

Input Sensing Circuit Design for OM1654

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Input Sensing Circuit Design for OM1654

AN004**CONTENTS**

1	SUMMARY
2	INTRODUCTION
3	STANDARD INPUT CIRCUIT CONFIGURATION
3.1	Considerations for sensor circuit design.
3.2	Example
3.3	Further comments:
3.4	OM1668 – Implementation in Thick Film Hybrid.
4	BRIDGE INPUT SENSING CIRCUIT FOR IMPROVED ACCURACY.
4.1	Typical bridge sensing circuit.
4.2	Guidelines for bridge component selection.
4.2.1	Resistors R11 and R12
4.2.2	Control potentiometer RV
4.2.3	Resistor R14
4.3	OM1677 – Hybrid thermostat control –bridged input.
5	ALTERNATIVE INPUT CIRCUIT ARRANGEMENTS:
6	REFERENCES
7	DEFINITIONS
8	IES INFORMATION

Input Sensing Circuit Design for OM1654

AN004

1 SUMMARY

The operating principles of the input sensor circuit requirements of OM1654 are discussed. Such sensing circuits are suited to applications requiring triac control of medium and high power resistive heating loads. The OM1654 offers the simplicity of direct mains operation via two high ohmic resistors, affording inherent immunity to mains-born transients and significantly reduced power dissipation.

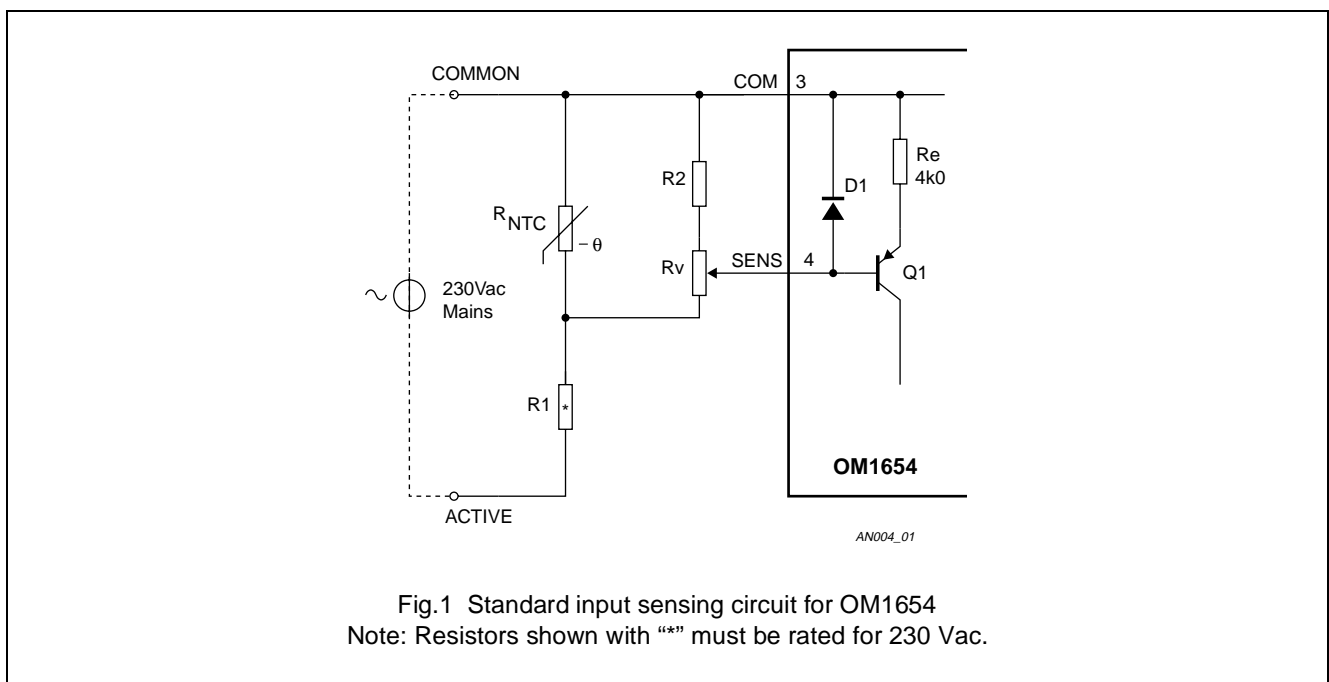
2 INTRODUCTION

The OM1654 is a simple zero-crossing triac control circuit, suitable for driving resistive (heating) loads. In a typical application the circuit is powered directly from the mains supply, via high ohmic supply resistors. The input sensing circuit of the OM1654 is intended to be used in conjunction with an NTC (negative temperature coefficient) temperature sensor, and control potentiometer. It is best suited to controlling heating appliances which require a large temperature control range (i.e. fry-pan, hot-plates etc.), where high accuracy is not a requirement. Also accuracy is supply voltage and IC temperature dependent. For more accurate temperature control applications, the OM1682 with bridge input is recommended.

3 STANDARD INPUT CIRCUIT CONFIGURATION

The typical input sensing circuit arrangement for the OM1654 is shown in Fig.1, with Q1, D1 & Re representing the equivalent OM1654 input circuit (ignoring additional functional and protection components). This is the circuit associated with the input "SENS" pin (i.e. pin 4). The input circuit normally is referenced to the common (neutral) line of the mains supply. Only negative half cycles are used for the sensing, with positive half cycles clamped by diode D1.

The external sense circuit consists of the NTC sensor (R_{NTC}) in a resistor divider network across the AC supply. A voltage is applied to the NTC via dropping resistor R1 connected to the mains "active". The control signal to "SENS" is provided by the potentiometer Rv, with R2 used to limit the control range.



Input Sensing Circuit Design for OM1654

AN004

3.1 Considerations for sensor circuit design.

The OM1654 data sheet (reference 1, page 6) shows the range of input voltages required to provide various duty cycles on the output. For convenience the information is given here in table 1.

Table 1

SENS VOLTS (RMS)	DUTY CYCLE
0.5	5%
0.52	25%
0.54	50%
0.58	75%
0.80	95%
0.92	100%

It can be seen that the control characteristic is not completely linear, and that the control range centres around an input voltage of 550mV rms (for 50% duty cycle), with most of the control provided over a range of ±50mV. Therefore the simplest approach to designing the input sensing circuit is to provide an input voltage of nominally 550mV (rms) at the required control temperature.

The procedure for designing the input sensing circuit is as follows:

1. Start by choosing an NTC which will provide a useful resistance at the control temperature, normally in the range of 2kΩ to 5kΩ. The value chosen for R_{NTC} will affect the value required for R1 (see 3 below), so it is best to keep R1 in the range of 220kΩ to 1M, so that suitable mains rated resistors can be used (for example Philips VR25 and VR37 series).
2. Establish (by calculation, measurement, or from data sheet table) the resistance value of the NTC sensor at each end of the proposed control range (i.e. for both maximum and minimum control temperatures).
3. For maximum accuracy (that is maximum voltage change for change in NTC resistance), select the total series resistance of R_V+R2 to be approximately equal to 10x the resistance value of R_{NTC} at the coldest point of the control range (i.e. at maximum NTC resistance). This gives minimal loading across the NTC.
4. Select a value for mains dropping resistor R1, which will provide the necessary input sense voltage (i.e. 550mV) across the total parallel resistance of R_{NTC}//(R_V+R2), using a value for the NTC resistance (R_{NTC}) which corresponds to the **highest** temperature in the

control range (i.e. when the potentiometer wiper is set to the "maximum" temperature position).

5. Knowing the total series resistance for R_V+R2, calculate a value for R2 which will provide a voltage on the junction of R_V and R2 equal to the required sensor input voltage (i.e. 550mV), using a value for the NTC resistance (R_{NTC}) which corresponds to the **lowest** temperature in the control range (i.e. when the potentiometer wiper is set to the "minimum" position).
6. Determine a value for the control potentiometer by taking the difference between the total control resistance (R_V+R2) evaluated in (section 3) above, and the calculated value for R2 (section 5 above).

This may be an iterative process, to find values that allow available standard potentiometer and NTC values to be used.

3.2 Example

Design the input sensing components for a controller using the OM1654, to control a heating load, to provide a control range of 0 to 40°C.

1. Since the mid point of the control range is 20°C we will use an NTC with a resistance of 2k2 @ 25°C. (e.g. Philips type 2322-640-64222, which has a β value of 3977).
2. Using the simple NTC formula

$$R_T = R_{25} \cdot e^{\beta \cdot (1/T - 1/298)}$$

(where T is the sensed temperature in °K) we can calculate the NTC resistance value (R_{NTC}) for the end points of the control range:

$$\begin{aligned} \text{At } T = 0^\circ\text{C} \quad R_{NTC} &= 7\text{k}47 \\ \text{At } T = 40^\circ\text{C} \quad R_{NTC} &= 1\text{k}16 \end{aligned}$$

3. For maximum accuracy (as per section 3.1-3 above) we can choose the value of the total resistance of the control potentiometer and series resistor (R_V+R2) to be equal to approximately 10x the maximum NTC resistance (R_{NTC}) at the coldest point of the control range (which is approx. 7kΩ at 0°C).

Therefore let R_V+R2 = 70kΩ.

4. Determine the value of R1: Knowing the value of the NTC, and the value of the series combination of R_V + R2, we can calculate a value of R1 which will provide the 550mV control input to the OM1654 at the highest temperature of the control range (i.e. maximum potentiometer setting).

$$R1 = \frac{R_p \cdot (V_s - V_o)}{V_o}$$

Input Sensing Circuit Design for OM1654

AN004

where:

R_p is the parallel resistance value of $R_{NTC} // (R_v + R_2)$
 given $R_{NTC} (@40^{\circ}C) = 1k16$, and $R_v + R_2 = 70 k\Omega$
 V_s is the supply voltage (in this case 230V rms)
 V_o is the control voltage on the sense input
 (i.e. 550mV rms).

This gives $R_1 = 476 k\Omega$
 (say 475 k Ω in E96 series).

- Determine the value of R_2 :
 This can be calculated first by determining the voltage across R_p at the coldest control temperature.
 (when $R_{NTC} = 7k47$)

$$V_o = \frac{V_s \cdot R_p}{(R_p + R_1)} = 3.22V$$

Then:

$$R_2 = \frac{V_{SENS} \cdot (R_v + R_2)}{V_o}$$

Where: $V_{SENS} = 550mV$, $(R_v + R_2) = 70 k\Omega$, $V_o = 3.22V$
 This gives $R_2 = 11k95$ (say 12k0 in E24 series).

- Determine the value of R_v :
 This is simply given by

$$R_v = (R_v + R_2) - R_2 = 58k\Omega$$

Unfortunately 58k Ω is an unusual value for a potentiometer.

One of the limitations of using the OM1654 over a smallish temperature range such as this, is that using the NTC as a starting point can result in unusual values for the potentiometer. Since only limited NTC resistance values are available, there is little scope to select an NTC value that will result in a sensible potentiometer value.

One way to overcome this problem is to use say a 100k Ω potentiometer, and put an additional resistor (R_3) across it of approximately 140k Ω to provide an equivalent potentiometer value of 58k Ω .

Alternatively use a potentiometer having a standard value as near as possible to the calculated value (say 50k Ω), and accept the slightly different temperature control range that this will provide, and possibly even recalibrate any indicator scales to reflect the actual control range.

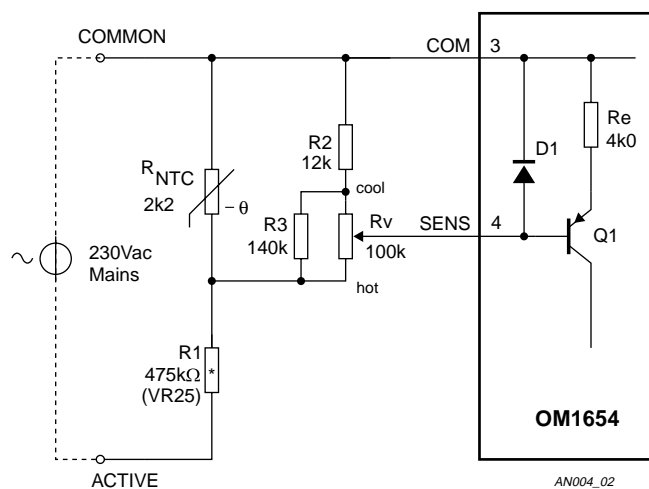


Fig.2 Final input circuit for the room heater example.

Input Sensing Circuit Design for OM1654

AN004

A further problem is that the resistance of the NTC thermistor response against temperature is logarithmic, and the use of a linear potentiometer will give a non-linear temperature scale. A logarithmic potentiometer may be able to be used in a circuit in which the two non-linear responses match.

IES can assist in creating a spreadsheet which will provide a graph of temperature versus potentiometer position.

3.3 Further comments:

1. Although the discussion and examples have shown the OM1654 being used in applications supplied from 230V mains, the same approach to designing input sensing circuits can be employed with 115V mains supply applications.
2. Unlike the precision thermostat controller (OM1682), the input sense circuit of the OM1654 monitors the absolute input voltage derived from the input resistor network. This voltage will be dependent on supply voltage level, so any variation or tolerances on the supply voltage will have a direct affect on the accuracy of temperature control.
3. In addition, the input sense voltage has a temperature coefficient of approx. $-2\text{mV}/^\circ\text{C}$, which can influence temperature settings if the OM1654 is operating at high ambients. In most applications where the OM1654 is used for heating appliances, and mounted where it remains at approximately room temperatures, in ambients below 50°C or in a controlled environment,

the effect of this temperature coefficient will be minimal, and can be taken into account in the design.

4. For controllers designed to operate over large temperature ranges, care needs to be taken regarding the range of possible voltages which may appear across the sensor. The greatest voltages will occur at the highest NTC resistance (i.e. lowest NTC temperature). It is possible that with significant voltage across the sensor, self heating will cause errors in the sensed temperature.
It is also important that the maximum voltage rating of the sensor and the potentiometer are not exceeded.
5. The input transistor Q1 of the OM1654 is (in analogue IC design terms) a lateral PNP transistor. One particular characteristic of these devices is the relatively low hfe value, which can be as low as 15. This means that the equivalent input impedance of the OM1654 input circuit could be as low as:

$$Z_{IN} = h_{fe} \cdot R_e = 60\text{k}\Omega$$

This can be a cause for temperature errors in the input circuit design.

6. The discussion here is limited to the input sensing circuit only. For calculating power supply component values and additional application information, refer to the application note on using the OM1654 (ref.2).

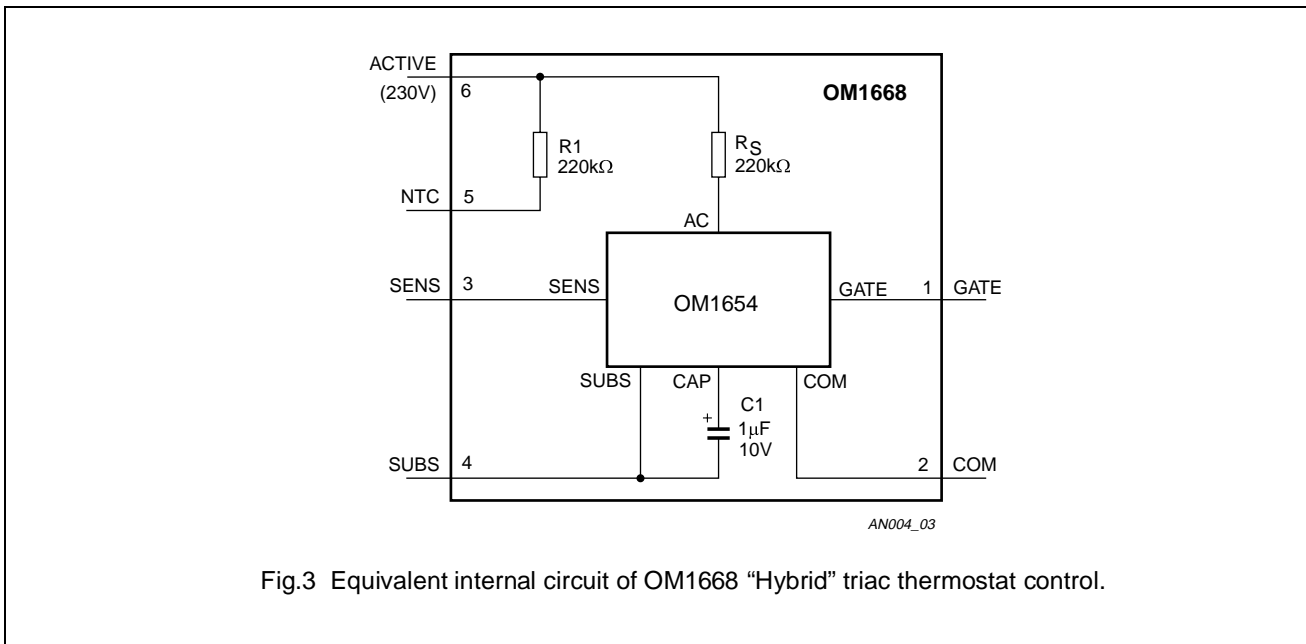


Fig.3 Equivalent internal circuit of OM1668 "Hybrid" triac thermostat control.

Input Sensing Circuit Design for OM1654

AN004

3.4 OM1668 – Implementation in Thick Film Hybrid.

For simplicity of use, the typical application circuit for the OM1654 has been realised in a thick-film hybrid circuit, designated OM1668. The hybrid incorporates the OM1654 integrated circuit, together with two 220kΩ mains resistors, and the timing capacitor C1. All that needs to be added to provide a complete application circuit is the control potentiometer, temperature sensor, supply filter capacitor and the triac. The internal circuit of the OM1668 is shown in Fig 3.

While the OM1668 is designed for 230Vac operation, 115Vac variants are possible on request.

Design of the input sensing circuit for the OM1668 and selection of external components is done in a similar manner to the previous discussion on the OM1654, with the exception of setting the value of mains dropping resistor R1. In the OM1668 this resistor is fixed internally at 220kΩ. In practice however this does not present a problem, since the freedom of sensor and potentiometer selection is sufficient to allow the hybrid circuit to be adapted to most typical applications. The general application circuit for the OM1668 is given in Fig. 4.

While the component values are not given for the NTC and Rv, these can be determined by following the steps provided in section 3.1.

To limit the control range provided by the potentiometer Rv, it may be necessary to include a resistor in series with the potentiometer (equivalent to R2 in Fig. 2).

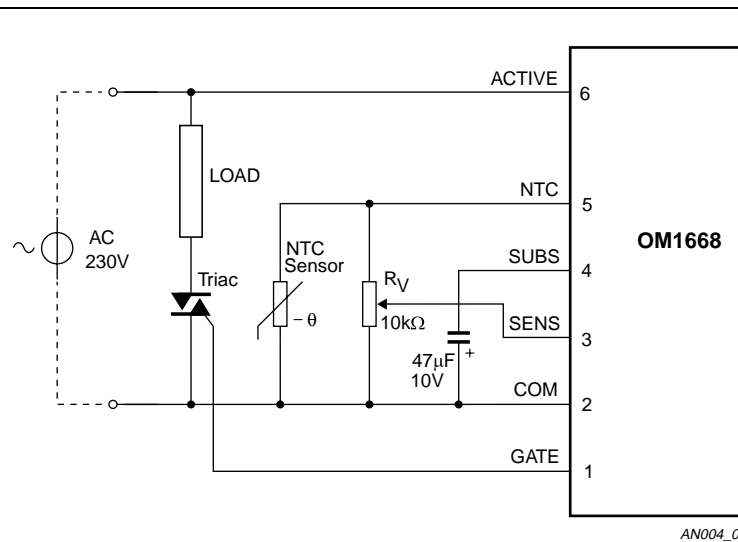


Fig.4 Typical application circuit for OM1668 (Triac control hybrid).

Input Sensing Circuit Design for OM1654

AN004

4 BRIDGE INPUT SENSING CIRCUIT FOR IMPROVED ACCURACY.

The standard input sensing circuit for the OM1654 is intended for use in heating applications where precise temperature control is not essential (e.g. cooking and domestic heating). It is accepted that the input sensing circuit is influenced by fluctuations in mains supply voltage. For applications demanding more accurate control, a bridge input circuit can be used. This provides a more accurate determination of NTC resistance, and eliminates sensitivity to mains voltage variations.

4.1 Typical bridge sensing circuit.

The typical bridge input sensing circuit is given in Fig. 5. This is a simple bridge made up of two resistor divider networks across the AC mains, incorporating the NTC sensor and R11 in one arm, and the potentiometer (together with R13) and R12 in the second arm. A voltage is derived from each arm of the bridge (V_x and V_y respectively), and compared by transistor Q2.

In a similar manner to the standard input circuit configuration (of section 3) the bridge circuit is only effective during negative half cycles of the mains voltage. Positive mains half cycles are clamped by the internal diode of the OM1654, and have no effect on the operation. Therefore the input sensing bridge need only be

considered when the “active” line is negative with respect to the “common”.

It can be seen then from Fig. 5 that as the temperature sensed by the NTC decreases (i.e. becomes colder) causing the NTC resistance to increase, the voltage at V_x becomes more negative. When it becomes sufficiently negative (i.e. approx. 0.6V below V_y) then transistor Q2 begins to conduct, which in turn pulls the SENS input pin of the OM1654 negative. Increasingly negative signals on the SENS pin cause the duty cycle of the triac switch to increase, thereby applying more heat to the load.

Diode D2 is used to protect the base-emitter of transistor Q2 when it is reverse biased during positive mains half cycles, and whenever V_y is more negative than V_x .

The “gain” of the comparator Q2 is approximately given by the ratio of $R14/R11$. For simplicity it is best to make $R14 = R11$ so that change of voltage on the input sense pin (pin 4) closely matches the change of voltage at V_x as the value of the NTC changes with temperature.

Apart from the obvious advantage of improved accuracy, the bridge input circuit also provide more flexibility in customising the input circuit to any given application. The control characteristic becomes a function of the input bridge circuit design, rather than being determined solely by the input characteristics of the OM1654.

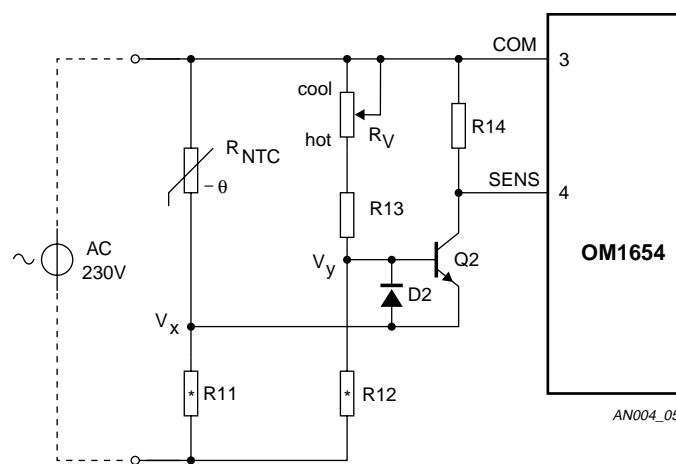


Fig.5 Bridge input circuit for OM1654.

Input Sensing Circuit Design for OM1654

AN004

4.2 Guidelines for bridge component selection.

There are a number of considerations to be taken into account when choosing component values for R11, R12, R13, R_V and the sensing element R_{NTC}. The considerations discussed in the application note AN003 with regard to the sensing bridge for the OM1682 (Precision Triac Control Thermostat IC), and are equally applicable here. These can be briefly outlined as follows:

4.2.1 RESISTORS R11 AND R12

1. Use mains rated resistors.

Remember that these circuits are connected directly across mains voltages, and can therefore be subject to large spurious signals and transients up to several kV. Suitable resistors should be used that will withstand these voltages without failing, or creating dangerous conditions.

Philips VR25 and VR37 resistors are specifically designed for this purpose, and their use in this application is recommended.

2. Let R_{11} and $R_{12} > 10 \times (R_{ma} \times R_{NTC})$ resistance.

This produces almost constant current into the NTC over the expected operational temperature range, and ensures that the voltage across the NTC is virtually proportional to its resistance.

It also limits the voltage on the NTC to $< 1/10$ of the mains voltage, to prevent self-heating effects of the NTC from creating errors in switching temperatures.

3. For simplicity let $R_{11} = R_{12}$.

This simplifies the analysis of the bridge, but otherwise is not absolutely necessary. Sometimes it is necessary to give R11 and R12 different values in order to provide a sensible value for the potentiometer R_V. If R11 and R12 have different values, the relationship of point 2 above should still be used.

4.2.2 CONTROL POTENTIOMETER R_V

1. Choose R_V to match the resistance change of the NTC.

The value of the potentiometer has to be chosen to match the change in resistance of the NTC so that switching occurs over the entire operating range. If the potentiometer is too small the operating temperature range will be decreased. The NTC values for either end of the temperature range are determined initially, and thus the size of the potentiometer can be determined. It is assumed that the temperature vs potentiometer setting is linear between the two end points.

2. Choose series resistor R13 for minimum potentiometer setting.

A resistor R13 is normally placed in series with the potentiometer so that the bridge can always be balanced. Without a series resistor, when the potentiometer is at minimum the NTC would have to be close to zero ohms in order to balance the bridge. For most NETs such a low resistance can not be achieved, so the thermostat will be ON all of the time at this end of the potentiometer range.

3. Using different values of R11 and R12 to allow suitable R_V value.

The size of the potentiometer required can be changed by altering the value of R11 and R12. Making R12 larger than R11 will result in a larger potentiometer being required and making R12 smaller than R11 requires a smaller potentiometer. This allows the size of the potentiometer to be adjusted so that a standard value potentiometer can be used. This is preferable otherwise mechanical stops would have to be used to ensure that the required operating range is not exceeded.

4.2.3 RESISTOR R14

1. The "gain" of the bridge circuit and comparator Q2 is approximately given by the ratio R14/R11. It is normal to make R14 = R11 so that the gain = 1. This is done so that the change in input voltage applied to the SENS pin (pin 4) of the OM1654 closely tracks the voltage at V_x about the balance point of the bridge.

If appreciable gain is provided by selecting a value for R14 such that $R_{14} \gg R_{11}$, then the output duty cycle of the OM1654 may change significantly for a small change in sensed temperature, making the control overshoot and possibly become unstable, unable to track small changes in sensed temperature.

Input Sensing Circuit Design for OM1654

AN004

4.3 OM1677 Hybrid thermostat control, bridged input.

A version of the bridge input circuit has been realised in a thick film hybrid type OM1677. All the relevant components of the bridge circuit have been incorporated into the hybrid, including the mains supply resistors. A circuit diagram of the OM1677 is shown in Fig. 6. Just a few external components are required to provide a complete

application. The required external components are simply the NTC sensor, control potentiometer, supply filter capacitor and the triac. This provides for a very simple but effective application of the OM1654.

A typical application circuit for the OM1677 is given in Fig. 7.

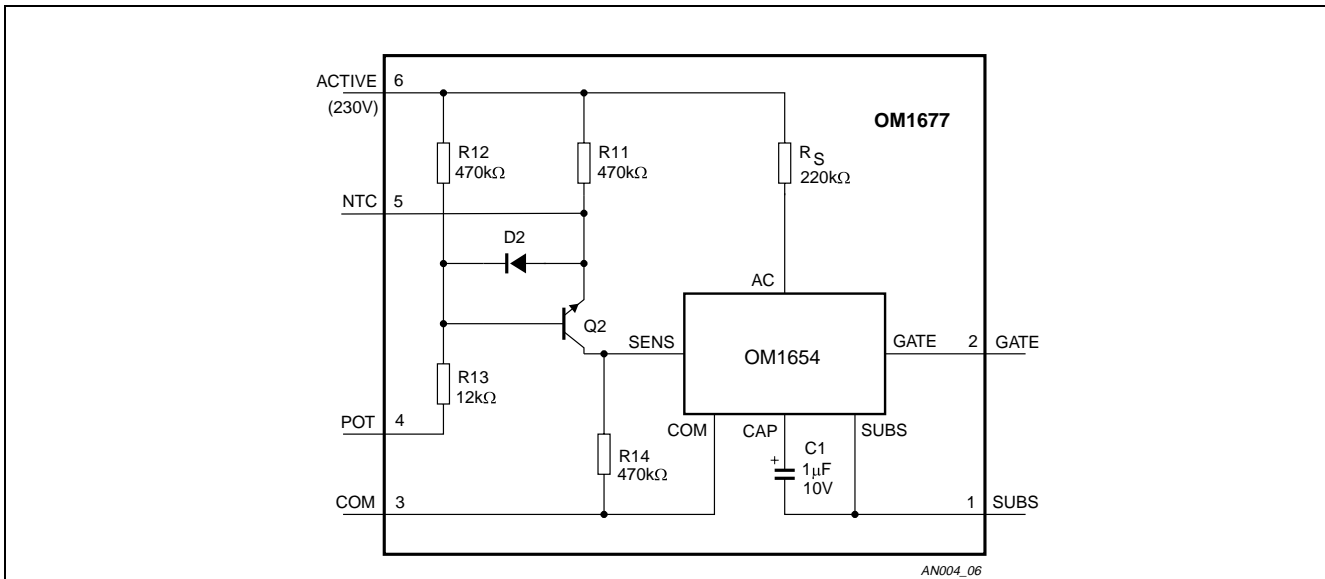


Fig.6 Internal circuit of the OM1677 (Hybrid thermostat control: bridged input).

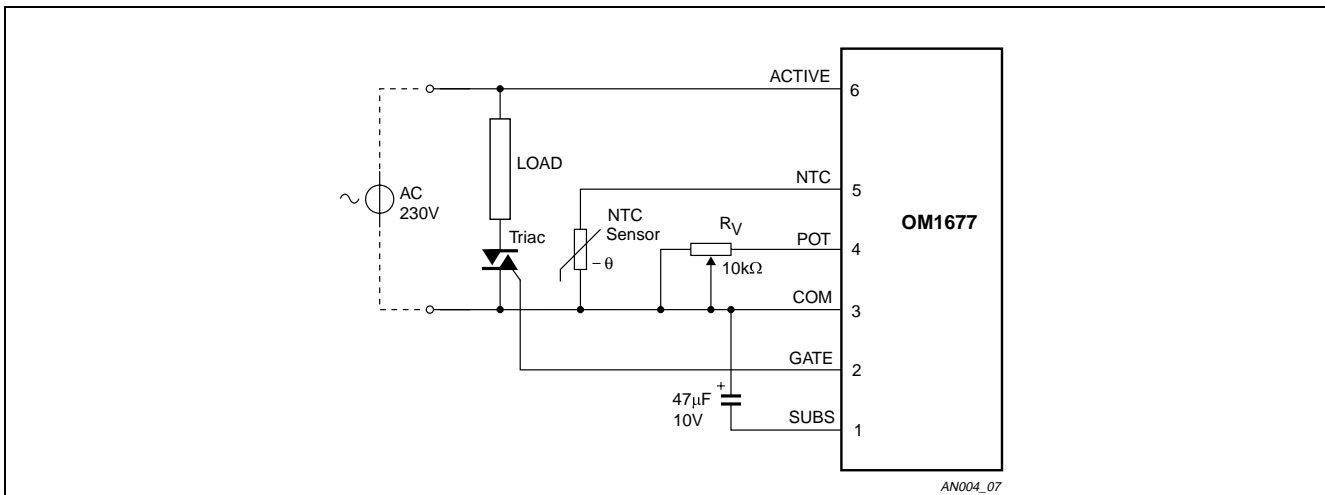
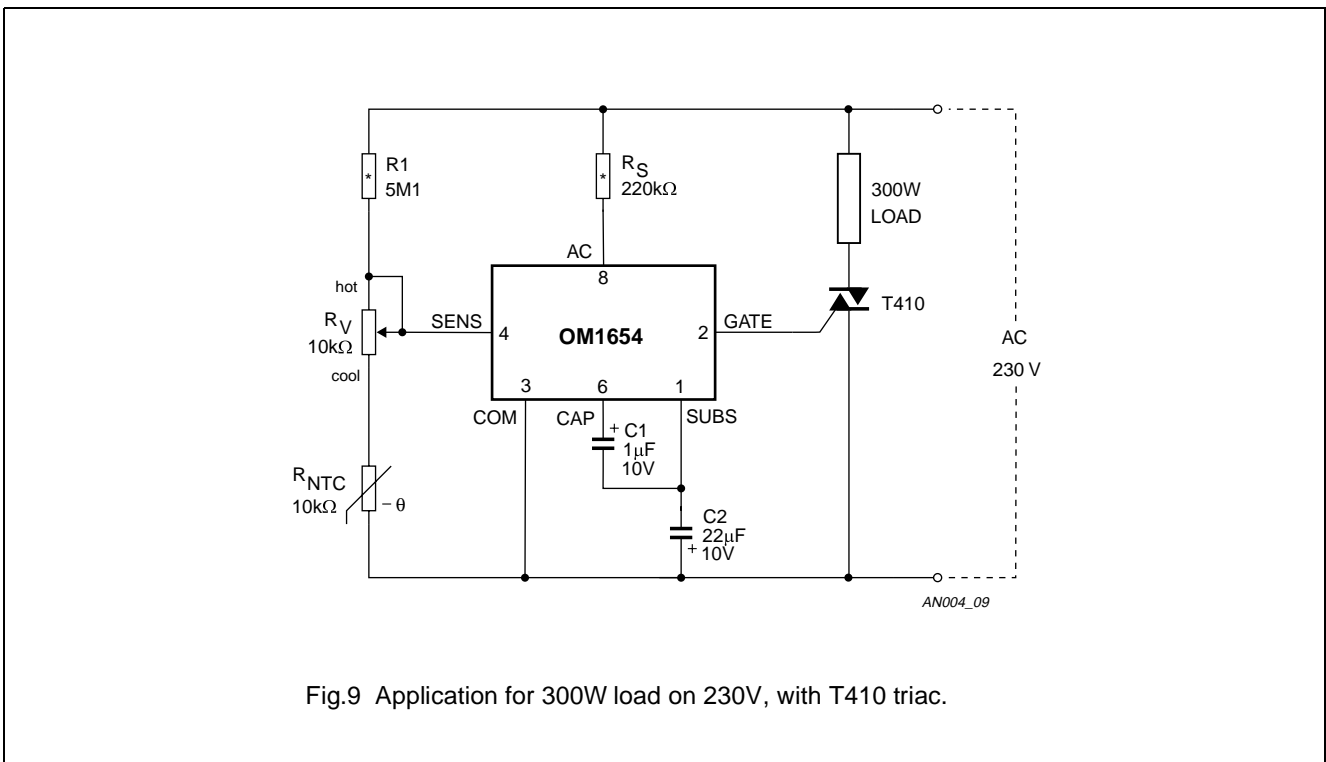
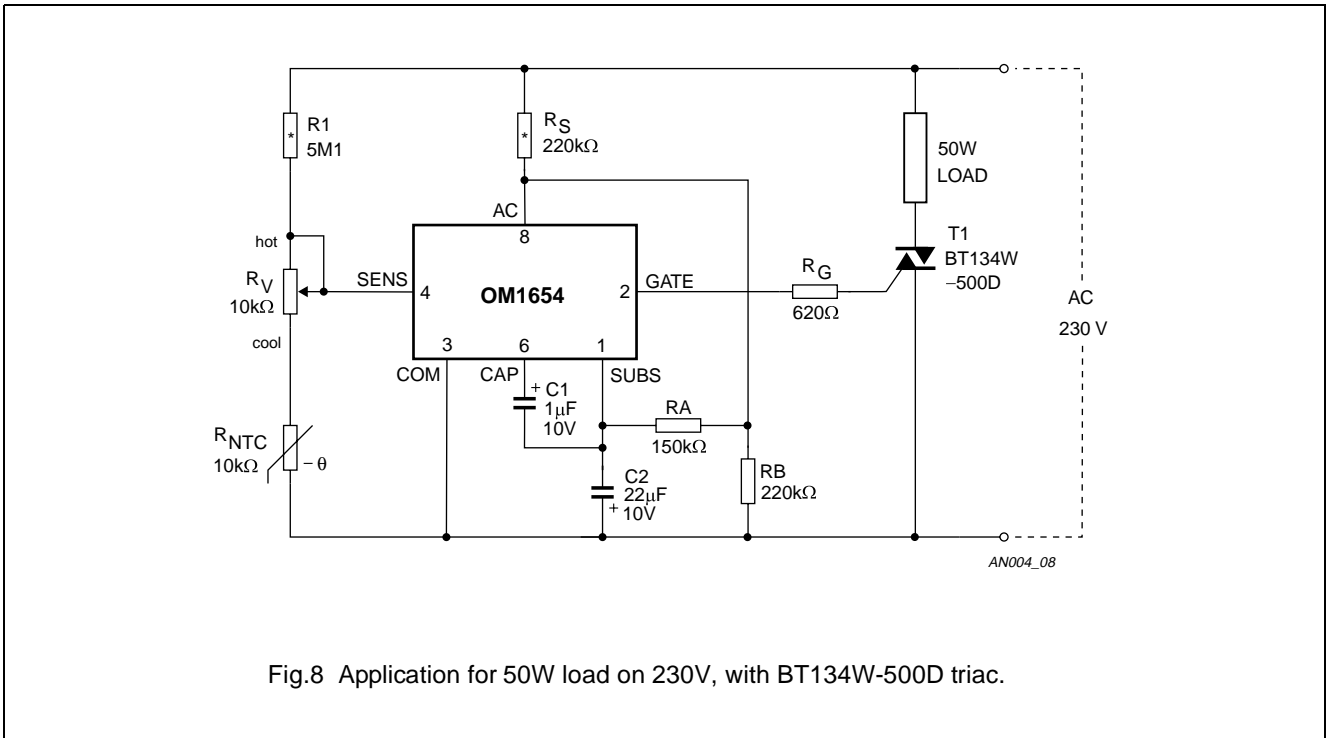


Fig.7 Typical application circuit for OM1677 (Hybrid thermostat control: bridged input).

Input Sensing Circuit Design for OM1654

AN004

5 ALTERNATIVE INPUT CIRCUIT ARRANGEMENTS.



Input Sensing Circuit Design for OM1654

AN004

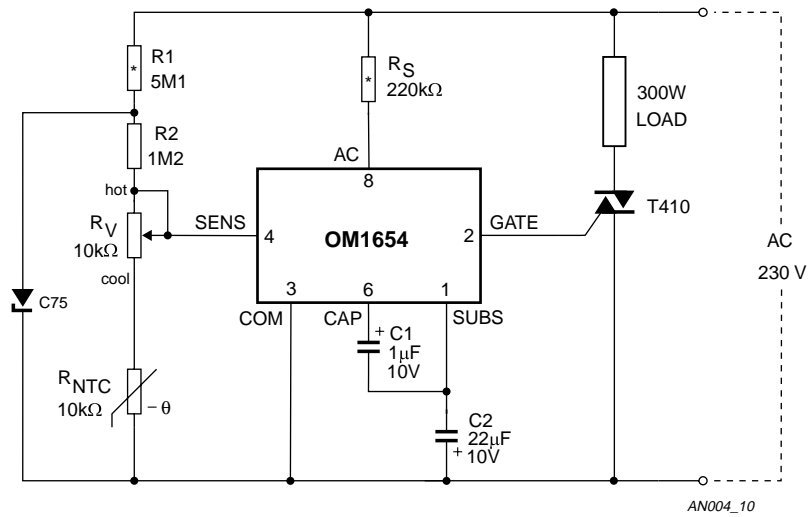


Fig.10 Application for 300W load on 230V with T410 triac.

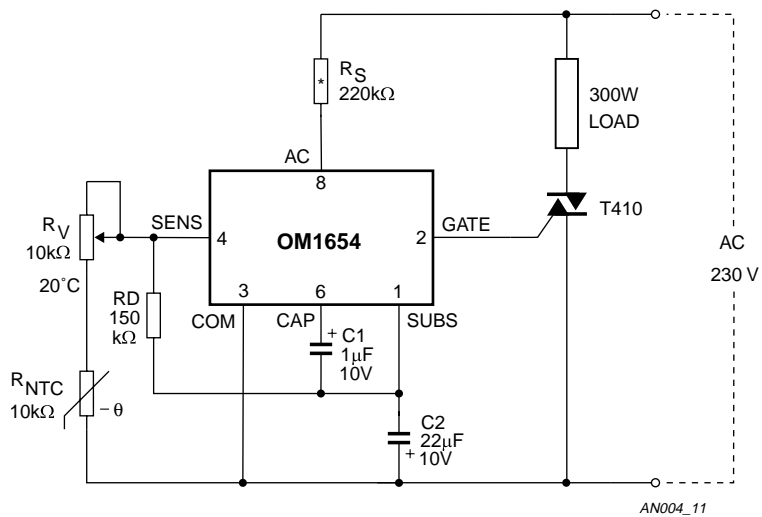


Fig.11 Application for 300W load on 230V, with T410 triac. Sensor circuit powered from IC regulated supply.

Input Sensing Circuit Design for OM1654

AN004

6 REFERENCES.

1. Data Sheet OM1654, "Simple zero-crossing triac control circuit."
2. Application Note AN002, "Using the OM1654 Simple Triac Control IC."
3. Data Sheet OM1668, "Hybrid triac thermostat control."
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Input Sensing Circuit Design for OM1654

AN004

Notes:

Input Sensing Circuit Design for OM1654

AN004

Notes:

Input Sensing Circuit Design for OM1654

AN004

7 DEFINITIONS

Data sheet status	
Engineering sample information	This contains draft information describing an engineering sample provided to demonstrate possible function and feasibility. Engineering samples have no guarantee that they will perform as described in all details.
Objective specification	This data sheet contains target or goal specifications for product development. Engineering samples have no guarantee that they will function as described in all details.
Preliminary specification	This data sheet contains preliminary data; supplementary data may be published later. Products to this data may not yet have been fully tested, and their performance fully documented.
Product specification	This data sheet contains final product specifications.
Limiting values	
Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 134). Stress above one or more of the limiting values may cause permanent damage to the device. These are stress ratings only and operation of the device at these or at any other conditions above those given in the Characteristics sections of the specification is not implied. Exposure to limiting values for extended periods may affect device reliability.	
Application information	
Where application information is given, it is advisory and does not form part of the specification.	

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