Fermilab

TM-820
2835

A SOLID-STATE INFRARED OPTICALLY COUPLED GATE PROTECTION SYSTEM

P. C. Czarapata, C. L. McGuire, J. B. Stoffel

October 10, 1978

ABSTRACT

At the time of this writing the majority of gate status (open or closed) sensor devices are of the mechanically operated microswitch variety. The problem of the devices is that they have multiple, non-detectable failure modes (i.e., mechanical failures, electrical failures). As a result, multiple switch installation is required for improved reliability. The object of this paper is to describe an alternate solution for this problem.

I. Introduction

In a mechanically activated microswitch system, the only method for testing proper switch function is to physically "open" or "close" the gate while monitoring the safety system for the proper response. This testing procedure must be performed at frequent intervals in an attempt to verify system operation. However, although the above procedure is used, a non-detectable fault can occur at any time between testing, resulting in an unreliable safety system.

A new approach to the fail conditions, as indicated above, is required. Since the primary problem is the uncertainty of the system status, a dynamic (self-checking) system is herein described.

II. Implementation

The heart of the new system is an infrared sensor and emitter manufactured by Texas Instruments, Inc. as spectrally matched sets. The emitter is the TIL-31 and the sensor is the TIL-81. The unique characteristic of the new system is not the infrared devices being used, but the way they are used! The first attempt utilized a 1 kHz square wave to drive the emitter, thereby returning a 1 kHz signal from the sensor. Now, the problem is how to process the information obtained from the sensor. One can think of this signal as containing four pieces of information:

1. The rising edge of the signal
2. The high state of the signal
3. The falling edge of the signal
4. The low state of the signal

The high and low states detect the dc state of the system and the edges as the ac or dynamic part of the system. Referring to Figure 1, the incoming signal is filtered to remove any noise components higher than the 1 kHz signal and then fed to the remainder of the circuit. Let us assume that we are starting with the rising edge of the square wave applied to the circuit. The rising edge is translated to TTL levels by the 75154 line receiver and inverted. The falling output of the 75154 causes FF1 to set Q = 1. The high state of the signal is sensed by re-inverting the output of the 75154 and applying it to the AND gate, G1, which, in turn, applies a high to the D input of FF3. FF3 has a gate pulse applied to it at T4 (the timing generators which will be discussed in a subsequent section) and places (and holds) a high on the output.

Turning now to the falling edge of the input signal, the 75154 output goes high, causing FF2 to set Q = 1 (via the inverters). The high level of the 75154 is also applied to G2 where it is ANDed with the Q output of FF2. The output of G2 puts a high on the D input of FF4. FF4 has a gate pulse applied at T12 which transfers (and holds) a high on its output. The purpose of T0 and T9 is to reset the edge sensing flipflops in order to prepare them to sense the next edge. There are now two static levels which rely on both an edge and the associated level being present. If the input signal stops changing levels, the outputs of both FF3 and FF4 will go low due to the loss of edge information. Likewise, any problem connected with a dc level will be discovered by either one of the signals going low.

The input signal can stop for several reasons. Among them are: the failure of either the emitter or the sensor, the failure of the device driving the emitter, the device driving the return cable, the infrared signal not being detected by the sensor (which implies the gate was opened), or the cable itself being faulty. All of these conditions are detected by one or both sets of signals from FF3 and FF4.

The addition of an exclusive OR will detect a parity error between the two flipflops and could be used to sound an alarm or trip the system. In order to further reduce the likelihood of undetectable failures due to physical damage or tampering, the return signal is required to be out of phase with respect to the driving signal. This prevents the system from working in case the cable was crushed and shorted together.

The normal mode of operation is the following (Figure 2). As the gate (or door) is opened, the box containing the emitter rotates off axis causing the sensor not to detect the 1 kHz infrared beam. Because the output of the emitter falls off to only 50% at an angle of 5° and the sensor falls off to half the current at a lens separation of .5 inches, a small angular change causes the output to change or, more precisely, be undetected. In practice, if the devices are mounted on the hinge side of a door (for mechanical stability), the door could only be opened 2.5 inches. This is far too small for anyone to pass through and certainly comparable to the case of a microswitch mounted on the hinge side.

The timing signal generator uses a Ne555 running in the astable mode. The output of the NE555 is sent to a 7493 divide by sixteen counter which has its output decoded into sixteen individual time increments by the 74154 four-line to sixteen-line decoder. Since FF3 and FF4 require high going gate signals, T4 and T12 are inverted before being sent to the output latches (FF3, FF4). The D output of the 7493 is buffered and used as the drive signals to the emitters. It should be noted that only one master oscillator and time generator is required per system up to the fanout limitations of the integrated circuits. If the oscillator stops running, a missing pulse detector could be used to trip the system.

One further modification to the system was made. This is the version proposed for implementation on the Meson Safety System. The major modification involved changing the frequency from 1 kHz to 20 Hz. The change to 20 Hz allows stiffer filtering on the input to eliminate noise, and since the system is below 60 Hz, normal ac line induced noise is rejected by the filter. The other modification is the elimination of the AND gates G1, G2. The dc checking of the circuit is accomplished by the fact that a large enough capacitance cannot be generated in the line to drive the filter at 20 Hz and there is no driving source to pull the filter high.

FERMILAB
ENGINEERING NOTE

SECTION	PROJECT	SERIAL-CATEGORY	PAGE
			1

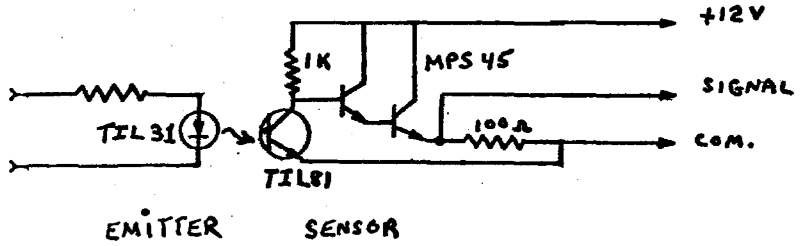
SUBJECT: INFRARED GATE SWITCH RECEIVER

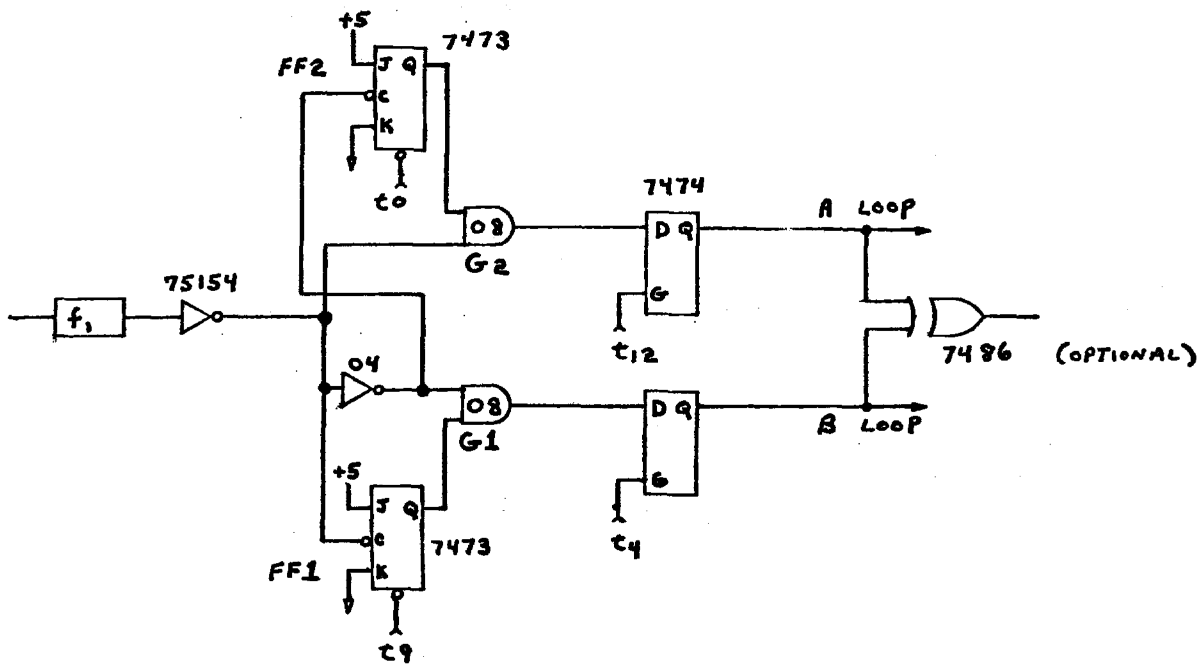
NAME: P. C. CZARAPATA

DATE: 7-21-78

REVISION DATE:

TM-820
2835





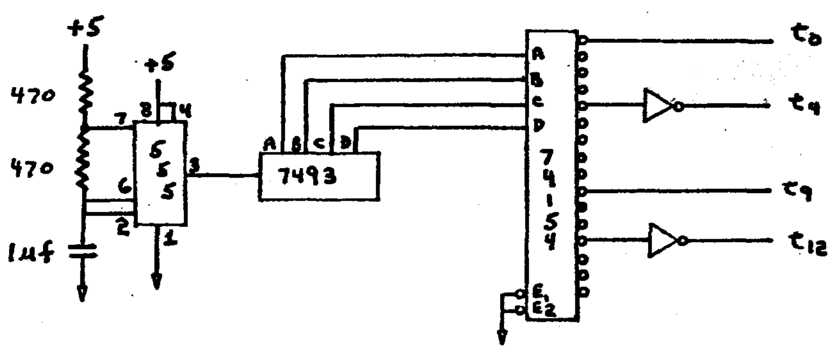


FIGURE 1

TM-820
2838

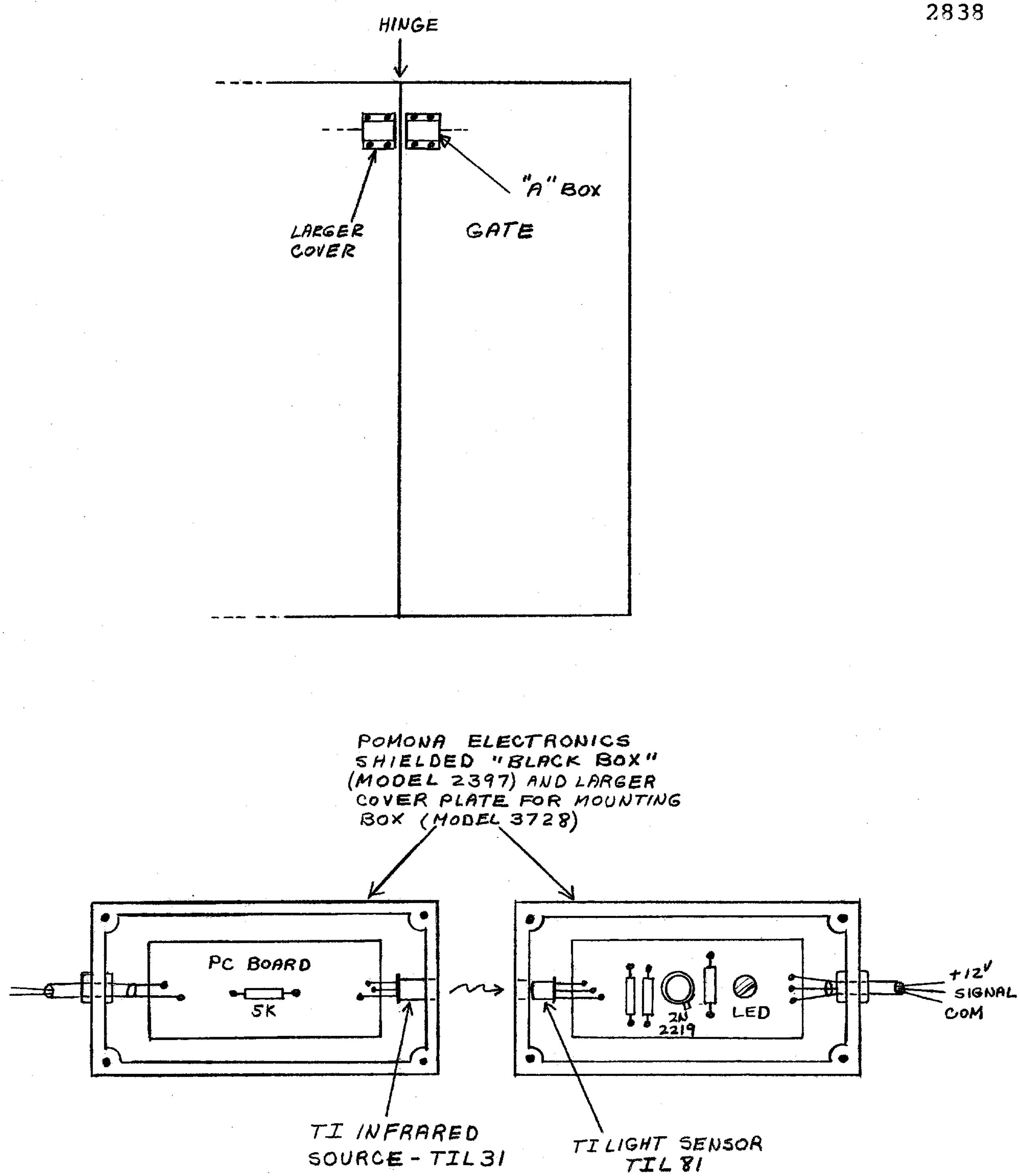


FIGURE 2

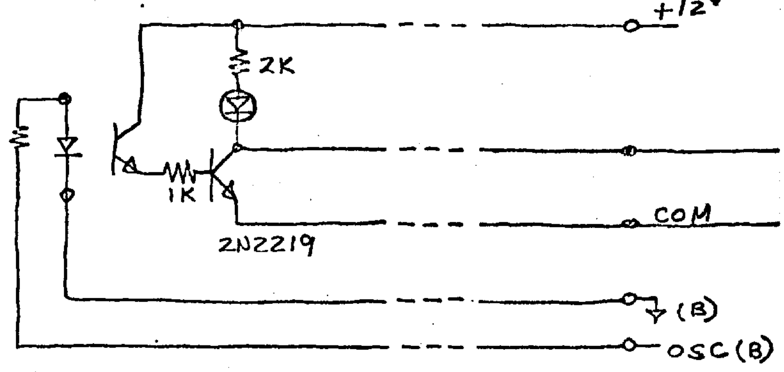
FERMILAB
ENGINEERING NOTE

SECTION	PROJECT	SERIAL-CATEGORY	PAGE

SUBJECT	NAME	
MODIFIED GATE SWITCH RECEIVER	J. B. STOFFEL	
	DATE: 9-8-78	REVISION DATE

TM-820
2835

DRIVER/SENSOR



GATE INTERFACE

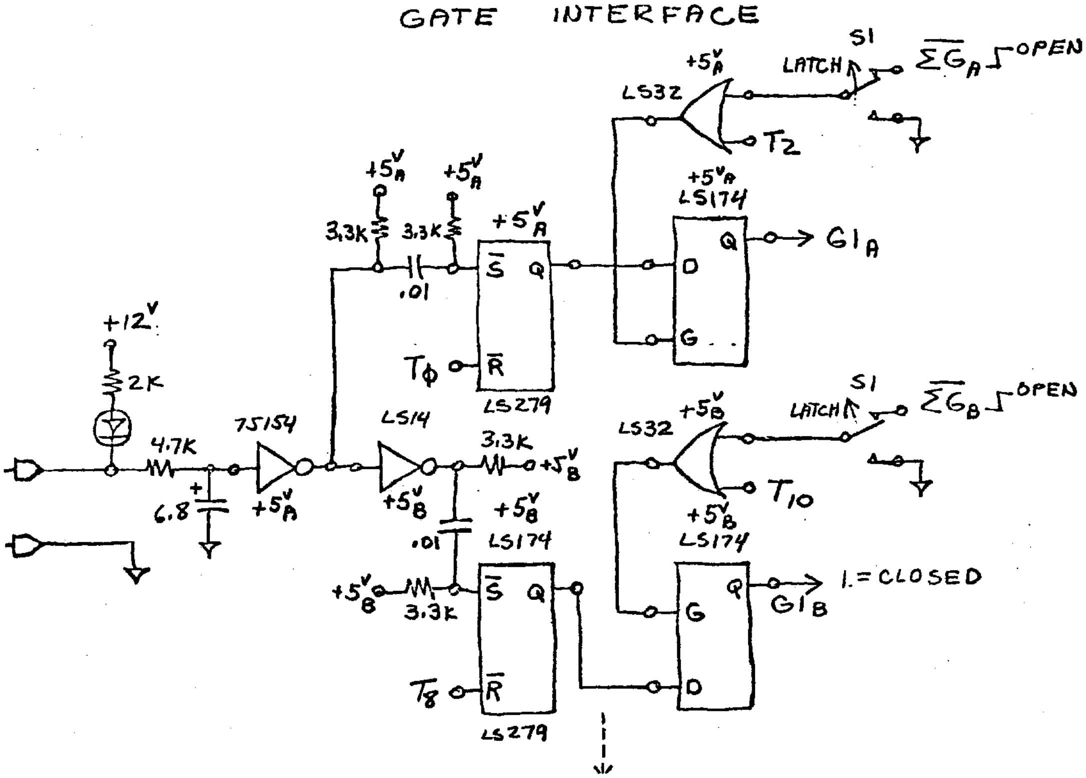


FIGURE 3