To our customers,

Old Company Name in Catalogs and Other Documents

On April 1st, 2010, NEC Electronics Corporation merged with Renesas Technology Corporation, and Renesas Electronics Corporation took over all the business of both companies. Therefore, although the old company name remains in this document, it is a valid Renesas Electronics document. We appreciate your understanding.

Renesas Electronics website: http://www.renesas.com

April 1st, 2010
Renesas Electronics Corporation

Issued by: Renesas Electronics Corporation (http://www.renesas.com)

Send any inquiries to http://www.renesas.com/inquiry.

Notice

1. All information included in this document is current as of the date this document is issued. Such information, however, is subject to change without any prior notice. Before purchasing or using any Renesas Electronics products listed herein, please confirm the latest product information with a Renesas Electronics sales office. Also, please pay regular and careful attention to additional and different information to be disclosed by Renesas Electronics such as that disclosed through our website.
2. Renesas Electronics does not assume any liability for infringement of patents, copyrights, or other intellectual property rights of third parties by or arising from the use of Renesas Electronics products or technical information described in this document. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
3. You should not alter, modify, copy, or otherwise misappropriate any Renesas Electronics product, whether in whole or in part.
4. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation of these circuits, software, and information in the design of your equipment. Renesas Electronics assumes no responsibility for any losses incurred by you or third parties arising from the use of these circuits, software, or information.
5. When exporting the products or technology described in this document, you should comply with the applicable export control laws and regulations and follow the procedures required by such laws and regulations. You should not use Renesas Electronics products or the technology described in this document for any purpose relating to military applications or use by the military, including but not limited to the development of weapons of mass destruction. Renesas Electronics products and technology may not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations.
6. Renesas Electronics has used reasonable care in preparing the information included in this document, but Renesas Electronics does not warrant that such information is error free. Renesas Electronics assumes no liability whatsoever for any damages incurred by you resulting from errors in or omissions from the information included herein.
7. Renesas Electronics products are classified according to the following three quality grades: "Standard", "High Quality", and "Specific". The recommended applications for each Renesas Electronics product depends on the product's quality grade, as indicated below. You must check the quality grade of each Renesas Electronics product before using it in a particular application. You may not use any Renesas Electronics product for any application categorized as "Specific" without the prior written consent of Renesas Electronics. Further, you may not use any Renesas Electronics product for any application for which it is not intended without the prior written consent of Renesas Electronics. Renesas Electronics shall not be in any way liable for any damages or losses incurred by you or third parties arising from the use of any Renesas Electronics product for an application categorized as "Specific" or for which the product is not intended where you have failed to obtain the prior written consent of Renesas Electronics. The quality grade of each Renesas Electronics product is "Standard" unless otherwise expressly specified in a Renesas Electronics data sheets or data books, etc.

   "Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; and industrial robots.

   "High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control systems; anti-disaster systems; anti-crime systems; safety equipment; and medical equipment not specifically designed for life support.

   "Specific": Aircraft; aerospace equipment; submersible repeaters; nuclear reactor control systems; medical equipment or systems for life support (e.g. artificial life support devices or systems), surgical implantations, or healthcare intervention (e.g. excision, etc.), and any other applications or purposes that pose a direct threat to human life.
8. You should use the Renesas Electronics products described in this document within the range specified by Renesas Electronics, especially with respect to the maximum rating, operating supply voltage range, movement power voltage range, heat radiation characteristics, installation and other product characteristics. Renesas Electronics shall have no liability for malfunctions or damages arising out of the use of Renesas Electronics products beyond such specified ranges.
9. Although Renesas Electronics endeavors to improve the quality and reliability of its products, semiconductor products have specific characteristics such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Further, Renesas Electronics products are not subject to radiation resistance design. Please be sure to implement safety measures to guard them against the possibility of physical injury, and injury or damage caused by fire in the event of the failure of a Renesas Electronics product, such as safety design for hardware and software including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult, please evaluate the safety of the final products or system manufactured by you.
10. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. Please use Renesas Electronics products in compliance with all applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive. Renesas Electronics assumes no liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
11. This document may not be reproduced or duplicated, in any form, in whole or in part, without prior written consent of Renesas Electronics.
12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products, or if you have any other inquiries.

(Note 1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its majority-owned subsidiaries.

(Note 2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.

\PPLICATION NOTE

RENESAS

HOW TO USE ZERO VOLTAG_ ...

"μPC1701C"

1. INTRODUCTION

Zero Voltage Switch "μPC1701C" is a bipolar analog integrated circuit to provide zero voltage switching control of resistance loads when used with triacs.
Zero Voltage Switching is a method of switching ON and OFF only at the zero crossing points of the sinusoidal, 50 or 60 Hz waveform.
This largely eliminates the radio frequency interference (RFI) problem.
The μPC1701C is suitable for mains-on-line operation and requires minimal external components, therefore allow simplification of circuitry and improvement in performance of control circuit.
The device is particularly suited for use in such applications as electric heating, range oven controls, hair dryers, oven in general, and industrial temperature control equipments.
Here we present a outline of zero voltage switching designs using Zero Voltage Switch (ZVS) "μPC1701C".

2. THE NECESSITY OF ZVS

AC power controller using triac is generally constructed as shown in Fig. 1. There are two ways which control AC power. One of the way is phase control shown in Fig. 2 (a) which is controled by varying phase angle.
The other one is zero voltage switching shown in Fig. 2 (b) which is controled by varying ON-OFF frequency with triggering triac at zero voltage point.
Phase control is possible to vary AC power continuously 0~100 % in half cycle of AC power supply, therefore, precision and response are well.
This is using in such applications as light dimmer, motor speed control and electric heating control.
However, abrupt current produces electromagnetic interference (EMI), when the triac turn on, and cause high frequency interference at specially radio frequency band.
Phase control will require adequate filtering in order to hold EMI within acceptable limits.
Such filters can become rather large and expensive and since it is anticipated that the allowed limits on EMI will decrease.
On the contrary, Zero Voltage switching, load current varies gradually following AC supply voltage waveforms, therefore it is possible to control AC power without RFI.
However this is not suitable for use in light dimmer, because this is ON-OFF control.

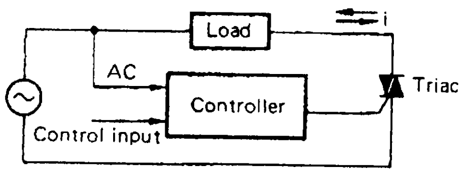


Fig. 1 AC Power Controller by Triac

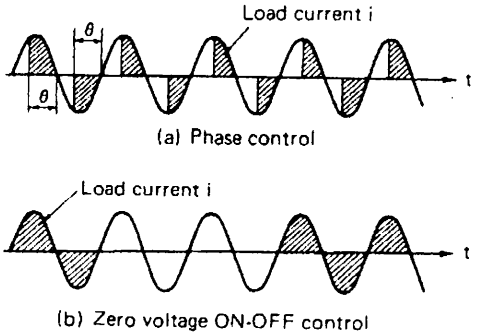


Fig. 2 Phase Control and Zero Voltage ON-OFF Control

The information in this document is subject to change without notice.

ent No. SEA-1201A
. D. No SEA-515)
'ublished December 1989 M
in Japan

© NEC Corporation 1981

3. OUTLINE OF ZVS "μPC1701C"

Fig. 3 shows a block diagram of μPC1701C, Fig. 4 shows a pin connections and the equivalent circuit is shown in Fig. 5. The features are as follows:

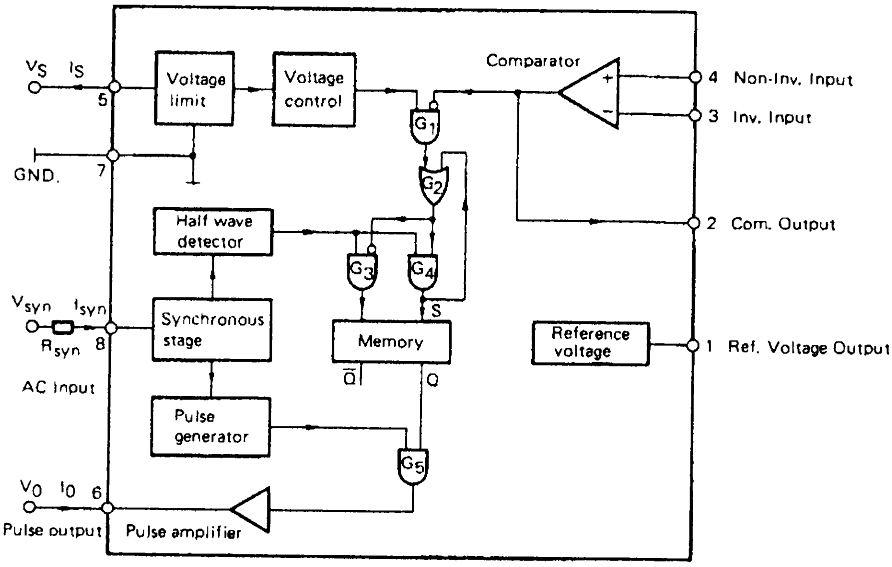
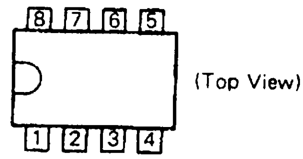


Fig. 3 Block Diagram



Pin No.	Function
1	Ref. Voltage Output
2	Com. Output
3	Inv. Input
4	Non-Inv. Input
5	V_S
6	Pulse Output
7	GND.
8	AC Input

Fig. 4 Pin Connections

- Symmetrical burst control
  Symmetrical burst control (each one cycle control, not half-cycle) – no DC current components in the load circuit.
- Enough output trigger pulse for triacs
  Negative output current pulse up to 250 mA with short circuit protection, and pulse widths is a few 100 μs.
- Prevention function of mistrigger
  Including low voltage detector – never generate mistrigger pulse, when the supply voltage for IC is low (ex. just after switched ON).
- Wide input common-mode range
  Comparator input constructed by PNP Transistors – wide input common-mode range.
  With output terminal of open collector – it is possible to adjust hysteresis.
- For resistive load
  μPC1701C is only for resistive load, because this IC is zero voltage detective type of AC supply voltage.

And absolute maximum ratings and electrical characteristics are shown in Table 1, 2.

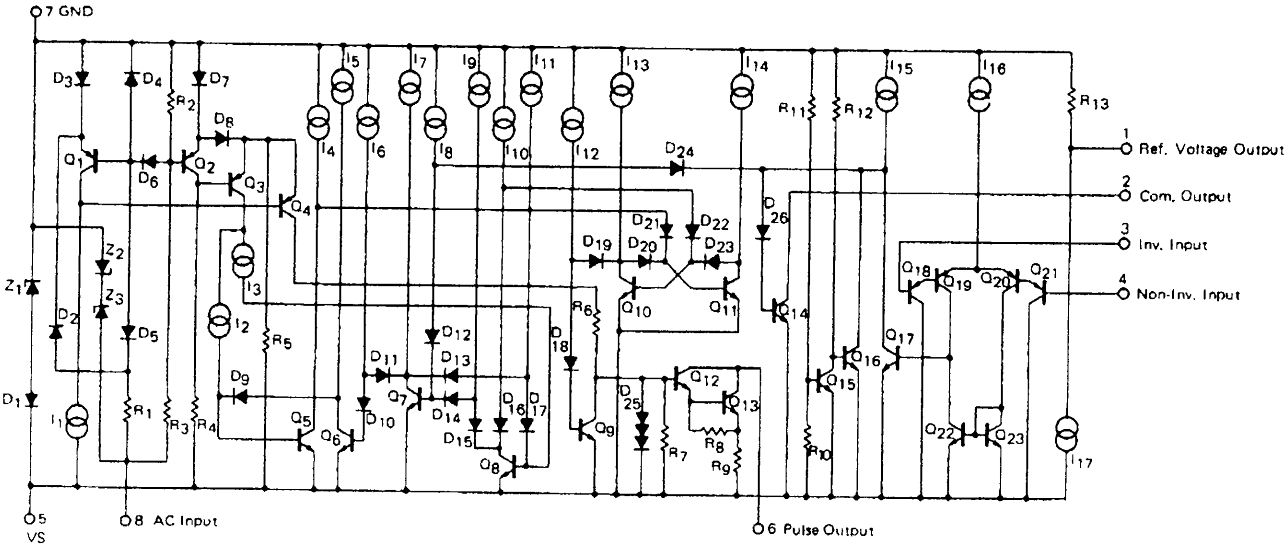


Fig. 5 Equivalent Circuit "μPC1701C"

Table 1 Absolute Maximum Ratings (Ta=25 °C)

ITEMS	SYMBOL	CONDITIONS	RATINGS	UNIT
Supply Voltage	Vs	External DC power supply terminal 7 – 5	–8.0	V
Average Supply Current	Is	External power supply	–40	mA
RMS Synchronous Current	Isyn	Commercial frequency power supply terminal 7 – 8	5.0	mA
Input Voltage	V_I	Terminal 7 – 1, 7 – 3, 7 – 4, 7 – 8	≦ |Vs|	V
Junction Temperature	T_j	–	125	°C
Operating Ambient Temperature	Topt	–	–20 ~ 70	°C
Storage Temperature	Tstg	–	–40 ~ 125	°C
Power Dissipation	P	–	350	mW

Table 2 Electrical Characteristics (Ta=25 °C, Vs=8 V, Vsyn=100 V_{RMS}, f=50~60 Hz)

ITEMS	PIN. NO.	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Circuit Current	Pin 5	$-I_S$	–	2.0	2.5	mA	Rsyn=56 kΩ
Supply Voltage 1	Pin 5	$-V_{S1}$	8.3	–	9.5	V	I_S=2.5 mA, Rsyn=56 kΩ
Supply Voltage 2	Pin 5	$-V_{S2}$	8.2	–	9.6	V	I_S=20 mA, Rsyn=56 kΩ
Synchronous Current	Pin 8	I_{syn}	0.3	–	–	mA	
Output Pulse Width	Pin 6	t_p	–	200	–	μs	Rsyn=56 kΩ
Output Voltage	Pin 6	V_o	5.0	6.0	–	V	I_o≦200 mA
Output Current	Pin 6	I_o	200	250	–	mA	R_o≦25 Ω
Output Leakage Current	Pin 6	I_{LO}	–	–	2.0	μA	
Input Offset Voltage	Pin 3, 4	V_{IO}	–	2.0	5.0	mV	
Input Bias Current	Pin 3, 4	I_I	–	0.5	1.0	μA	
Common Mode Input Voltage Range	Pin 3, 4	$-V_{ICM}$	0	–	6.5	V	
Output Leakage Current	Pin 2	I_{LC}	–	–	0.2	μA	
Reference Voltage	Pin 1	$-V_R$	3.7	4.0	4.2	V	I_R≦1 μA

4. ZERO VOLTAGE ON-OFF CONTROL CIRCUIT AND μPC1701C

Basic constitution of zero voltage control circuit using ZVS "μPC1701C" is shown in Fig. 6.
ZVS is connected to AC line directly, so this circuit requires minimal external components.
Basically the circuit operation is as follows: (see Fig. 3)
Near the zero point of AC supply voltage, Amplifier Q_1 supplies the triac triggering current (negative gate drive) from zero voltage detector which is composed of the synchronous stage and the pulse generator, and also the triac triggering current is controled ON or OFF by output signal of the Comparator.
More detail of circuit operation is as follows:

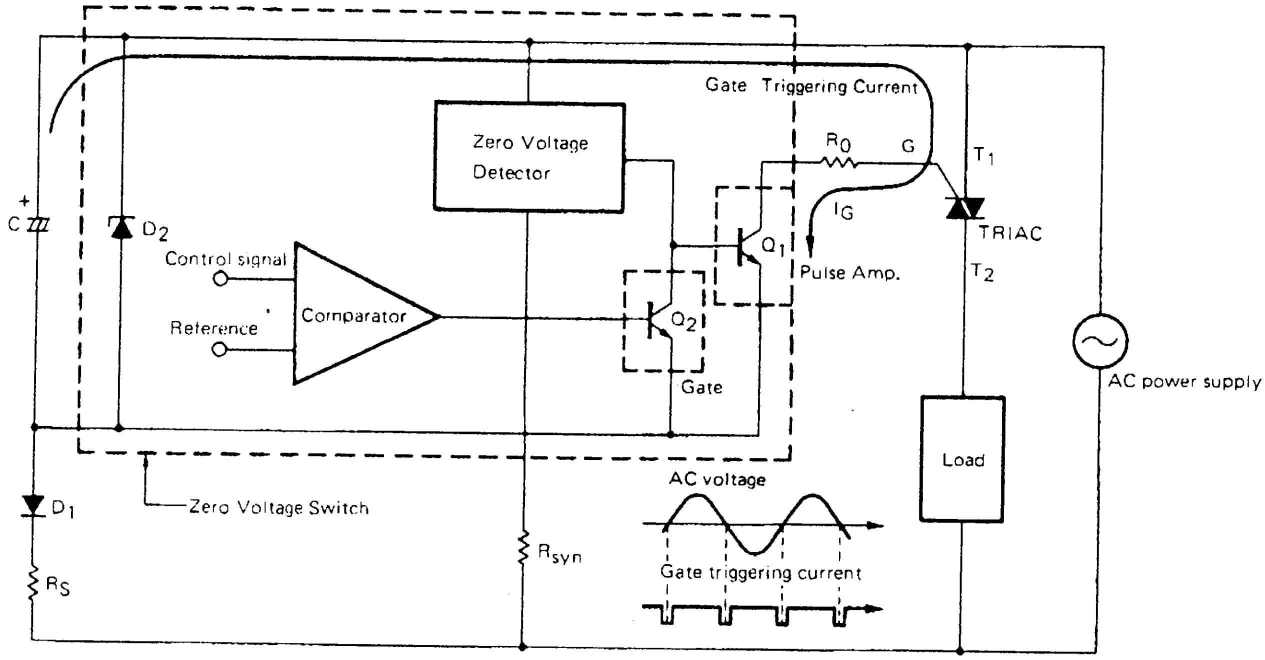


Fig. 6 Zero Voltage ON-OFF Control Circuit

– Application Example –

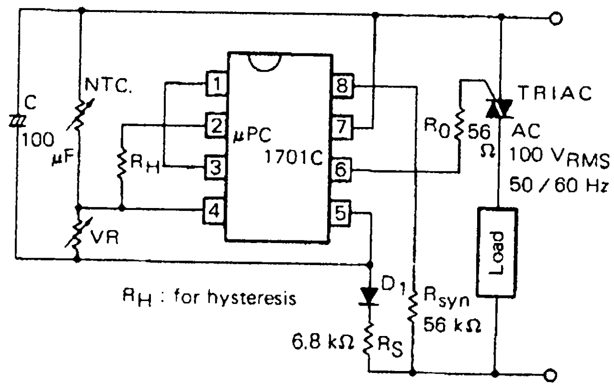


Fig. 7 ON-OFF Temperature Control Circuit

1) Power supply of ZVS

In Fig. 6, the power supply capacitor C is charged up to the zener voltage (V_Z) of D_2 through diode D_1 and Rs, typically 8.5~9.0 V.

The circuit current (Icc) of one cycle controled logic, comparator, etc. connected in parallel to D_2 is max. 2.5 mA at 8.0 V. Supply voltage Vs of absolute maximum rating in Table 1 is specified only by using external DC power supply with over 40 mA power supply current (Is), because over 40 mA current destroy the D2.

Average DC voltage of half wave rectifier circuit is 45 % of R.M.S. AC power supply voltage (V_{RMS}), therefore the current (Is) flowing into ZVS is;

$$Is = (0.45\ V_{RMS} - V_Z)/Rs \qquad \text{.....................} \quad (1)$$

Example, Rs = 20 kΩ (V_{RMS} = 100 V, Vz = 9 V), Is = 1.8 mA

But Is is lower than the circuit current (2.5 mA), so it is necessary to decrease Rs value in the range of max. 40 mA Is, because no current flow into zener diode D2 and it is impossible to get normal circuit conduct.

Rs is determined by thinking about a sensor current and gate triggering average current (will be discussed later).

2) Zero point detect and triac trigger

The zero voltage detector (in Fig. 6) is in the biased state wherein the AC voltage across the Rsyn is applied.

Only at point near the zero voltage, output signal of the zero voltage detector turns on Q2.

Triac gate triggering current supply from capacitor C through T1 terminal, G terminal, Ro, and Q1.

Regarding Fig. 7 (one of the application circuit), Zero point is detected by AC voltage applied ZVS terminals between 8 and 7, and equivalent transistor which is shown in Fig. 6, Q1 is included in terminal between 6 and 5.

This transistor switch has a constant current characteristic and can flow the current minimum 200 mA.

Ro is determined by thinking about triac gate sensitivity and power consumption of Ro.

3) Comparator

Another important function is comparator which controls triggering pulse ON-OFF.

When output of comparator is low level in Fig. 6, Q2 is off and triggering pulse flows through Ro and Q1 by output signal of zero voltage detector.

In real circuit, as shown in Fig. 3, there is one cycle control function which is composed of memorys G1~G4 after output of the comparator.

In Fig. 7 the comparator in μPC1701C compares the reference voltage of the inverting input terminal 3 with the voltage of the noninverting input terminal 4 which is devided by variable resistance VR and temperature sensor NTC (negative temperature coefficient thermistor).

4) Rsyn, Rs, Ro and C design in Fig. 6, 7

(1) Rsyn value

Triac gate triggering pulse width tp is changed by Rsyn value.

Example, at V_{RMS} = 100 V,

Rsyn = 20 kΩ	–	tp ≒ 150 μs
Rsyn = 56 kΩ	–	tp ≒ 200 μs
Rsyn = 100 kΩ	–	tp ≒ 300 μs,

But the tp is produced at zero point of AC voltage as a center, so 1/2 tp is efficiency for triggering the triac. Rsyn is designed so that $1/2tp > t_L$ (latching time of the triac). Latching time t_L is determined employing equation (2).

$$I_{LOAD} = (\sqrt{2}\ V_{RMS}/R_L) \sin \omega t \geq I_{Latch} \qquad \text{.....................} \quad (2)$$

(R_L; Load resistance, I_{Latch}; triac latching current)

The other way making tp wider is a capacitor Csyn connection between terminal 7 and 8.
(Csyn; 1000 pF~20000 pF, 25 V)

(2) Ro value

Ro is determined employing equation (3).

$$I_{GT} < I_G = \{8.5 - (V_{GT} + V_{6-5})\}/R_0 \quad \text{.........................} \quad (3)$$

I_{GT} ; triac gate trigger current (thinking about temperature characteristic)
I_G ; triggering current for triac (Peak value)
8.5 ; charging voltage of C
V_{GT} ; triac gate trigger voltage
V_{6-5} ; voltage between terminal 6 and 5, about 1 V

(3) Rs value

Rs is determined employing equation (4), (5), (6)

$$I_{G(AV)} = 2 \times I_G \times tp \times f \quad \text{.................................} \quad (4)$$

f; frequency of AC supply

$$Is = Icc + I_{G(AV)} + I(sensor) \quad \text{................................} \quad (5)$$

Icc ; circuit current of ZVS, 2.5 mA max.
I(sensor); sensor current

$$Rs \leq (0.45\, V_{RMS} - 9)/Is \quad \text{............................} \quad (6)$$

Rs consumption power is shown as equation (7)

$$Ps = (V_{RMS} - 9)^2/2Rs \quad \text{....................} \quad (7)$$

(4) C value

It is possible to use 100 μF until Is is about 4 mA. But we recommend using 220 μF and the capacitor voltage is enough to be 15 V.

(5) Reference voltage

The circuit shown in Fig. 7 is using a included reference voltage in ZVS (connected terminal 1 and 3).
If it is necessary to control more precision, it is better to connect the terminal 3 to divided resistor between terminal 7 and 5.

(6) Hysteresis design

Hysteresis is set up by R_H which is connecting to output terminal 2 (open collector) as shown in Fig. 8. When a resistance of the thermistor is high in low temperature, transistor Q_{14} is On, V_R and R_H is connected in parallel. As temperature increase, voltage of terminal 4 becomes to be higher than voltage of terminal 3 and Q_{14} to be OFF.
Therefore, the voltage of terminal 4 is higher than the parallel voltage of V_R and R_H.

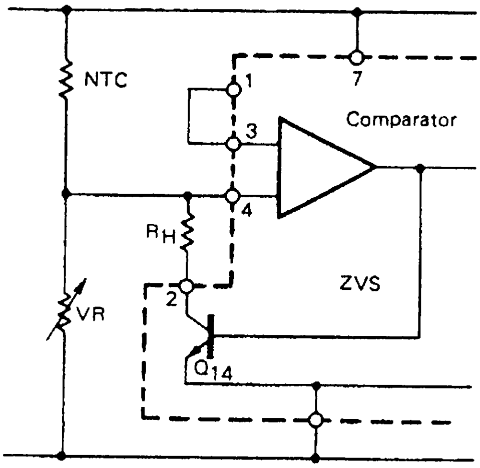


Fig. 8 Hysteresis Circuit

5. TIME PROPORTIONAL CONTROL WITH ZERO VOLTAGE SWITCHING

Fig. 9 is an example of time proportional control using "μPC1701C".
In this circuit the modulation generator is a rélaxation oscillator, using the N13TI Programmable Unijunction Transistor (PUT), which produces a sawtooth waveform with a period determined by R_TC_T.
The gate voltage of PUT is determined by R_R between terminal 1 and 7, which is reference voltage at open (∞) and 2 V at 39 kΩ.
This resistor is used for setting limits to voltage terminal 3 (comparator input terminal) and terminal 4, because common mode input voltage range of comparator is from a voltage terminal 5 to 1.5 V under voltage terminal 7.
Capacitor 0.1 μF between terminal 3 and 4 is used for prevention of wrong operation which repeat ON-OFF every one cycle, when OFF change to ON.

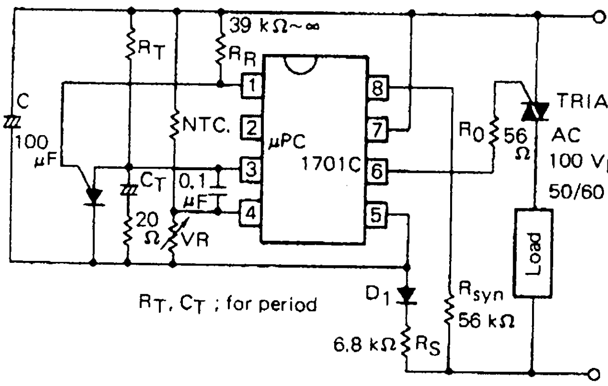


Fig. 9 Time Proportional Temperature Control Circuit

6. OTHER APPLICATION

Fig. 10 is an example of solid state relay application. One more terminal (synchronize input) is necessary, but it is possible to set up hysteresis by comparator, so that ON-OFF operation will be smooth as compared with analogue variation of photo diode.
Fig. 11 is an application for SCR. Fig. 12 is also for SCR, triggering pulse is only generated in half cycle, SCR anode positive.
Fig. 13 is triac triggering circuit which terminal 5 is connected directly to AC line. Triggering pulse is only generated in half cycle, triac T_2 positve, so that it is necessary to delay triggering pulse by connection C_1 or C_2.
Be careful with noise, because this circuit is not complete zero voltage switch.

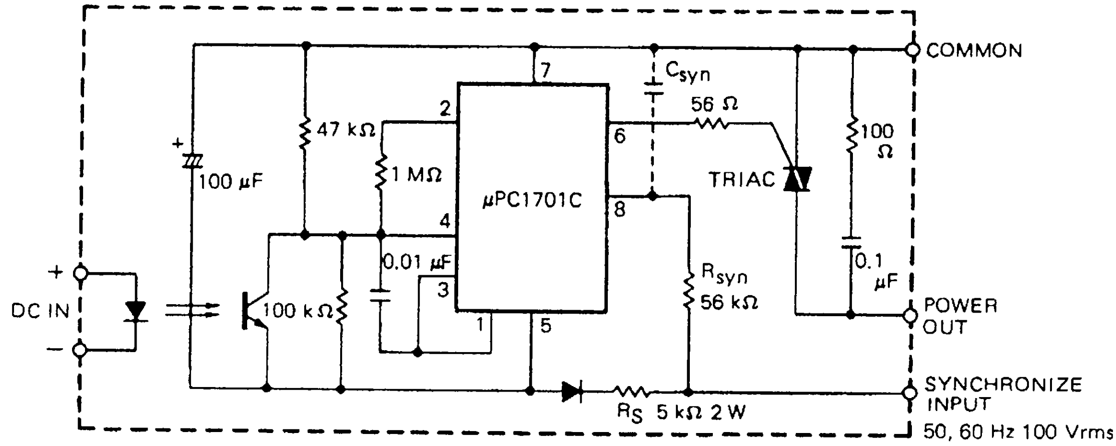


Fig. 10 Solid State Relay

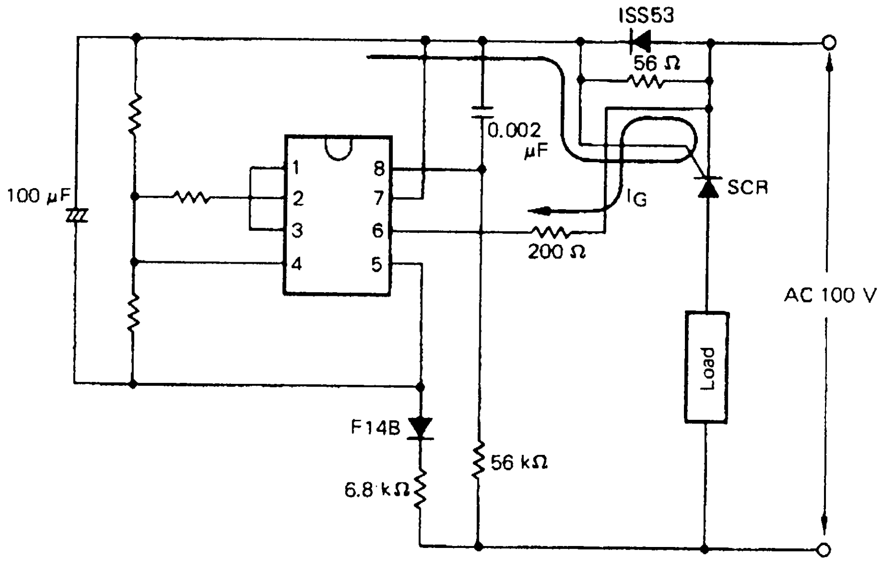


Fig. 11 Zero Voltage SCR Triggering Circuit

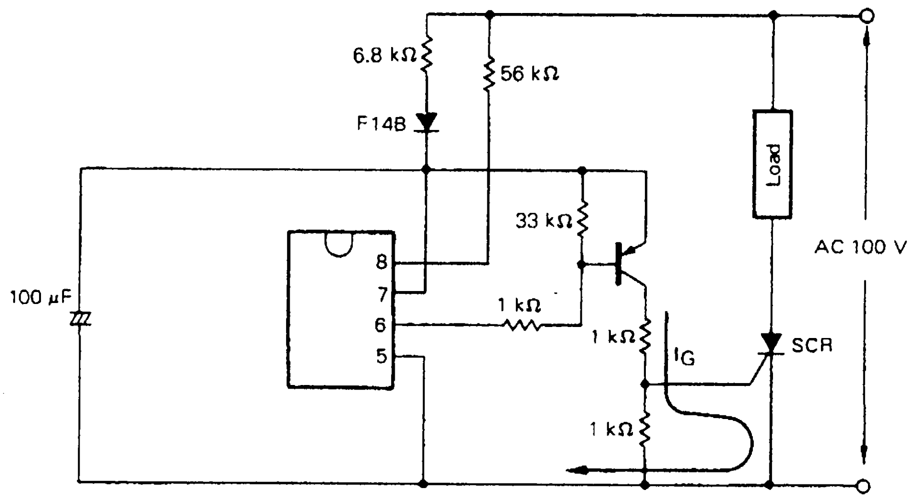


Fig. 12 SCR Triggering Circuit with Direct Connection Terminal 5 on Line

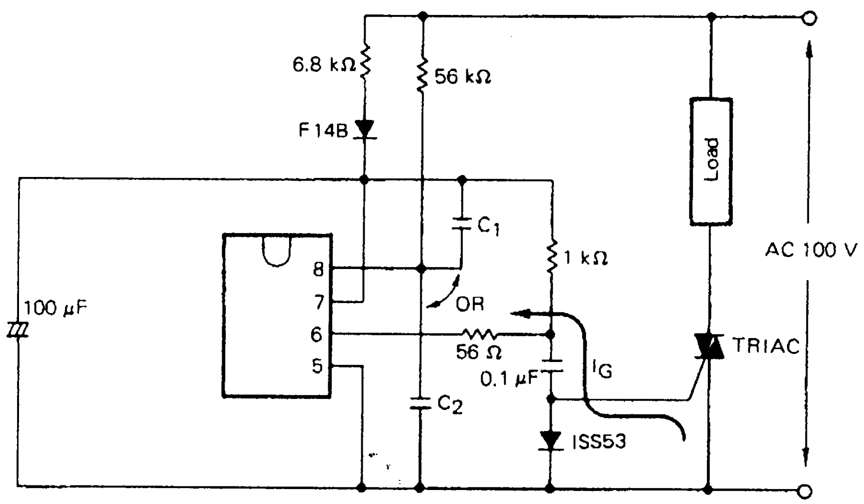


Fig. 13 Triac Triggering Circuit with Direct Connection Terminal 5 on Line

No part of this document may be copied or reproduced in any form or by any means without the prior written consent of NEC Corporation. NEC Corporation assumes no responsibility for any errors which may appear in this document.
NEC Corporation does not assume any liability for infringement of patents, copyrights or other intellectual property rights of third parties by or arising from use of a device described herein or any other liability arising from use of such device. No license, either express, implied or otherwise, is granted under any patents, copyrights or other intellectual property rights of NEC Corporation or of others.

The application circuits and their parameters are for references only and are not intended for use in actual design-in's.