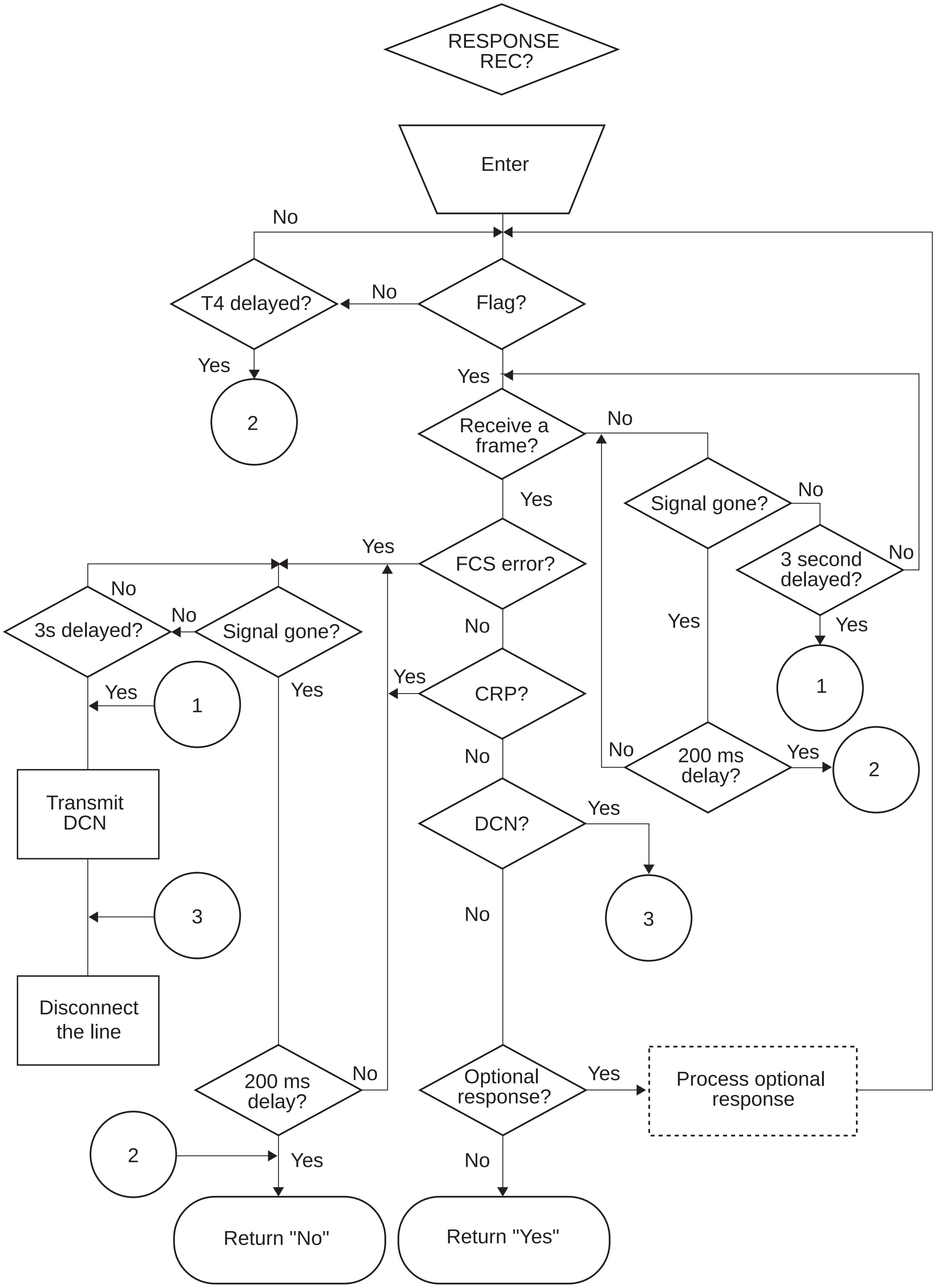


Fig. A-56 Receiving Station Procedure 6



T4=4.5s±15%,manual units
T4=3.0s±15%,automatic units

Fig. A-57 Response Reception Procedure

A

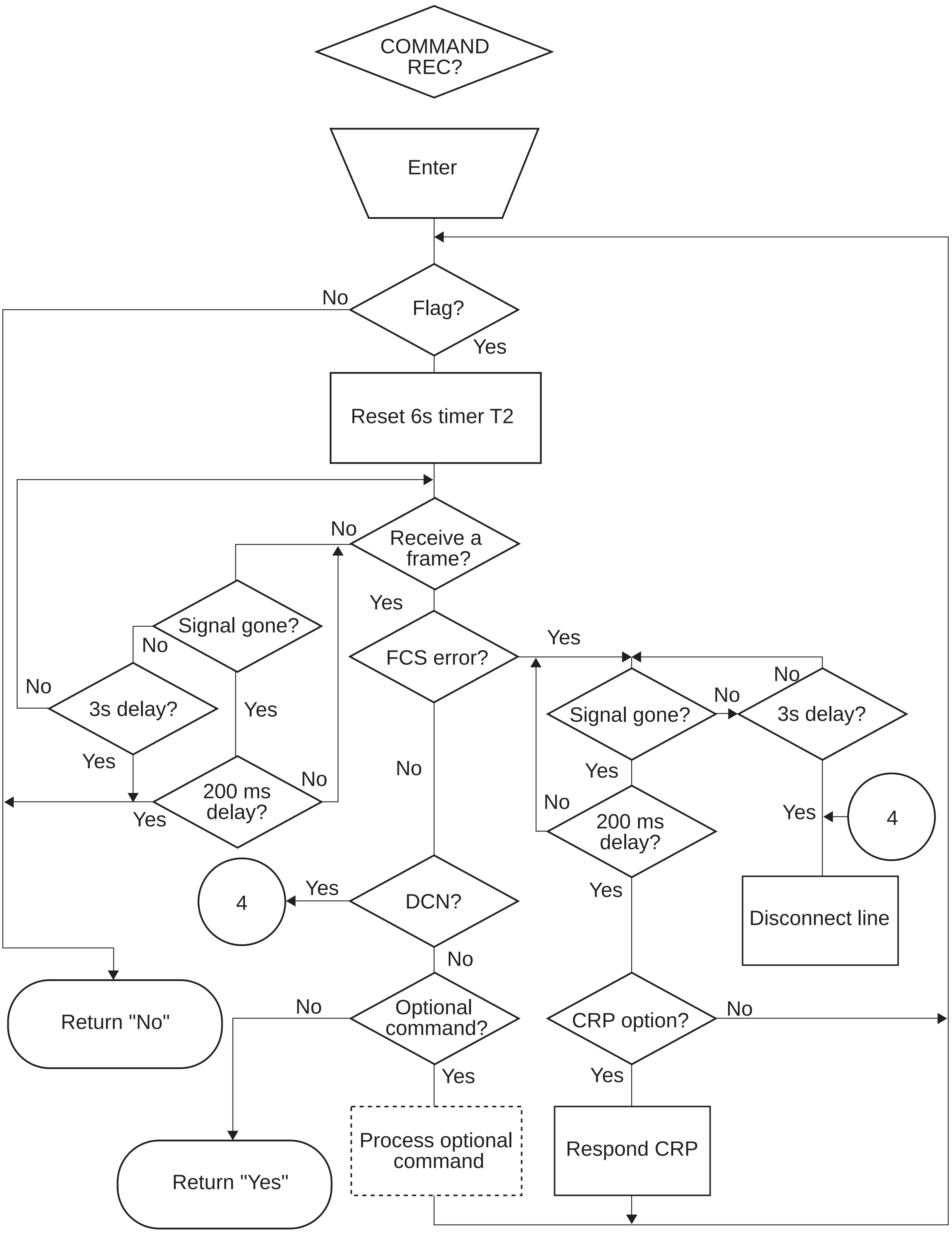


Fig. A-58 Command Reception Procedure

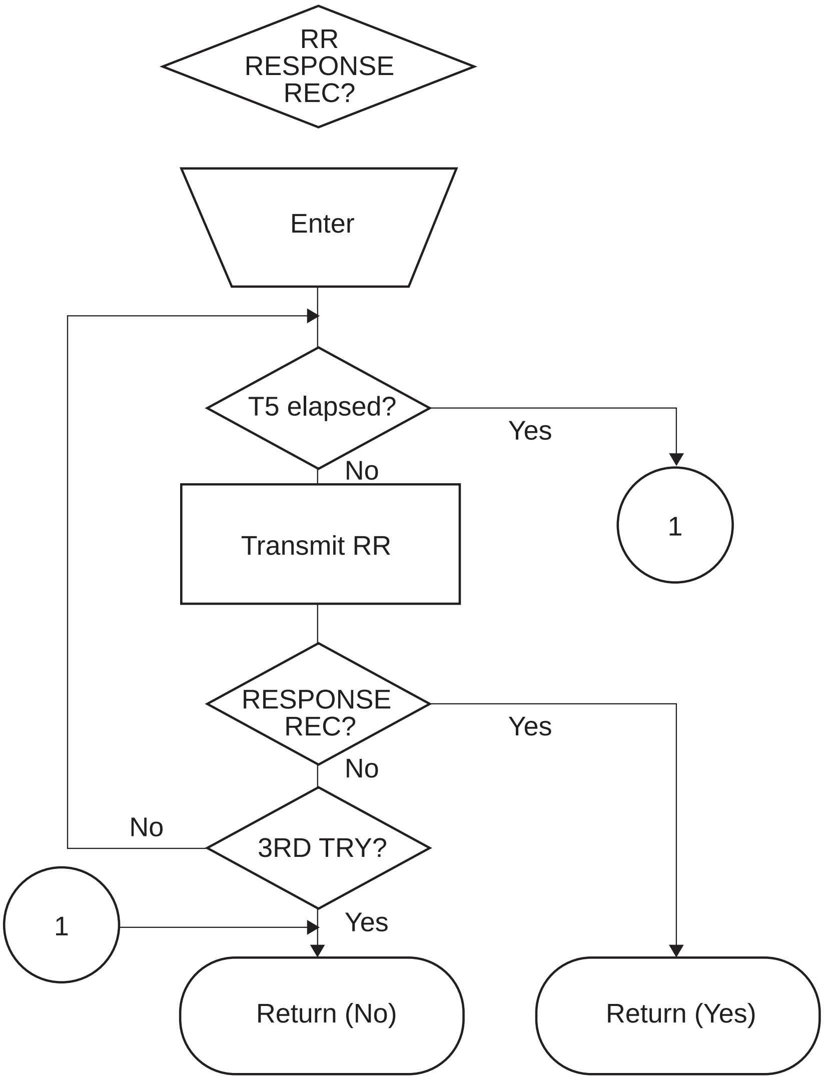


Fig. A-59 RR Response Reception

A

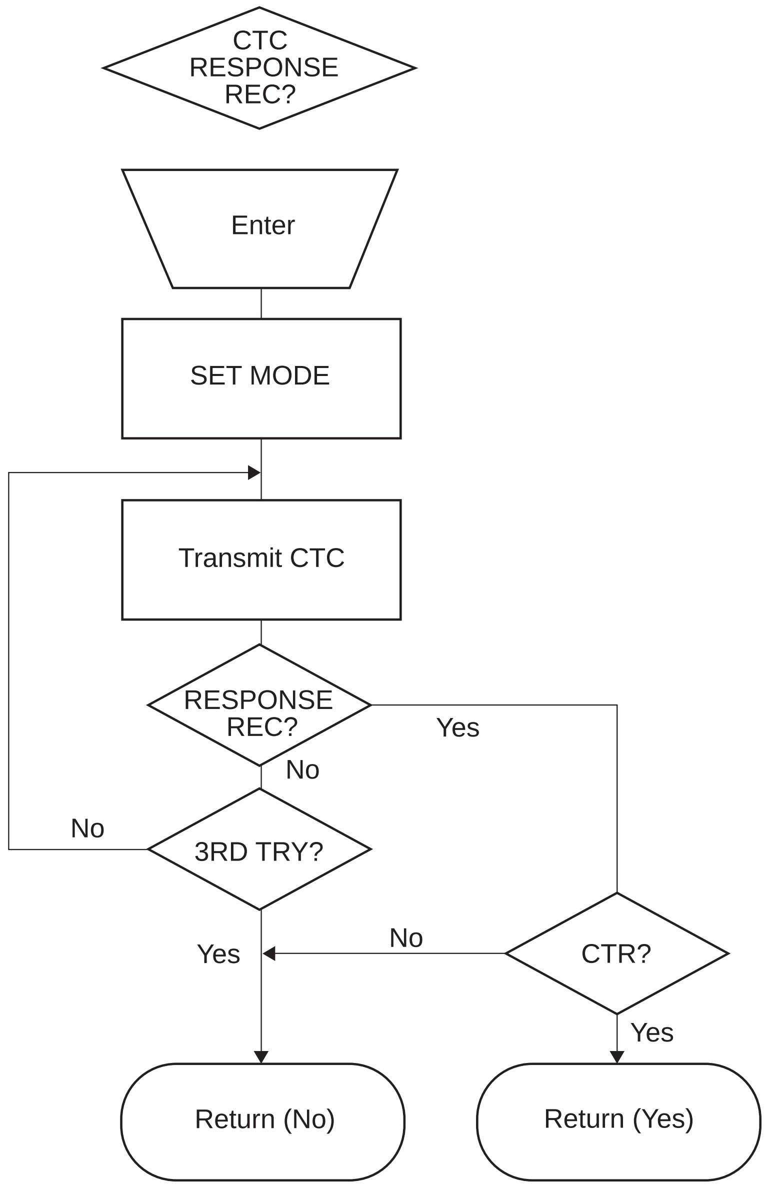


Fig. A-60   CTC Response Reception

GLOSSARY

A

AC (Alternating Current)

Current whose direction of flow is inverted periodically.

Answering machine connection mode

This function is for automatically judging whether the incoming call is a facsimile or a telephone call when the answerphone is connected to the facsimile. If the incoming call is a facsimile, it is received. If it is a telephone call, it is recorded to the answering machine.

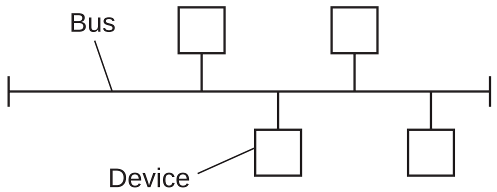
ASCII code

ASCII stands for American Standard Code for Information Interchange. ASCII code expresses a total of 128 characters (alphabet, number, symbol, space, line feed, tab and computer control codes) using seven bits. Of all the various codes in the world, almost all alphabetic characters are created based upon these ASCII codes.

B

Bus

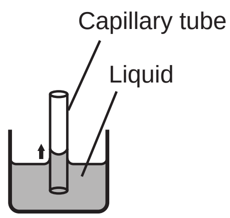
A digital transfer path shared by multiple devices. Connection of these devices on this bus is called bus connection. For a bus connection, ICs or other elements are sometimes connected on the circuit board or a digital terminal is sometimes connected to an ISDN line.



C

Capillary phenomenon

The phenomenon where the level of a liquid in a tube is higher or lower than the level of the liquid outside the tube when a thin tube is placed upright in the liquid.
A fountain pen is a familiar example of this phenomenon.



CODEC (COde/DECode) IC

IC for coding and decoding data

CPU (Central Processing Unit)

Of the three individual functions (I/O unit, control unit and arithmetic logic unit) combined in the MPU, the CPU combines the control unit and arithmetic logic unit.

D

DC (Direct Current)

Current whose direction of flow is constant in one direction.

A

DMA (Direct Memory Access) Transfer

A system internal function, transfer of data groups (memory blocks) that does not pass through the CPU. DMA transfer can speed up system performance as it does not place a load on the CPU.

Document length

The length of the document in the vertical scanning direction. The length of the document in the horizontal scanning direction is called the document width.

Double feeding

The state that occurs when two or more sheets of recording paper loaded on the paper cassette or tray or two or more documents placed on the copy board are fed at the same time.

Driver IC

IC for driving motors, solenoids and other components. Transistor arrays are often used for the driver IC. When the driver IC arrives, current is allowed to pass to supply the current for driving components.

DTMF (Dual Tone Multi Frequency)

A signaling method that uses a combination of two specific frequencies like that in push button dialing.

E

Exchange

The equipment for connecting lines from terminals and exchange stations.

F

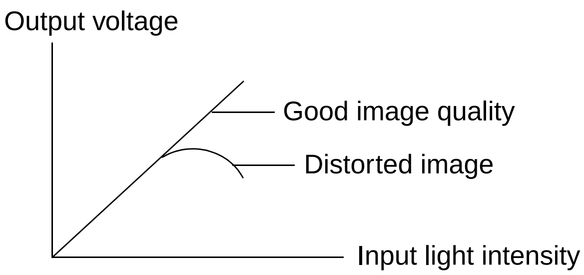
Friction coefficient

The ratio between the friction force parallel to a contacting surface acting on contacting parts and the force acting perpendicularly on a mutually contacting surface

G

Gamma characteristics

Gamma characteristics express the relationship between input light intensity and output voltage. When the output voltage is proportional to the input light intensity, the reproduction image quality will be good. The image becomes distorted as this relationship is inverted.



H

Hamming distance

The number of different bits between two signals of a determined bit length. The following shows an example for a 3-bit signal.

000 and 000: Distance 0
000 and 100: Distance 1
000 and 010: Distance 1
000 and 001: Distance 1
000 and 101: Distance 2
000 and 110: Distance 2
000 and 011: Distance 2
000 and 111: Distance 3

Horizontal scanning

Reading of documents in the horizontal direction is called “horizontal scanning,” and the number of pixels per unit length when the horizontal scanlines are separated into pixels is called the “horizontal scanning density” (horizontal resolution). G3 facsimiles separate scanlines into 8 or 16 pixels per 1 mm, so the horizontal scanning density becomes either 8 dots/mm or 16 dots/mm, respectively.

I

IETF

IETF stands for Internet Engineering Task Force.

ISO

ISO stands for International Organization for Standardization.

ITU-T

ITU-T stands for International Telecommunication Union-Telecommunication sector. It was formerly known as CCITT before its name was changed to ITU-T in March 1993.

M

Modulo 2

“Modulo” is an arithmetic operator that indicates the remainder. “Calculating the modulo 2 of a certain number” refers to the remainder obtained by dividing that number by 2.

MPU (Micro Processing Unit)

The part that controls the core functions of a computer. The MPU is divided into three parts with different functions, the I/O unit, control unit and arithmetic logic unit (ALU).

N

Non-feed

The document placed on the copy board is not fed.

P

Pixel

The smallest element that comprises an image.

Pseudo bell

The bell that is rung by the facsimile when it judges whether or not the incoming call is a telephone call in the FAX/TEL switching mode

Pseudo ring back tone

The signal that is sent to the other party while judgment is performed as to whether the incoming call is a facsimile or a telephone call in the FAX/TEL switching mode. While this signal is being sent, the DC loop is formed which means that the call is charged.

R

Relay

A component that functions as a switch for turning a circuit ON or OFF by opening/closing of contacts. Some relays function as relays without contacts just like a transistor, and others use the action of heat or magnetism.

RFC (Requests for Comment)

This document issued by the IETF relates to technical information for the Internet, and comprises further documents that are identified by number. RFC describes protocol sets or HTML language.

RTC

RTC stands for Real Time Clock, the clock circuit that counts date and time.

V

Vertical scanning

Reading of documents in the vertical direction is called “vertical scanning,” and the number of scanlines per unit length when the document is separated in the vertical scanning direction is called the “vertical scanning density” (vertical resolution). G3 facsimiles separate documents into 3.85 lines, 7.7 lines or 15.4 lines per 1 mm, so the vertical scanning density becomes one of 3.85 lines/mm, 7.7 lines/mm or 15.4 lines/mm.

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