A CIRCUIT TO RELIABLY DETECT THE PRESENCE OF A FLAME

The Problem:

Conventional circuits to detect a flame consist of a flame sensor (which may be a flame rod, photoresistive cell, photoconductive cell, photovoltaic cell, thermistor, thermocouple, etc.), a detector circuit and except in the case of the photovoltaic cell and thermocouple, a bias device (usually a resistor or constant current source).

The sensor may be on the ground (low side sensor) or hot (high side sensor) side of the sensor's input as shown in drawing PAT1. In conventional circuits, the presence of a flame causes the impedance of the sensor to drop. This reduces the voltage at the detector's input in the case of a low side sensor. In the case of a high side sensor, the reduction of impedance raises the voltage at the detector's input.

While the circuits illustrated in PAT1 have a capacitor installed between the sensor and the amplifier/detector, conventional flame detectors do not. The connection is made directly.

This has the problem that if the sensor develops a problem that manifests itself as a lowering of impedance or if the wiring to the sensor develops a short circuit, the detector will be unable to determine if the flame has gone out.

If the sensor is faulty or if the wiring has short circuited and the flame goes out, the detector will be unable to detect this. Therefore, the safety circuits in the burner's control box will not turn off the flow of fuel.

In the past this has caused unattended heaters to pump large amounts of fuel into the area surrounding the heater. This is extremely hazardous and if it does not cause a fire or explosion, it is very messy and costly to clean up.

Unless the flame sensor can be built in such a manner that a short circuit or a faulty sensor cannot be interpreted by the detector as a burner having a good flame, the burner is a safety hazard and it would only be a matter of time before a disastrous fire or explosion occurred for some user of the burner.

The Solution

After trying complex circuits to detect a shorted sensor, several faulty sensors were found that caused the detector to sense the presence of a flame when indeed, there was none. It was noted that when a flame was present, the voltage at the sensor input varied from 2V to 6V at a frequency of at least 10Hz [1] (riding on top of a DC signal that averaged 2 to 5 Volts) provided the sensor used was a solid state photoconductive cell. However, the signal at

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[1]The frequency actually varies randomly but in all cases was at least 3 Hz, always mixed in with random frequencies up to several hundred hertz.

the detector's input was pure DC if the sensor was shorted or defective. Also, if the flame went out, the signal was DC.

Since we want the burner to treat a shorted or defective sensor the same as if the flame went out, we had to develop a circuit that detected the varying or AC component of the varying DC signal. The circuit had to give us a valid output as long as the signal from the sensor varied but if the amplitude of the AC signal riding on top of the DC level went too low or disappeared altogether, the detector would then give an invalid output which the safety circuits would then use to shut down the burner, especially the delivery of fuel to the burner.

While this circuit will shut down the burner if the sensor becomes faulty or if the sensor is shorted, even though there may be a good flame, it fails "safe". With a conventional circuit, when a failure occurs, it fails "unsafe".

First, the detect a rapidly varying flame and to give us a good signal, a sensor was needed that detects a frequency high enough to see the "flicker" of a flame instead of its average brightness. The slow response time of a thermocouple, thermistor and photoresistive cell rules these devices out. A fast sensor such a solid state photoconductive cell (such as a phototransistor), a flame rod, etc. must be used.

This signal is then passed through a device known as a **capacitor. This is the central point of the claim.** By passing the AC signal which is riding on a DC level through a capacitor[2], the DC component of the signal is removed. Only the AC portion remains.

This AC component may be amplified in some cases and is then passed onto a detector of some sort that gives an output when the AC signal is present and an opposite output when the AC signal is absent.

This operation cannot be reliably performed without the use of a capacitor as the DC level on which the AC component is riding may vary quite a bit due to different types of fuel used in the burner, ambient air temperature, etc. Only with the use of the DC blocking capacitor will this circuit operate reliably.

Therefore, our claim is to have invented a way to detect a flame reliably, while making the system fail in a safe manner if the flame sensor is defective or is short circuited. The detection is done be detecting the flicker of the flame rather than the flame itself in an electronically controlled heating system burning liquid or gaseous fuel.

Typical circuit

Tthe claim is for a method of detecting the flicker of the flame rather than the flame itself. In drawing PAT2, a typical

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[2]A capacitor is an electronic component that has several functions. It is mainly used to store energy and to allow the passage of an AC signal while blocking a DC signal. This function id known in the industry as "DC Blocking".

circuit for this function is illustrated. Note that except for the use of a DC blocking capacitor, C1, the circuitry could be implemented in several ways.

The implementation used in the International Thermal Research model is shown. The sensor receives its DC bias through R1. In normal operation this results in an average DC voltage at point "A" of anything from 2V to 6V DC with a voltage source of 8V. In other units, this bias source, R1, may be replaced a constant voltage source, constant current diode or several other devices of circuits.

However, by using a high speed detector, in this case a photo transistor (being used in photoconductive mode), at point "A" there will also be an AC voltage of about 1V peak to peak. This varies, in practice, from about 0.5V to 3V at random. This is the variability in flame brightness commonly known as "flicker".

The AC component of the signal is passed through the capacitor "C1" to point B. At this point, the DC part of the signal is removed. The AC signal here will vary, on average, from about +0.5 to -0.5V. If the signal goes to a higher level that -0.6V, the amplifies, U1A may be damages. Therefore diode "D1" is included. D1 serves no function in making the circuit work. It is there only to protect the amplifier when it is operating on a single supply voltage. The use, or lack of use of D1 is not integral to the claim.

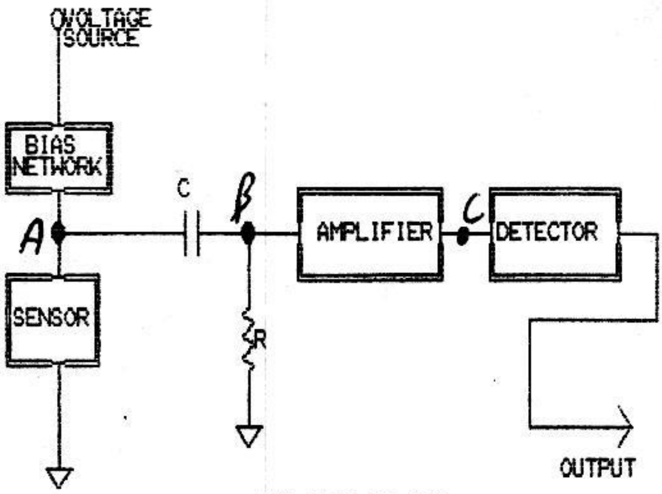
The AC signal is amplified by amplifier U1A. The amplifier design is not important and it is only necessary as the detector diode D2 will not conduct if the signal at point "C" does not exceed 0.6V.

When the signal at point "C" exceeds 0.6V, the voltage at point "D" starts to rise. When this voltage exceeds the Voltage Reference at point "F", the output of the detector, point "E" changes state and the circuit supplies a signal to other circuitry giving an indication of a good flame.

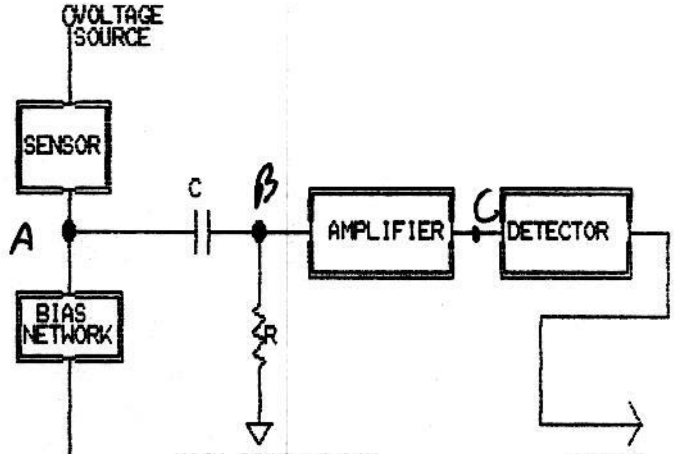
Since the flame is flickering, the voltage at point "C" is not constant. It rises and falls. Therefore, we want the signal at point "E" to only indicate "no flame" when the AC signal has stopped for several seconds. Therefore, the signal at point "D" is held by capacitor C@, acting as an energy storage device. This reverse blocking is done by D2. The voltage at point "D" only rises when the voltage at point "C" exceeds the voltage at point "D" by 0.6V. Otherwise, the voltage at point "D" is held.

However, to allow the detector to detect a loss of signal at points "A", "B" & "C", the voltage stored by C2 at point "D" is discharged by R5. If the AC signal stops, the charge on C2 will be drained away by R5 in several seconds, causing the detector, U1B, to indicate a loss of flame or other fault.

Original idea to detect the flicker of the flame by Ed Robinson of
International Thermal Research Ltd.
Circuitry to implement the idea by Dan Fraser of Surrey BC.
Report written by Dan Fraser of Surrey BC



LOW SIDE SENSOR



HIGH SIDE SENSOR

AME FLICKER DETECTOR	Dwn	DAN FRASER
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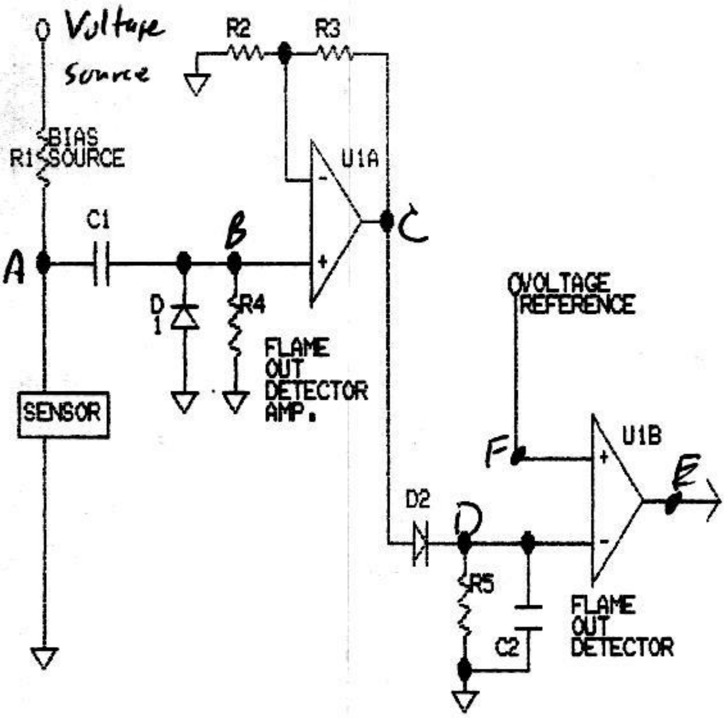

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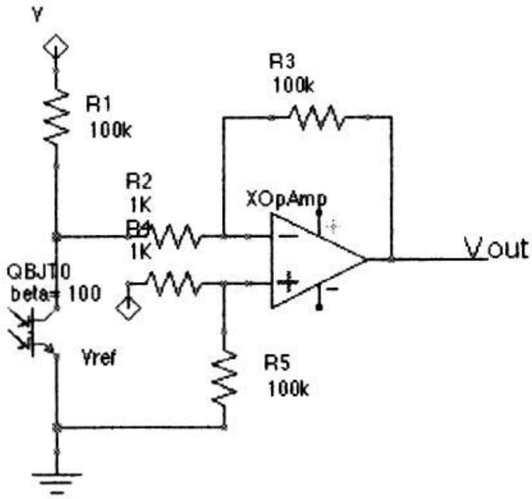

The reference source can easily be created with a potentiometer. Starting with this basic design we should be able to create an acceptable "black box" for the flame detection. We can narrow the field of view by placing the phototransistor inside a tube, and we can enhance its sensitivity by using a reflector. Experimentation will be necessary. Let me know of any improvements you make so we can post them on this site.

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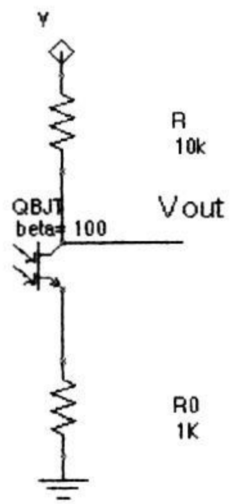
Flame Detector

Overview:

A flame emits a broad spectrum of electromagnetic radiation from far infrared to ultraviolet. Choosing an appropriate sensor is a matter of effectiveness, complexity, and cost. For our purposes, sensing the near infrared range offers the best cost to performance ratio. Using a common infrared phototransistor, it is relatively easy to design the appropriate circuitry to sense a flame from several feet.

Design:

Phototransistor - This operates as a normal transistor except base current is replaced by light intensity. Consequently there are only two leads to the device. The most basic type of shunt feedback amplifier is shown below:



Surprisingly, this design can be made very sensitive by eliminating R0 and using a large value for R. However, this does not produce the most versatile and predictable design. The addition of a few operational amplifiers will create a much more desirable circuit. We want to be able to tune out the ambient infrared light to achieve a 0V to 5V swing in output with 5V occurring when the detector is pointed directly at the flame from a predetermined distance. This will require an operational amplifier connected in a difference amplifier configuration using a tunable reference source. A simplified diagram is shown below.