

# APPLICATION CIRCUITS OF MINIATURE SIGNAL RELAYS

## Application Examples and Guide to Use

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## 1. PREFACE

Miniature signal relays are used in a wide range of fields including communications equipment, measuring instruments, factory-automation equipment, and audio systems. With unique characteristics, unavailable in other devices, miniature signal relays are suited to a wide variety of roles.

This document introduces specific application examples in each of the above application fields for your reference.

### For Right Use of Miniature Relays

#### **DO NOT EXCEED MAXIMUM RATINGS.**

Do not use relays under exceeding conditions such as over ambient temperature, over voltage and over current. Incorrect use could result in abnormal heating, damage to related parts or cause burning.

#### **READ CAUTIONS IN THE CATALOG.**

Read the cautions described in EM Devices' "Miniature Relays" when you choose relays for your application.

The application circuits and their parameters are for reference only and are not intended for use in actual design-ins.



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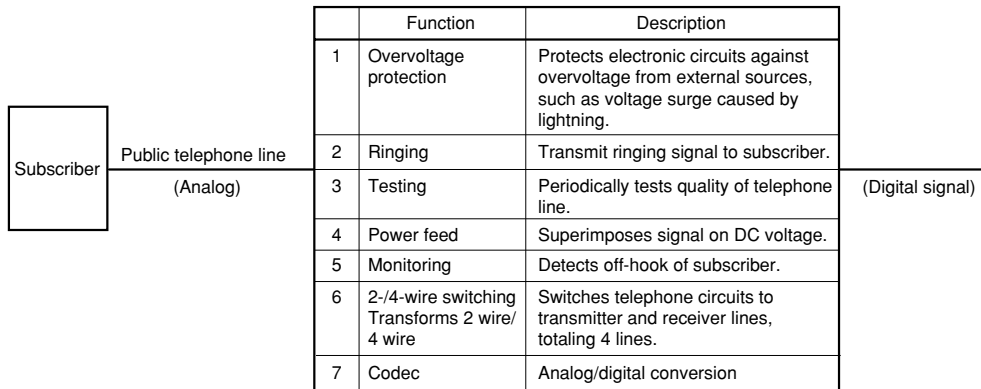
## 2. APPLICATION EXAMPLES

### 2.1 Communications Equipment

#### (1) Switching system

- **Function of subscriber circuit**

The subscriber circuit of an switching system connects a public telephone circuit to the central office switch. The main functions of the subscriber circuit are shown in Figure 1.



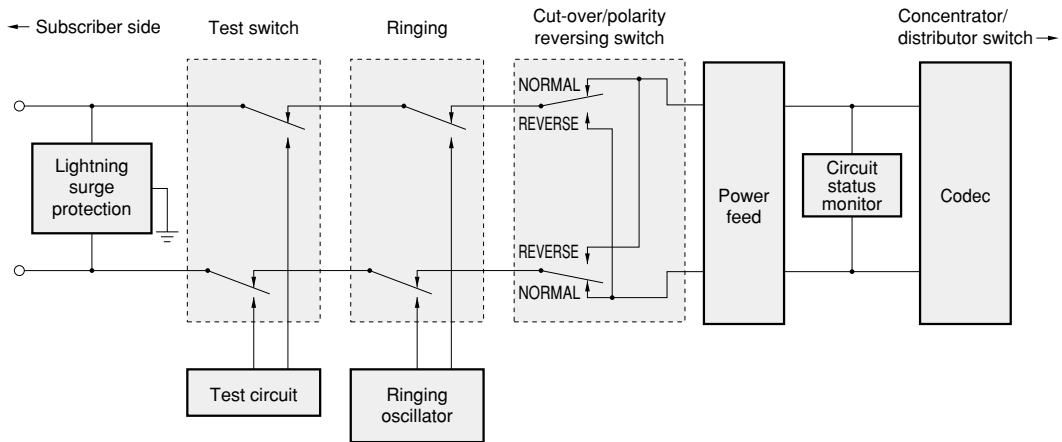
**Figure 1. Function of Subscriber Circuit**



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- **Relay circuit**

Signal relays are used for the “ringing”, “testing”, and “polarity reversing switch” functions of the subscriber circuit. Note, however, that signal relays are not used for a subscriber circuit for a general telephone set connected to the NTT D70-type switching system.



**Figure 2. Example of Using Relay in Subscriber Circuit**

- **Required specifications of relay**

- Breakdown voltage between opening contacts: 1000 V.AC MIN.  
Surge: 1500 V MIN.
- 2-transfer contacts



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## (2) Key telephone and PBX (private branch exchanger)

### • Use of relays

A key telephone has functions for distributing multiple incoming calls to extensions, or to establish calls between extensions. Latest key telephone sets set-ups offer many more functions by digitalization.

Of these functions, the "trunk line switching" and "ringing transmission" functions are the same as those of switching system. (Refer to the description of switching system on the preceding page).

Because electric power of key telephones and PBXs are supplied from a commercial power source, the telephones cannot be used when there is a power failure. To cope with this, their circuits are designed so that communication can still be carried out via basic analog telephones (telephones that don't contain ICs such as the traditional rotary-dial telephone) even if a power failure occurs.

In such a circuit, the relay coil is always energized and the make contact closed as shown in Figure 3. If a power failure occurs, the break contact is closed because no power is supplied, and the communication path with the public telephone line is established.

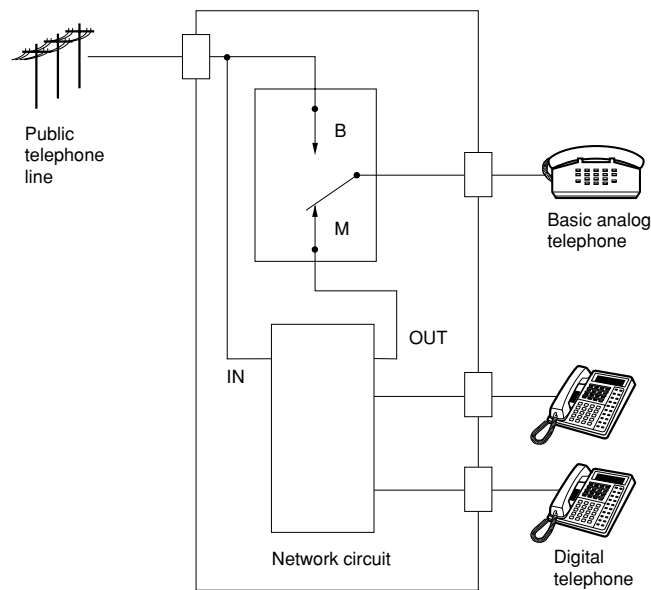


Figure 3. Subscriber Circuit of PBX

### • Required specifications of relay

- Breakdown voltage between opening contacts: 1000 V.AC MIN.  
Surge: 1500 V MIN.
- 2-transfer constant (normally closed contact is necessary.)



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### (3) Transmission equipment

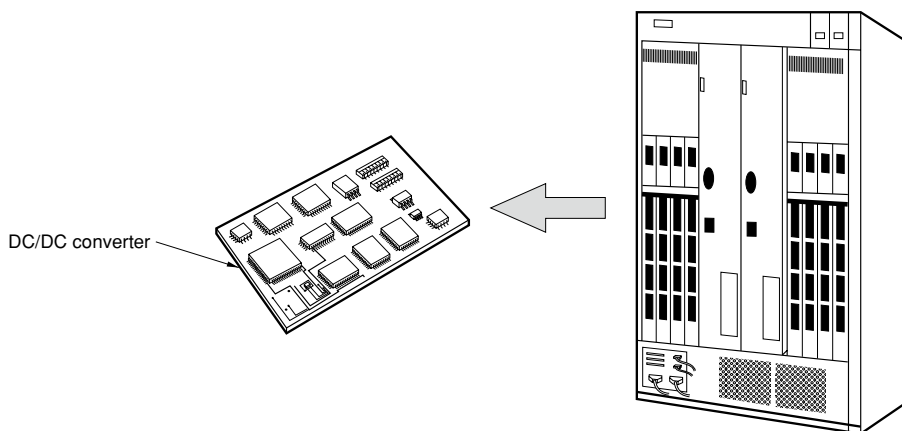
- **Designing power supply of transmission equipment**

When a large capacity power supply is used to distribute power to many printed circuit boards with electronic components in transmission equipment, the centralized power unit in the equipment generates 24/48 V.DC from a 100-/200-V.AC commercial power source. At this high voltage, the current to be distributed to each printed circuit board can be lowered and the thickness of the wiring can be reduced.

The DC/DC converter on each board converts the 24/48 V.DC to 5 to 12 V which is used by the electronic components.

- **Use of relays**

If a fault occurs in the power supply on the board, it is necessary to report this information to the central control unit. A relay is used for this purpose. When power is supplied to the coil of the relay, the make contact of the relay passes a current. In case of an abnormality, the break contact conducts, indicating the occurrence of the abnormality.



**Figure 4. Relay in Transmission Equipment**

- **Required specifications of relay**

- 1- or 2-transfer contact (normally closed contact is necessary).



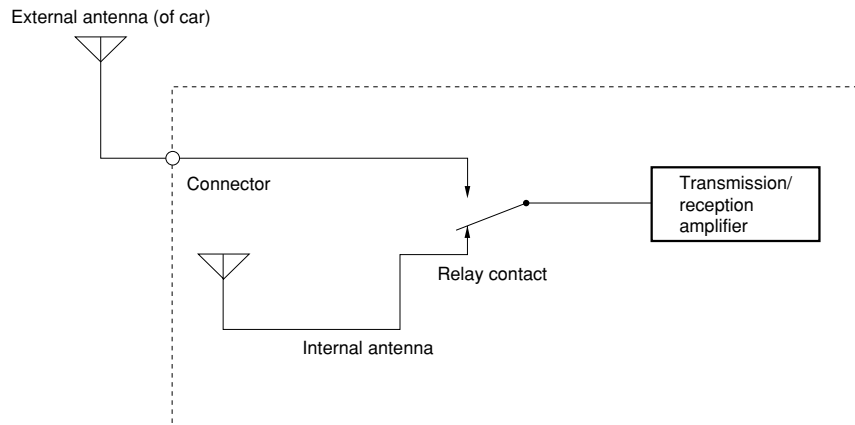


#### (4) Cellular telephone

- **Use of relays**

When a cellular telephone is used outdoors, the internal antenna is used. Those who often use the telephone in a car use the external antenna installed in the car. Therefore, a function to select either the internal or external antenna is required.

The relay used between these antennas and the internal transmission/reception amplifier of the telephone is required to have a frequency bandwidth of 800 MHz to 1.5 GHz, an isolation loss of 20 to 30 dBm, and an insertion loss of 1 dBm. Therefore, even general-purpose miniature relays not designed to support high frequencies can be used in cellular telephones.



**Figure 5. Relay Circuit in Cellular Telephone**

- **Required specifications of relay**

- Small and lightweight: Mounting height of 5 mm MAX.
- 2-transfer contact



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(5) LAN

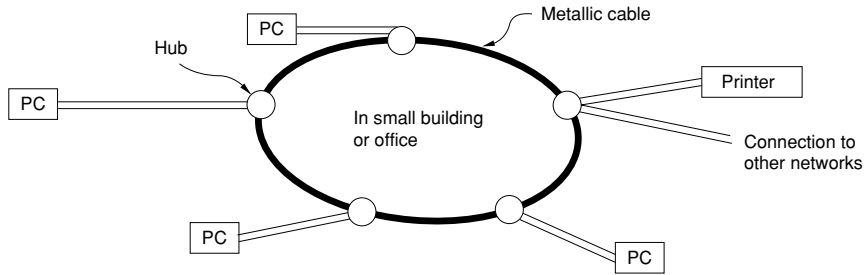
• **Use of relay**

A LAN (local area network) is organized to share information among computers and to exchange electronic mail in office or a small building. In a token ring which is one type of LAN, a relay is used at the branch portion of network called the hub.

Figure 6 briefly illustrates the circuit control block using a relay in the hub.

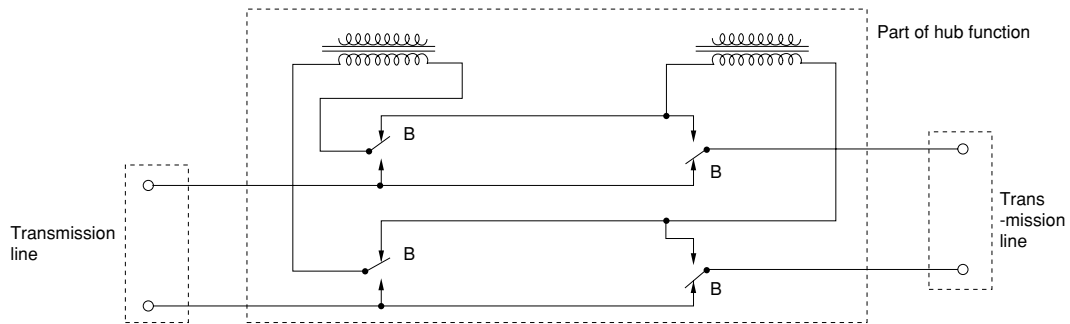
Transmission lines extend toward the left and the right in this figure, and computers are interfaced via a line transformer. The relay contact is located so that, when this transformer is not used (i.e., when the computer is not connected to network), the left and right transmission lines are bypassed the computer.

**[Example of LAN]**



**[Example of using relay in a hub]**

Function to bypass the transmission lines when computer is not connected



**Figure 6. Example of Using Relay in Token Ring**

• **Required specifications of relay**

- 2-transfer contact × 2 or 4-transfer contact



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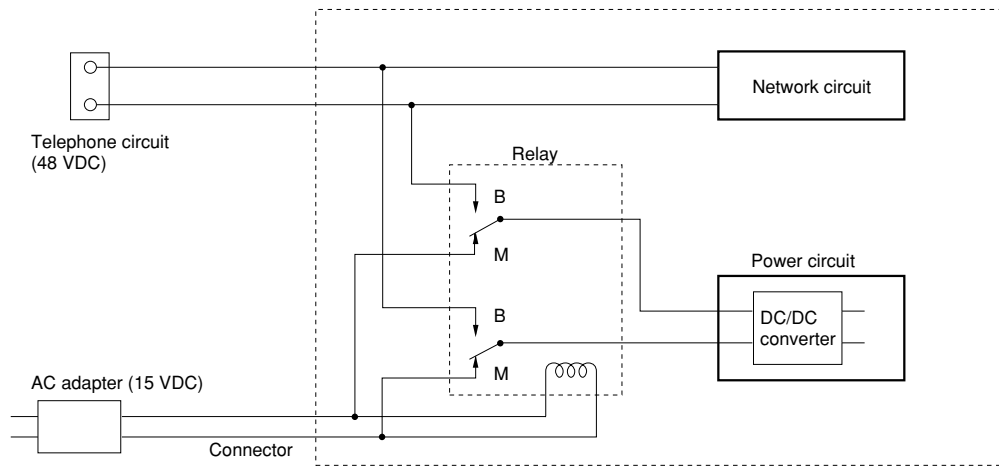
## (6) PHS

- **PHS for offices**

Digital cordless telephones are used in some offices to implement a communication network by expanding some of the functions of the existing PBX and connecting about 100 fixed stations (BS), which are equivalent to the main unit of a cordless telephone, throughout office.

- **Use of relays**

These fixed stations are supplied with power from a local AC 100/120/220-V source in the vicinity of the installation. To maintain functionality even during a power failure, they can be supplied with power temporarily by using the circuit voltage of the PBX.



**Figure 7. Use of Relay in Power Circuit of a Fixed Station**

- **Required specifications of relay**

- 2-transfer contact (normally closed contact is necessary).
- Low power consumption of coil



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## (7) Modems for computer communication

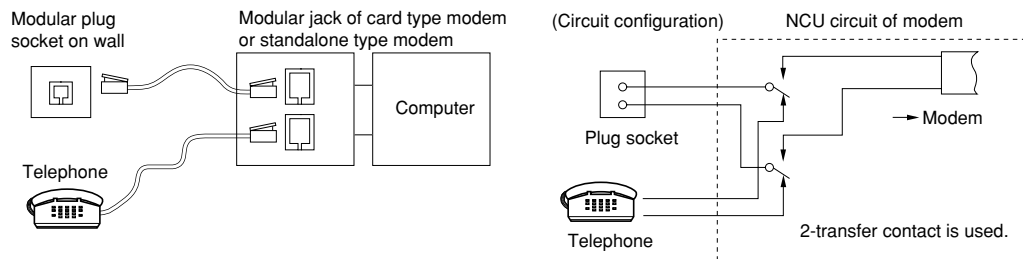
- **Format of a communication modem**

To connect a computer to a communication center via a public telephone network, a communication modem is necessary. This modem is connected to the modular plug socket of the public telephone line directly (using a specially prepared line for connecting modems) or by sharing the line with the telephones.

- **Use of relays**

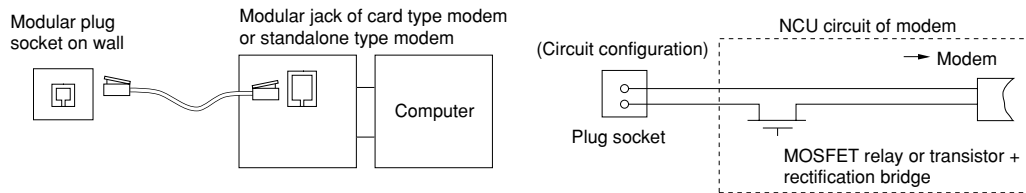
When a telephone line is shared with a telephone, the telephone usually takes precedence. Therefore, switching a circuit is necessary when the modem is used.

### [If an external telephone is used]



\* When computer communication is not performed, the telephone can be used without the modified wiring.

### [Direct connection]



\* When the modem is directly connected to the public telephone line, miniature relays are not used in most cases because the "switching function" is not necessary.

\* A MOSFET relay (transistor switch) is used to provide a hook switch function and a dial pulse function.

**Figure 8. Example of Using Relays in Modems**

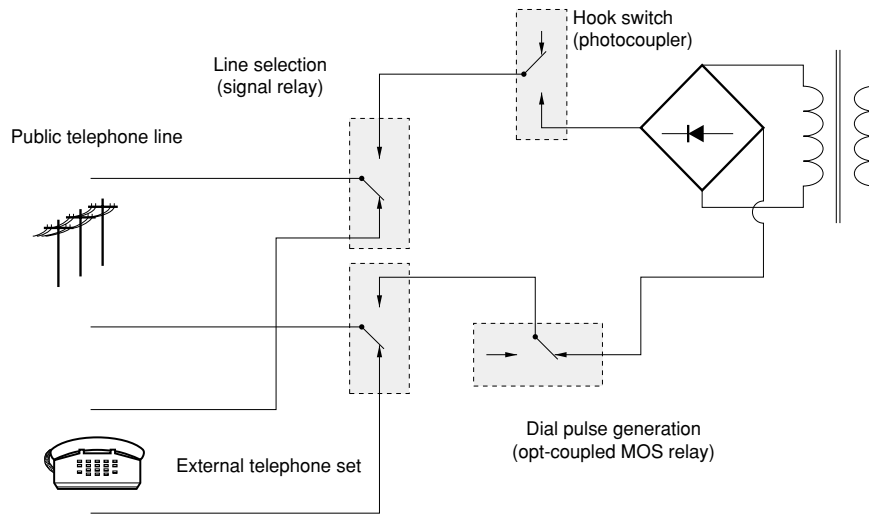


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- **Details of NCU circuit**

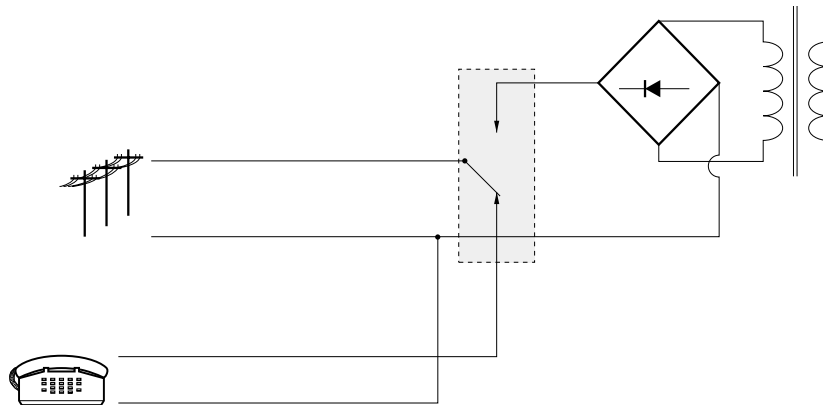
**<Standard circuit example>**

A signal relay with two transfer contacts is used to select a line. A photocoupler and an opt-coupled MOS relay are used as a hook switch and for dial pulse generation.



**<Simplified circuit>**

In this example, a relay with only one transfer contact is used to select a line and to generate dial pulses.



**Figure 9. NCU Circuit**

- **Required specifications of relay**

- 1- or 2-transfer contact (normally closed contact is necessary) .
- Breakdown voltage between opening contacts and between coil and contact: 1000 V.AC MIN. (surge: 1500 V MIN.)



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## (8) Terminal adapter (TA)

- **Use of terminal adapter**

ISDN services can be used by using a public telephone line, and the telephone can be used during computer communication such as Internet access.

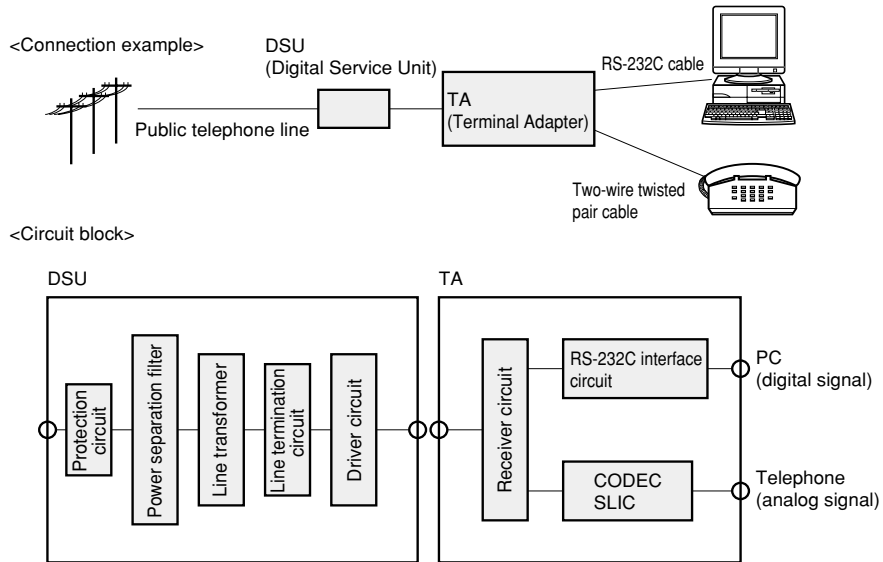


Figure 10. Configuration of Terminal Adapter



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## General telephone service

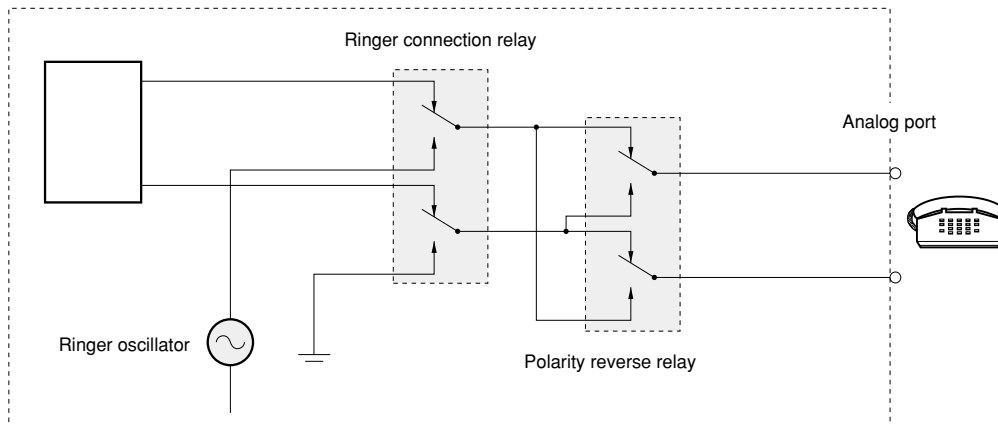
- **Use of relays**

Relays are used in two ways in the SLIC block (subscriber circuit) of a terminal adapter.

<1> A ringer connection relay is connected to a general telephone set. The output of a ringer oscillator is connected to the analog port of this telephone set. As a result, the bell of the telephone rings.

<2> A polarity reverse relay reverses the connected polarity of the general telephone set.

**Caution** The function of the ringer connection relay may be provided in the SLIC IC (subscriber circuit IC). Polarity reversion may be omitted.



**Figure 11. Subscriber Circuit of Terminal Adapter**



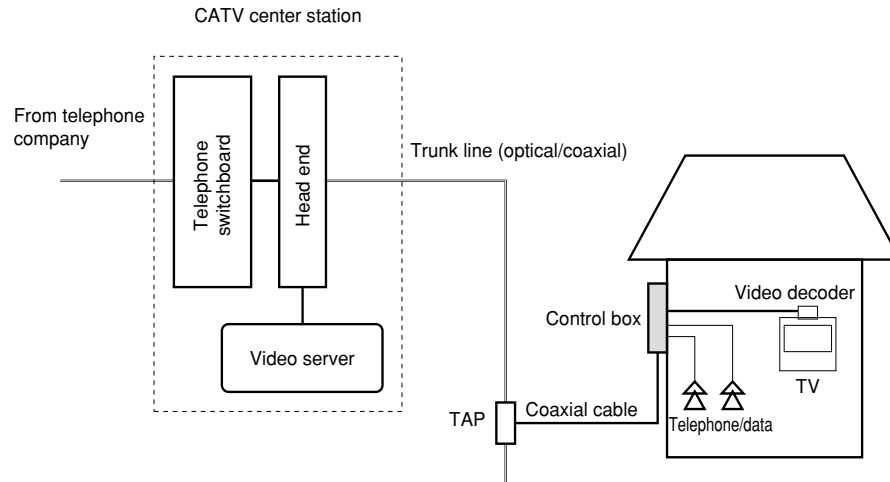
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## (9) CATV telephone

- **Outline of system**

A CATV (cable TV) telephone system provides telephone services by using the communication network of optical cables and coaxial cables intended for CATV services.

This system uses a control box that is installed at the entrance of the coaxial cable installed for a household.



**Figure 12. Outline of CATV Telephone System**

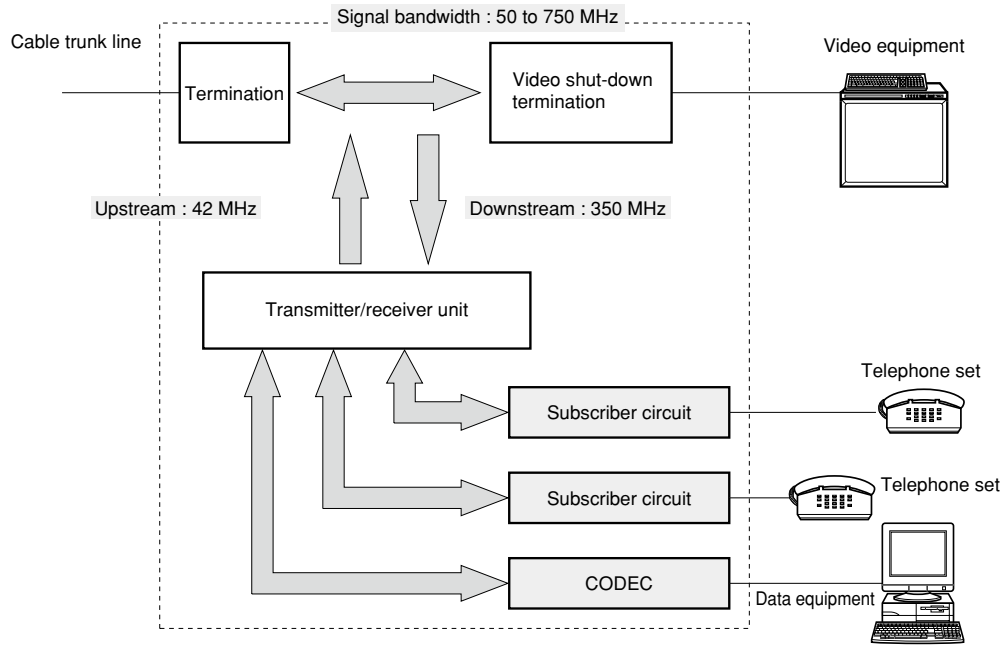


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- **Control box system configuration**

In the control box, video signals for CATV services and telephone/data transmission signals for added services are separated.



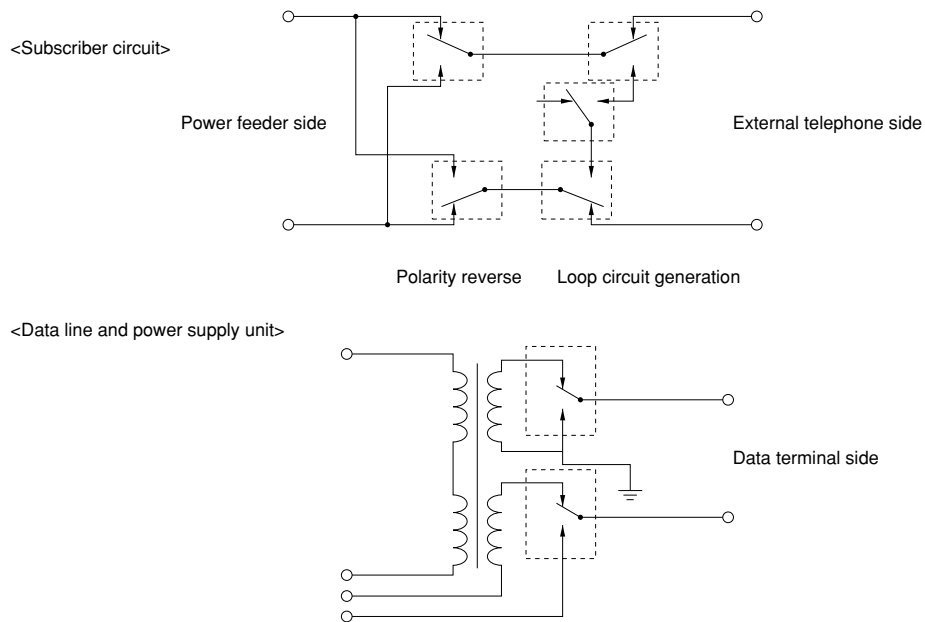
**Figure 13. System Outline of Control Box**



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- **Use of relays**

The control box has a subscriber circuit for telephone services in the same manner as a telephone switchboard. The functions of the relay in the subscriber circuit include “polarity reversal” and “loop circuit generation”. A relay is also used in the data communication equipment.



**Figure 14. Example of Using Relay in Control Box**



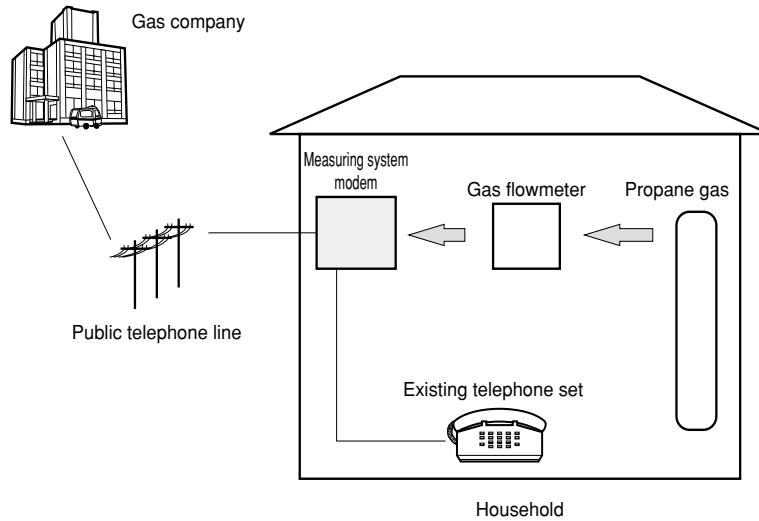
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## (10) Gas measuring modem

- **Gas measuring system**

This system measures the quantity of propane gas used and reports it together with maintenance information to the gas center (gas company).

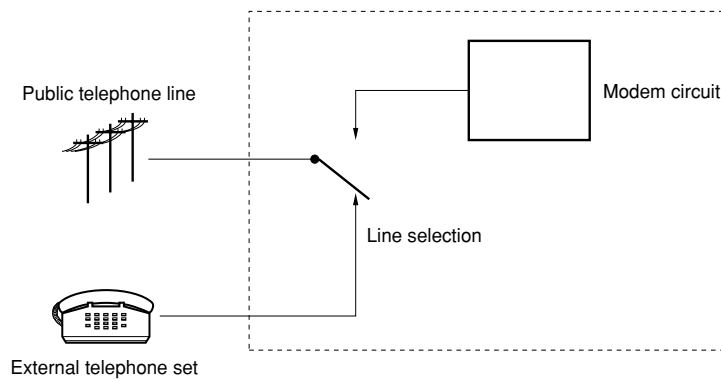
In this system, a communication modem is used because a public telephone line is used.



**Figure 15. Gas Measuring System**

- **Use of relays in NCU block of measuring system modem**

A function to select lines is necessary because an existing public telephone line is used.



**Figure 16. Example of Using Relay in Measuring Modem**



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- **Required specifications of relays**  
Refer to (7) Modems for computer communication.

## 2.2 Measuring Instruments

### (1) Semiconductor tester

- **Semiconductor tester**

When testing more than one object, a tester with a high accuracy is used while one of many subjects is selected. In the case of a memory IC where each memory cell must be individually tested, the tester must have a selection function.

For high-accuracy testing, calibration must be carried out occasionally to cancel out external disturbances. Because this function must be realized by the tester itself, an internal selector circuit is necessary.

A tester used in production facility must offer as short a time as possible for selection, and for testing, to increase the throughput per unit time. A relay used in such a tester, therefore, must have a short operating time.

- **Use of relays**

Figure 17 shows an example of the circuit of a DC (direct current) characteristic tester. In this figure, relays are used to select a path that goes through the test subject, which is a sample, from the current source, and a path which does not go through the test subject.

This selection enables calibration, which tests the characteristics of the tester itself, to be carried out.

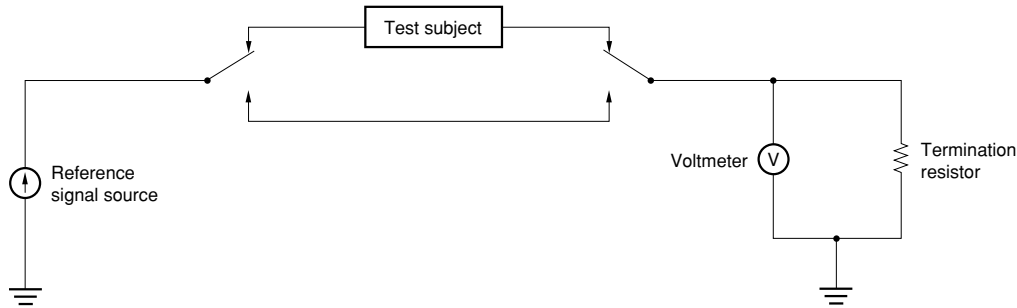


Figure 17. Use of Relays in Semiconductor Tester

- **Required specifications of relay**

The switch function, which is one of the functions of semiconductors, is the same function as a relay. Therefore, the "contact of the relay" is required to have a much higher performance than that of the test subject.

- Insulation resistance between opening contacts :  $10^8 \Omega$  (500 V.DC) MIN.
- Contact resistance :  $1 \Omega$  MAX.  
Temperature coefficient: 1 %/deg. MAX.
- Operating time : 10 ms MAX.
- Transfer contact
- High-frequency characteristic : Little distortion when transmitting square wave of about 100 MHz



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## 2.3 Office Machines

### (1) Fax machines

- **NCU circuit of fax machines**

Not only fax machines, but any other systems using public telephone lines have an NCU circuit (network control unit) that controls the line.

One of the basic functions of this NCU circuit is “switching the line” to an external telephone. This function is the same as that introduced in (7) Modems for computer communication in 2.1.

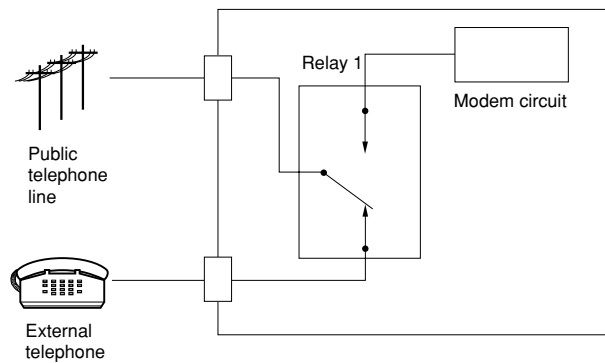
- **Use of relays**

Because the range of application of relays has expanded as the functionality of equipment increases, examples of relays in applications other than line switching are also introduced below.

<1> Figure 18 shows a fax machine with a telephone for household use. “Relay 1” is used to switch over between the internal telephone and an external telephone.

<2> In the set in Figure 19, “relay 2” is connected to an external telephone. In this case, both the internal telephone and external telephone can be used. If the ringing tone is too loud, the external telephone can be disconnected by opening the contacts of “relay 2”.

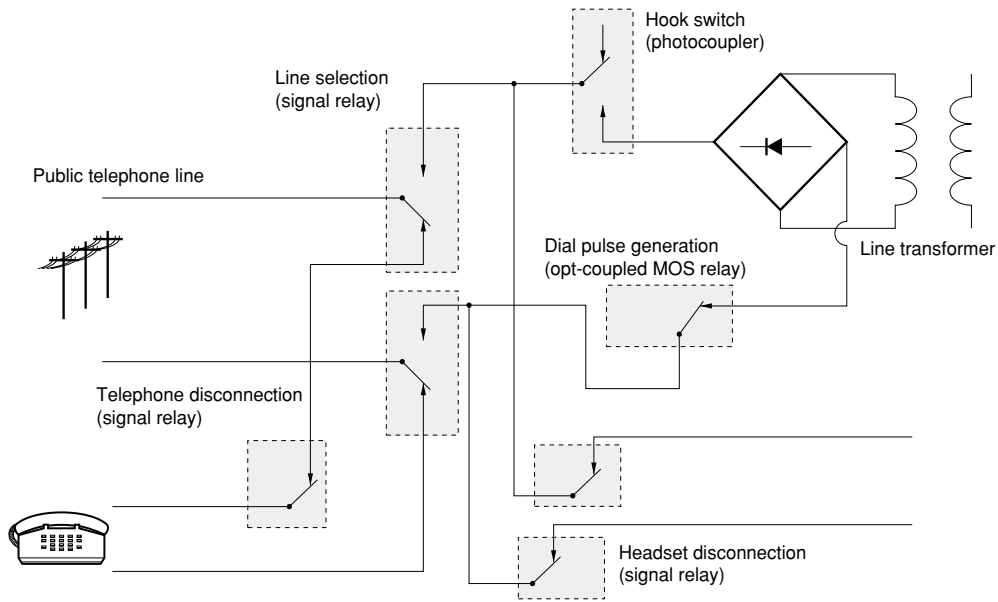
“Relay 3” is used to connect a test circuit. This test circuit automatically identifies the type of public telephone line (dial or push-phone line, and line speed) and performs the initial setting up when the fax machine is installed.



**Figure 18. Example of Using Relays in a Fax Machine (1)**



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**Figure 19. Example of Using Relays in a Fax Machine (2)**

Figure 19 shows an example in the NCU circuit of a facsimile machine for business use. "Line selection" is carried out in the same manner as the other NCU circuits. A relay is used to disconnect the external telephone so that incoming calls cannot be received, or to use a headset attached to the facsimile.

• **Required specifications of relay**

- Breakdown voltage between opening contacts: 1000 V.AC MIN.  
Surge: 1500 V MIN.
- Breakdown voltage between coil and contact: 500 V.AC MIN.  
\* Devices used in Europe are required to conform to the IEC950 standard.  
(Example) Breakdown voltage: 1500 V.AC MIN., creepage distance: 2 mm MIN., etc.
- 2-transfer contact or 2-continuous contact

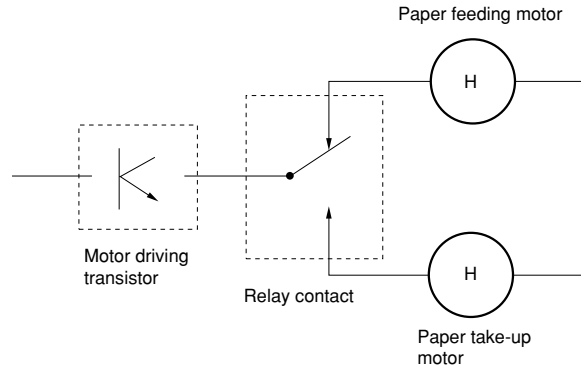


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## (2) Printers

- **Use of relays**

Some portable printers have separate motors for taking up paper and feeding the paper during printing, because of structural limitations. Therefore, two driver ICs are necessary for driving the respective motors. These motors, however, do not operate at the same time. Therefore, a relay is used to eliminate one driver IC and thereby to reduce the cost and mounting area.



**Figure 20. Example of Using Relays in Printers**

- **Required specifications of relay**

- 2-transfer contact
- Low profile shape: 5 mm MAX.

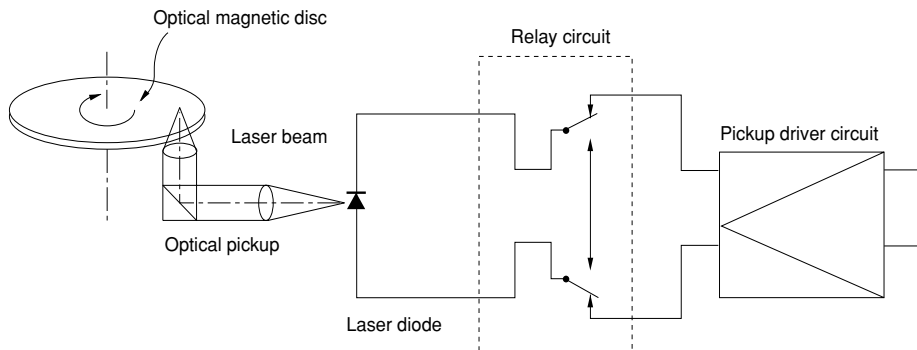


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### (3) MOD (optical magnetic disc drive unit)

- **Use of relays**

An external magnetic field and a laser beam are used to write information to an optical magnetic disc. The light-emitting diode that is used to generate the laser beam generally emits light when even a minute charge is applied. Therefore, both ends of the light-emitting diode is short-circuited to prevent light from being emitted due to static electricity and thus wrong data from being written when the optical magnetic disc is not in use.



**Figure 21. Example of Using Relay in Optical Magnetic Disc Drive Unit**

- **Required specifications of relay**

- 2-transfer contact
- Contact resistance : 1  $\Omega$  MAX.
- Low profile shape : 5 mm MAX.



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#### (4) Battery chargers

- **Use of relays**

Nickel-Cadmium (Ni-Cd) batteries have a memory effect in that their saturated charging voltage drops if the batteries are repeatedly charged when they are not completely discharged. To prevent this effect, the batteries must be completely discharged.

In the circuit in Figure 22, if the batteries are placed in the charger, a mechanical switch detects the batteries and therefore, the switch turns ON. Then the batteries start discharging via the discharging resistor. The voltage of the batteries is detected by the detector circuit, and the contacts of the relay are closed by a transistor. At this point, the mechanical switch turns OFF, and the discharging current flows through the relay contacts.

When discharging has progressed sufficiently and the voltage reaches a specific level, the transistor is turned OFF by the detector circuit, and the relay contacts open.

In this way, the batteries are discharged and then charged. The charging process, however, is not shown in this example.

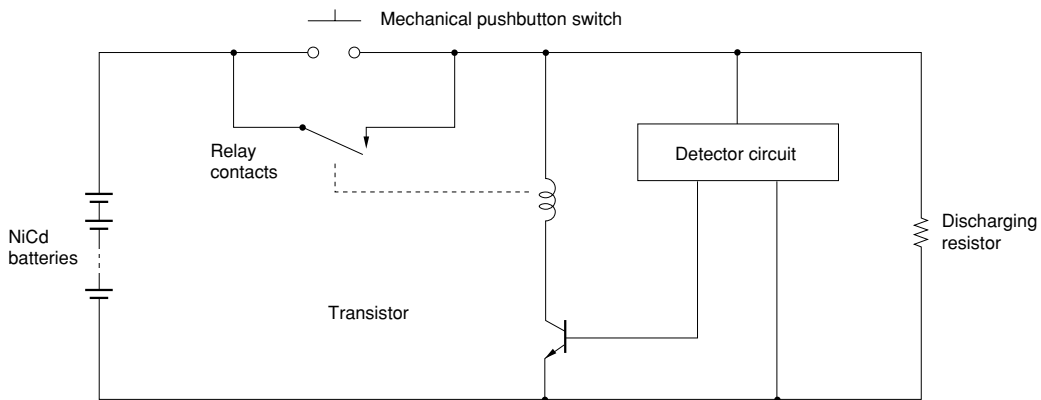


Figure 22. Example of Using Relays in a Chargers

- **Required specifications of relay**

- Contact pair of more than 1 transfer contact
- Contact resistance: 0.1  $\Omega$  MAX.
- Contact current : 2 A MIN.



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## 2.4 Household Appliances and Audio Systems

### (1) Cordless telephones

- **Use of relays**

The function is similar to that of the NCU circuit of a fax. This section introduces representative circuit examples.

<1> The positions of the relay contacts shown in Figure 23 illustrate the status when the cordless telephone is not connected to the power supply. This function allows calls to be received from an external telephone by using an attached headset in the event of a power cut.

<2> "Relay 2" in Figure 24 serves as a "hook switch".

When the handset of a conventional telephone is lifted from the cradle, the switch is turned ON. This relay implements this function.

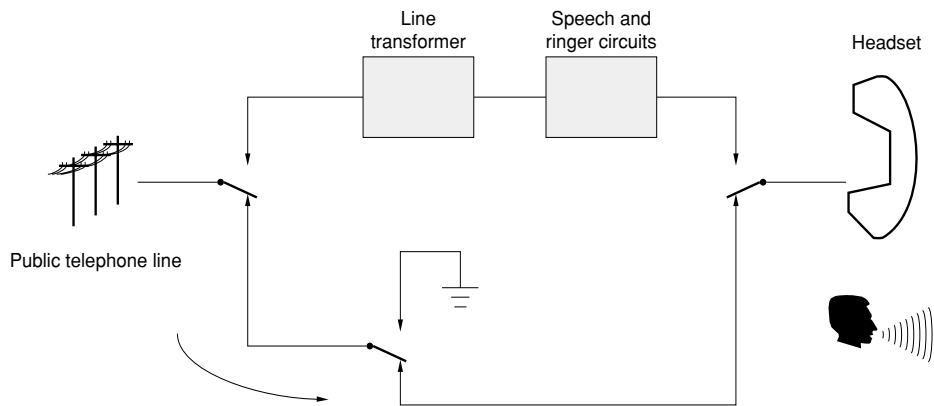


Figure 23. Example of Using Relays in a Cordless Telephone (1)

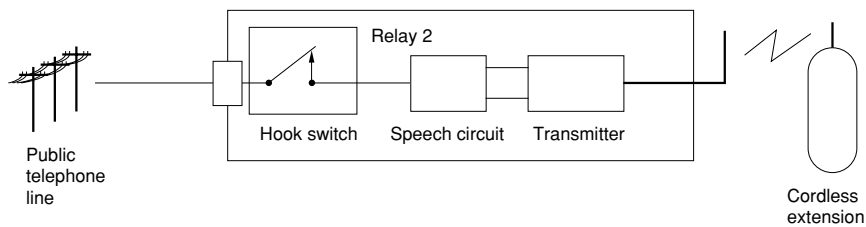


Figure 24. Example of Using Relays in a Cordless Telephone (2)

- **Required specifications of relay**

- Breakdown voltage between opening contacts: 1000 V.AC MIN.  
Surge: 1500 V MIN.
- Breakdown voltage between coil and contact: 500 V.AC MIN.
- 2-transfer contact



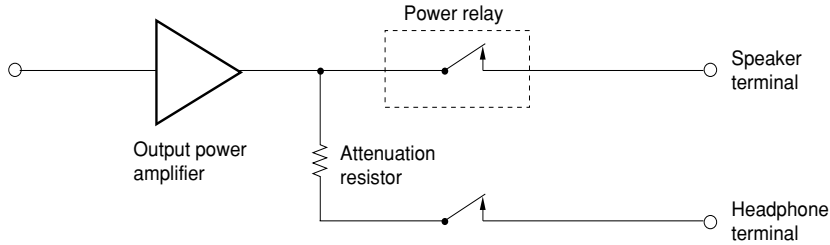
## (2) Audio amplifiers

- **Use of relays**

Relays are used in audio amplifiers as follows:

### <1> Headphone switch

The output of the amplifier can also be connected to the headphones, not only to the speakers. A system that does not produce a dedicated headphone output divides and distributes the amplifier output via resistors and connects it to the headphone via relay contact.

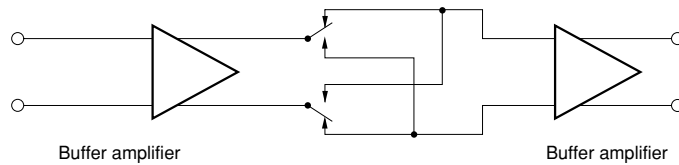


**Figure 25. Example of Using Relays in a Headphone Circuit**

### <2> Phase conversion reverse switch

Sound is generated when the diaphragm of the speaker moves back and forth. The same sound is produced regardless of whether the diaphragm moves backward or forward (this is called a phase). In audio systems for business use or luxury systems, the phases for recording and playback are matched for more faithful reproduction.

Relay contacts are used to reverse the phase in the signal processing circuit of such audio systems.



**Figure 26. Example of Using Relays in a Phase Compensation Circuit**



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### <3> Input selector switch

A selector switch is used to select different audio sources such as CD and tape. As shown in Figure 27, this switch consists of relay contacts connected in parallel. Only the relay contacts corresponding to the selected source are closed, and the signals from the source are transmitted to the output circuit.

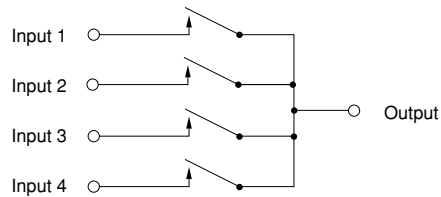


Figure 27. Example of Using Relays in an Input Selector

- **Required specifications of relay**

- 2-transfer contact
- Gold-plated contacts are preferred in luxury audio systems because these contacts do not degrade. In addition, silver-palladium alloy is preferred as the base material of the contacts.
- Contact resistance: 0.1  $\Omega$  MAX.

### (3) CD player

- **Use of relays**

The function to temporarily cut excessive audio signals when selecting the beginning of a track on a compact disc is called muting. Sometimes a relay may be used for this function. When the muting function is selected, the relay contacts are closed. Because the output of the buffer amplifier and output pin are grounded via resistor as shown in Figure 28, no output signal is produced from the pin. In the normal status where the relay contacts are open, the output of the amplifier goes through to the output pin.

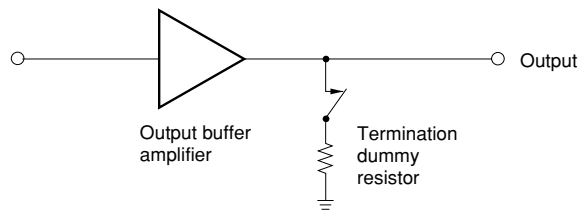


Figure 28. Example of Using Relays in a Muting Circuit

- **Required specifications of relay**

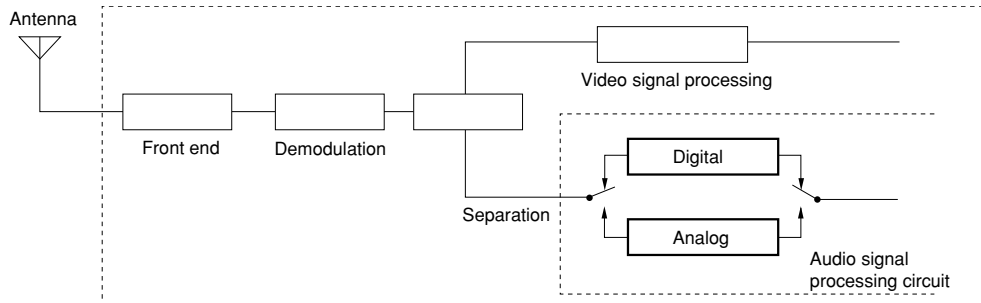
- Insulation resistance between opening contacts: 1000 M $\Omega$  MIN.
- Contact resistance: 1  $\Omega$  MAX.



#### (4) BS tuners

- **Use of relays**

BS tuners and VCRs with a BS function have a digital audio signal processing circuit that supports B-mode digital broadcasting, and either this circuit or analog audio signal processing circuit can be selected. In Figure 29, a relay is used to select either the digital or analog circuit.



**Figure 29. Example of Using Relays in a BS Tuner**

- **Required specifications of relay**

- 2-transfer contact



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## (5) Car navigation

### • Car navigation

The "Audio guide" is one of the functions of a car navigation system. If a car navigation system is provided as a genuine part of a car, the speaker at the side of the driver's seat is used for the "audio guide".

### • Use of relays

Usually, when the radio or compact disc player is being used, the speakers are connected to the audio amplifier via the break contact of the relay. When the "audio guide" is used, they are connected to the audio guide amplifier of the car navigation system via the make contact of the relay.

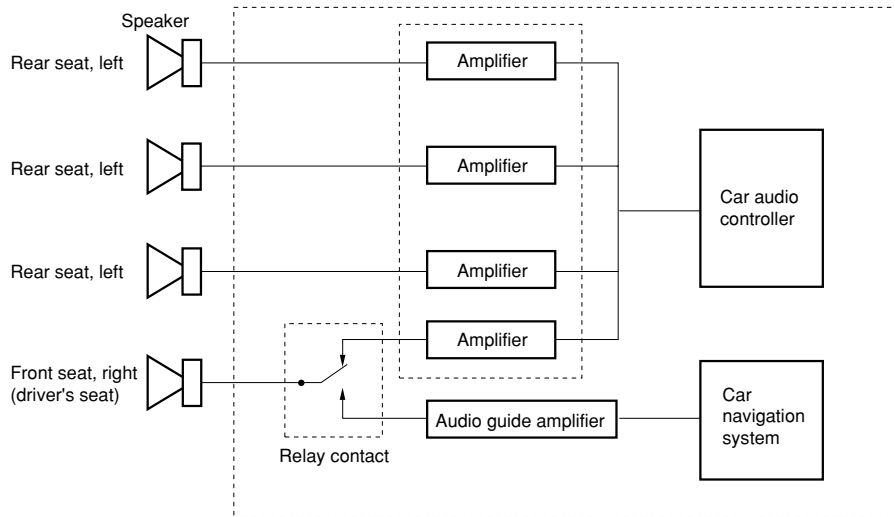


Figure 30. Example of Using Relays in a Car Navigation System

### • Required specifications of relay

- 2-transfer contact
- Contact current: 10 A peak (short time)



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## (6) CS tuner

### • Added function of CS tuner

In multi-channel TV services using CS (communication satellite) broadcasting, viewers can select and choose to pay for certain pay-per-view channels.

In this case, a function that periodically collects and reports billing information to a center via a public telephone line is necessary.

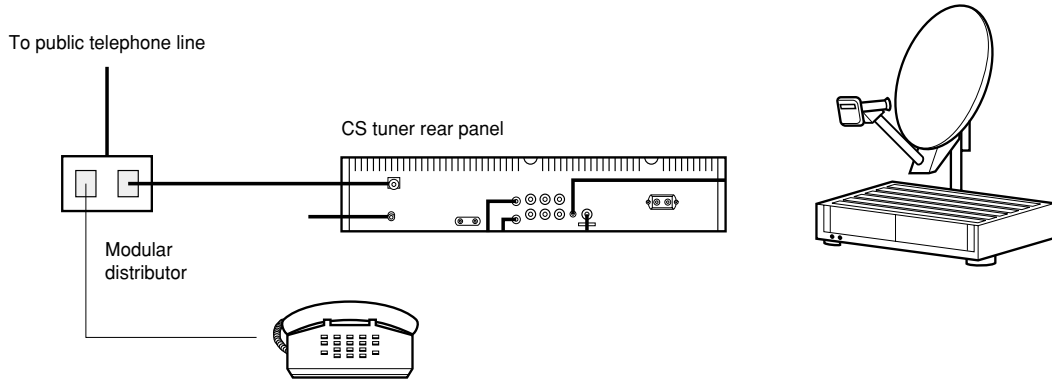


Figure 31. Function of CS Tuner

### • Use of relays

The CS tuner in this system has a modem circuit that provides a communication function, and a relay is used in the NCU circuit of the CS tuner.

In this example, the NCU circuit is simplified. The telephone set and modem are connected in parallel, and the make contact of the relay closes when the modem is used.

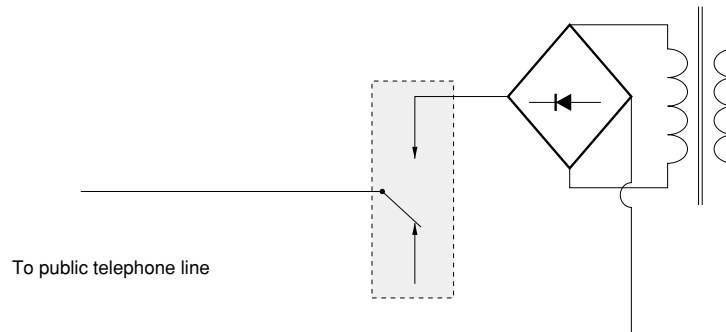


Figure 32. Example of Using Relay in CS Tuner

### • Required specifications of relay

- 1-transfer contact (1 make contact)
- Breakdown voltage between opening contacts: 1000 V.AC MIN.



## (7) DVD player

### • Added function of DVD

If a VCR is connected to a television set that has only one external input terminal, a DVD player cannot be connected at the same time.

If the DVD player has an external extension terminal, however, the player can be connected.

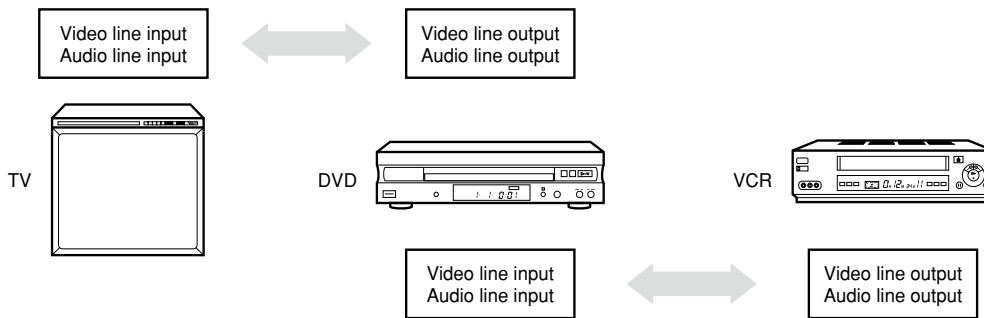


Figure 33. Functions of DVD Player

### • Use of relays

When the DVD player is not in use (when power is not supplied to it), signals from the VCR pass through the break contact of the relay.

When the DVD player is turned on, the relay selects the output of the DVD.

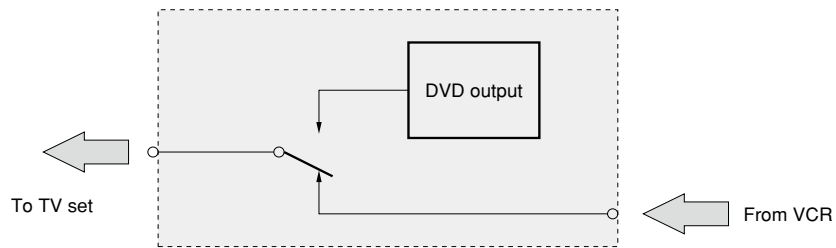


Figure 34. Example of Using Relay in DVD Player

### • Required specifications of relay

- 2-transfer contact
- The video signals must be able to pass without distortion.



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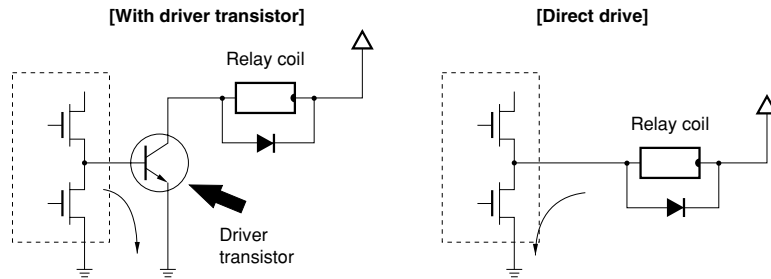


### 3. GUIDE TO USE

#### 3.1 Coil Driver Circuit

##### (1) Basic driver circuit

Signals output from a logic IC may be used via a driver transistor or directly.



The transistor is turned ON by the source current from the logic output.  
 → Relay coils are driven by the collector current of the transistor.

Relay coils are driven by the sink current to the logic output.

##### (2) Direct drive methods and points to be noted

Signals are directly driven by an IC by using the source current or sink current.

Select an IC by taking the current capacity and residual voltage into consideration.

	Operating Status	Releasing Status
Sink current drive		
Source current drive		

Note the output current capacity.

Make sure that the relay is not released by a residual voltage when it is OFF.



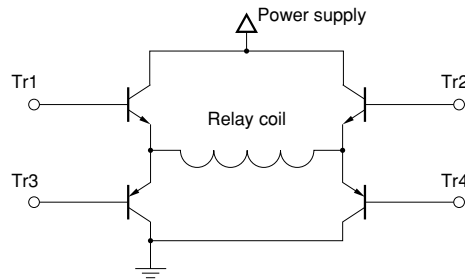
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### (3) Driver circuits of latching relay

- **Single-winding latching relay (1)**

The direction of the current must be changed when a single-winding latching relay is set and when it is reset. The latching relay can be used in the following timing in the following basic circuit using four transistors.

**[Basic circuit]**



**[Timing]**

	Tr1	Tr2	Tr3	Tr4
Set	ON	OFF	OFF	ON
Reset	OFF	ON	ON	OFF

**[Note]**

- Provide appropriate time differences between the complementary transistors (Tr1 and Tr2, and Tr3 and Tr4).
- Use a coil voltage that is within the specified recommended conditions (time width and voltage).



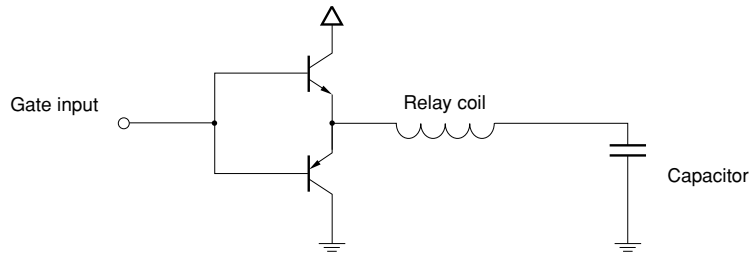
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- **Single-winding latching relay (2)**

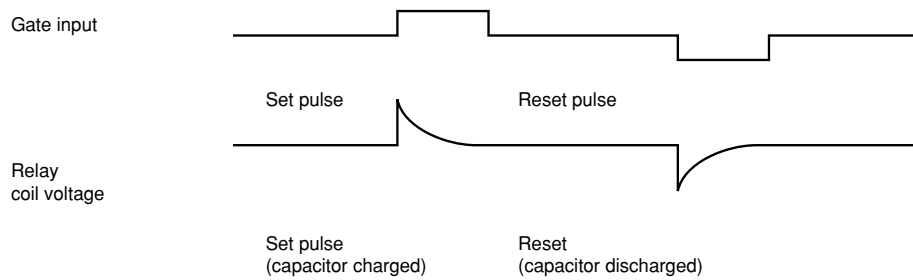
In this example, two transistors, NPN and PNP, are used. These transistors operate complementarily by switching the polarity of the gate input between positive and negative.

In this way, the capacitor is charged and discharged to control the direction of the current flowing through the relay coil.

**[Basic circuit]**



**[Timing]**



**[Notes]**

- Provide an appropriate time differences between the complementary transistors.
- Provide an appropriate time interval between mutual gate inputs so that the capacitor can completely charge and discharge.
- Use a coil voltage that is within the specified recommended conditions (time width and voltage).

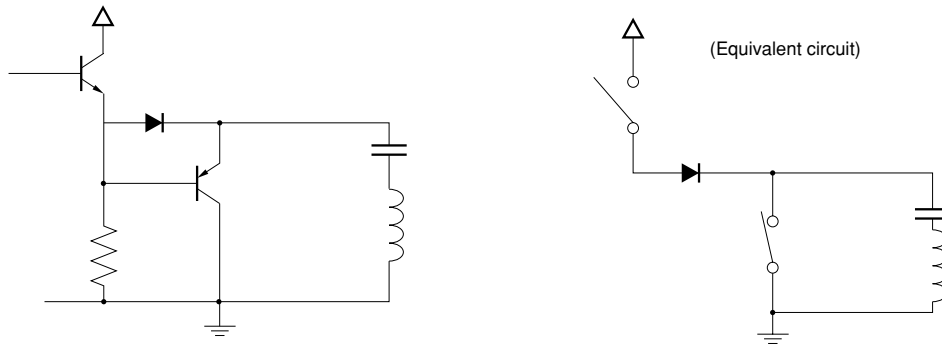


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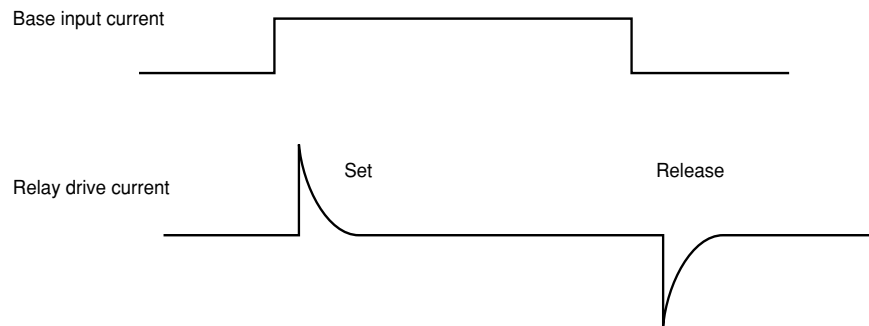
- **Single-winding latching relay (3)**

Unlike the previous example, the gate input is controlled only by the current in the forward direction in this example. The rising/falling of the input of this gate is used as a trigger to charge/discharge the capacitor and to control the direction of the current flowing through the relay coil.

**[Basic circuit and equivalent circuit]**



**[Timing]**



**[Notes]**

- Provide an appropriate time width for the base input so that the capacitor is completely charged and discharged.
- Use a coil voltage that is within the specified recommended conditions (time width and voltage).



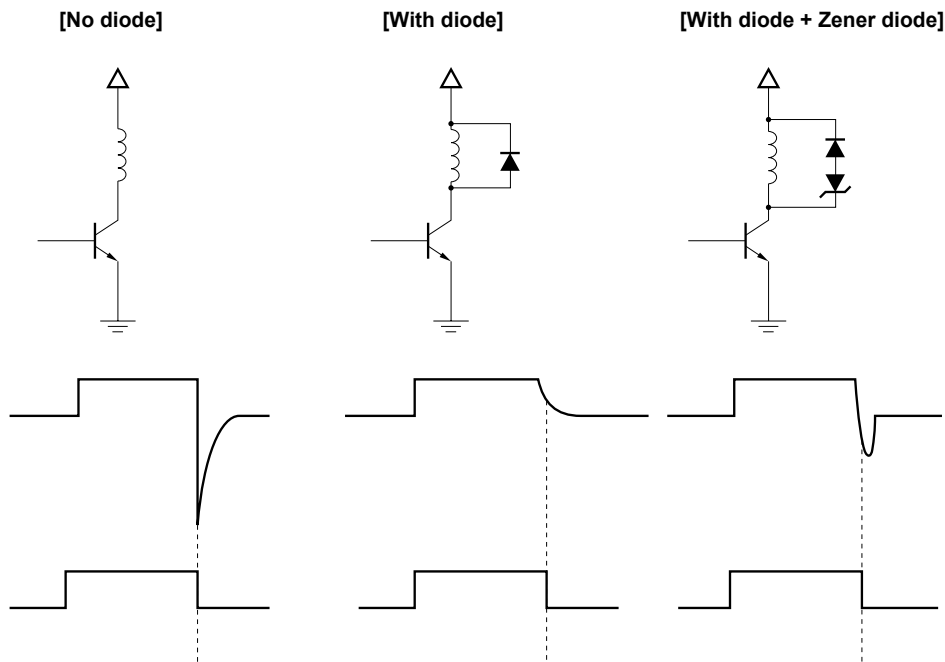
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#### (4) Improving driver circuit

- **Improving resetting time**

Generally, a diode is connected to absorb the counter electromotive force and thereby to protect the transistor that drives the coil. This extends the release time of the relay.

However, the release time can be improved by connecting a Zener diode.

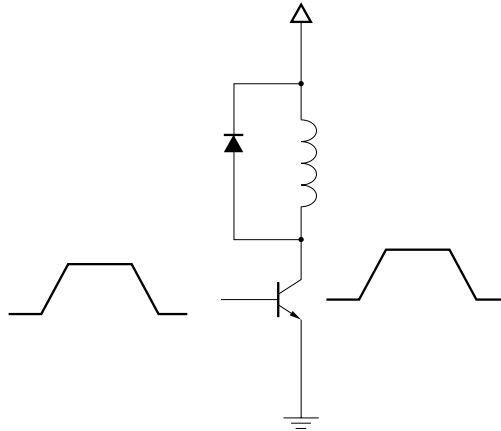


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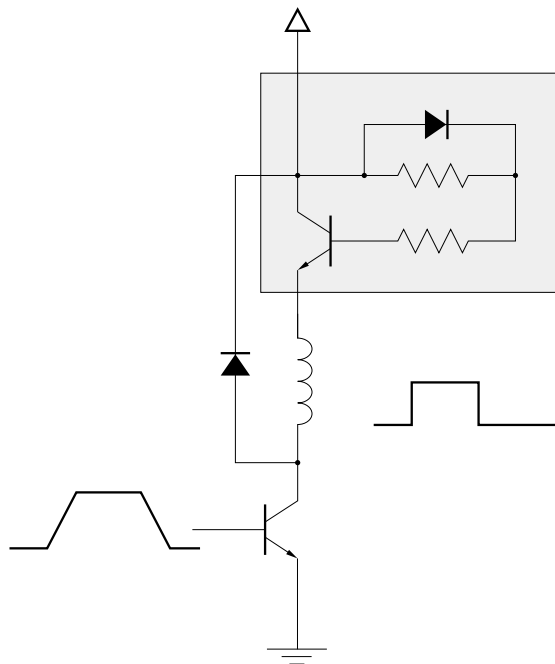
- **Shaping drive wave**

If the rise and fall of wave that drives the relay is slow, the operating mechanism may not completely operate or the bounce time may increase. Consequently, the full performance of the relay may not be utilized. In this case, the wave can be shaped to make the rise and fall of the wave sharper by connecting a waveform shaping circuit.

**[Before improvement]**



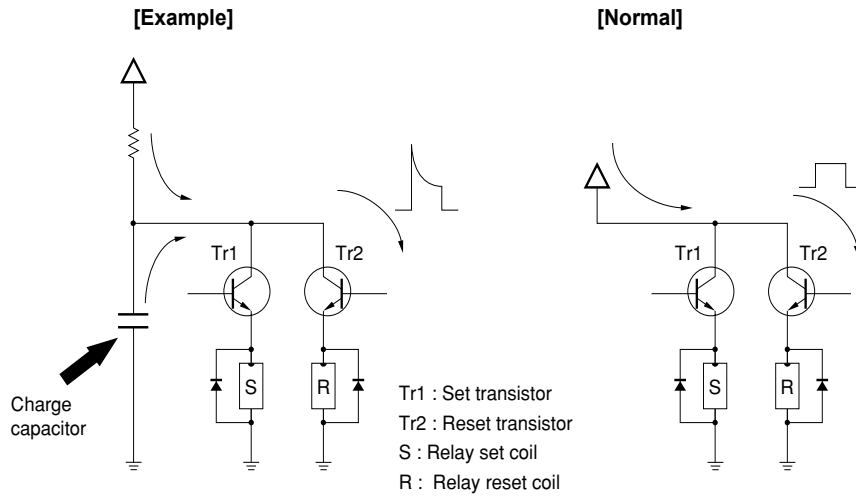
**[After improvement] (with waveform shaping circuit)**



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- **Shortening drive pulse width by using charge capacitor**

The drive pulse width can be shortened by connecting a capacitor to use the discharge current.



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### 3.2 Checking Relay Operation (for safe design)

This section explains a desk-top method of checking the operation of a relay.

#### [Conditions]

Rated coil voltage	: 5 V (power consumption: 140 mW)
Operate voltage	: 3.75 V MAX. (20 °C)
Supply voltage	: 6 V ± 10 % (-10 to +40 °C)
Operating ambient temperature	: +40 °C MAX.
Voltage loss of driver	: 0.6 V MAX.

#### [Calculation example]

##### • Step 1

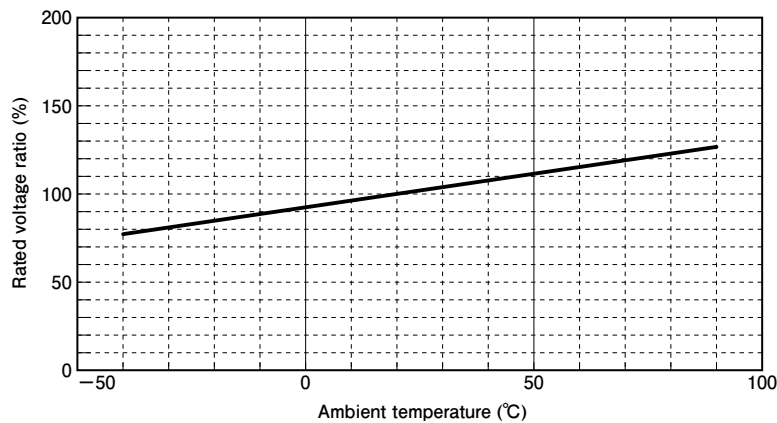
Calculate the minimum voltage at which the coil is driven at a standard temperature, 20 °C.

$$\begin{aligned}\text{Drive voltage} &= (\text{Minimum value of supply voltage}) - \text{Voltage drop of (driver)} \\ &= 6 \text{ (V)} \times (1 - 0.1) - 0.6 \text{ (V)} \\ &= 4.8 \text{ V}\end{aligned}$$

##### • Step 2

Find the operate voltage of the relay at the maximum operating temperature from the technical documentation (change of operate voltage with ambient temperature).

Change of Operate Voltage with Ambient Temperature



From this figure, it can be determined that the relay operates at a voltage of 108 % at 40 °C, as compared with the standard voltage at 20 °C.

Calculate the minimum voltage at 40 °C.

$$\begin{aligned}\text{Guaranteed operating voltage} &= (\text{Operate voltage}) \times (\text{Compensated temperature value}) \\ &= 3.75 \text{ (V)} \times 1.08 \\ &= 4.05 \text{ (V)}\end{aligned}$$

This result indicates that drive voltage: 4.8 (V) > guaranteed operating voltage: 4.05 (V), and therefore, it is confirmed that the relay can operate normally.



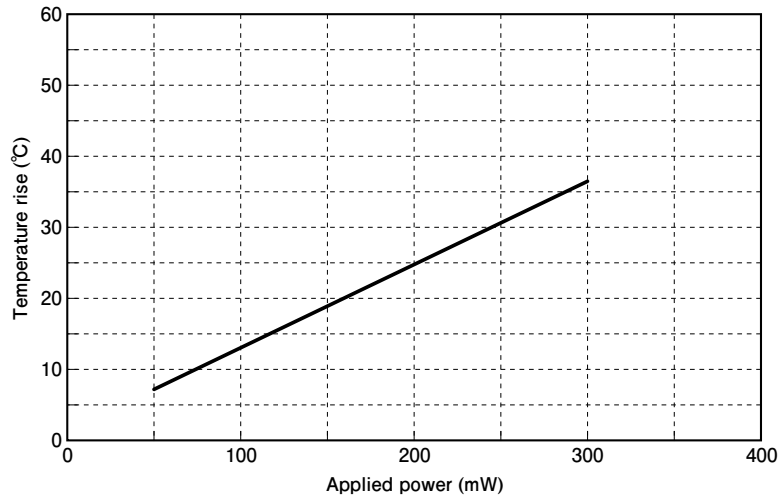
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- **Step 3**

As a hot start condition, the rated voltage is applied to the relay and turned off once the internal temperature of the relay has risen, and then the voltage is applied again to the relay.  
Find the temperature rise of the coil from the technical documentation (coil temperature rise characteristics).

Coil Temperature Rise Characteristics



This chart indicates that the temperature of the relay rises by 18 (°C) at the rated power consumption of 140 mW.

- **Step 4**

- The apparent ambient temperature is as follows where the upper-limit value of the ambient temperature is 40 °C and the temperature of the coil is 18 °C.

$$\begin{aligned} \text{Ambient temperature} &= 40 + 18 \text{ (}^\circ\text{C)} \\ &= 58 \text{ (}^\circ\text{C)} \end{aligned}$$

- At this time, calculate changes in the operate voltage due to the ambient temperature in the same manner as Step 2.  
The relay operates at a voltage of 115 % as compared with the standard condition at 20 °C.
- Calculate the guaranteed operating voltage at this time.

$$\begin{aligned} \text{Guaranteed operating voltage} &= (\text{Operate voltage}) \times (\text{Compensated temperature value}) \\ &= 3.75 \text{ (V)} \times 1.15 \\ &= 4.31 \text{ (V)} \end{aligned}$$

This result indicates that drive voltage: 4.8 (V) > guaranteed operating voltage: 4.31 (V), and therefore, it is confirmed that the relay can operate normally.



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