Brewer Micrometer Optical Switch Triggering

Prepared by Michael Brohart and Jonathan Davies

Introduction

In order to achieve its high wavelength accuracy the Brewer Spectrophotometer uses a stepper motor driven micrometer to precisely position a diffraction grating according to an automatic wavelength calibration procedure. As part of this procedure, knowledge of the micrometer position relative to a fixed point on the spectrometer frame is necessary. The location of that point is determined by monitoring the signal from one of two optical switches positioned at either end of the micrometer travel. The current software monitors the signal from the slotted optical switch at the bulkhead of the instrument as the grating arm flag, travels through it. Using this optical switch eliminates the possibility offset values changing over time due to wear of the driven components in the system.

The optical switch (OPTEK Technology P/N OPB806) consists of an IR LED on one side of the slot and a NPN phototransistor on the other. These optical switches are usually wired so that the phototransistor is saturated ON when the slot is empty, and OFF when an opaque flag is in the slot. The output from the phototransistor can be used to drive the CMOS digital input directly when it is in one of these two states with just a supply voltage and a pull down resistor (figure 3.).

With the introduction of single board electronics, it was noted that in the original configuration the Brewer Spectrometer optical sensor triggering/motor movement for the micrometers were unreliable and seemed to worsen over time. Eventually the movement became so erratic that the mercury wavelength calibration (HG) tests would fail. This problem was investigated by Kipp & Zonen in comparison with multi-board electronics Brewers. Kipp & Zonen determined new motor settings to mimic the previous version of electronics. This adjustment provided dependable motor movement, but made it apparent that the optical switch triggering was less stable than desired, ranging within +/- 5 steps but occasionally more.

For reliable operation and for proper calibrations of the instrument, the position of the flag must be consistently detected by the optical switch to a precision of less than 2 motor steps.

Background and Testing

According to the OPTEK data sheet, the optical switch will transition from full ON to fully OFF as the edge of the flag moves through a distance of about 2 mm between the LED and the phototransistor. The Brewer specifications state that the micrometer will move 1.000 mm for every 576 motor steps.

During the transition region, the output from the phototransistor varies with flag position.

The microcontroller chip reading the optical switch perceives a logic low when its input is below 0.9 volts and a logic high when the input is above 1.9V assuming a 5V supply to the sensor and the control chip. Levels in the 1 volt range between logic states produce unpredictable values. Given the tiny distance the micrometer moves during each motor step, in its original configuration, it can take 60 or more steps for the optical switch output to traverse this undefined state (figure 1.).

Tests done with Brewer #195 show that a flag entering the sensor will switch states between 1.9 and 1.4 volts and a flag being extracted from the sensor will switch states between 1.4 and 0.9 volts.

By increasing the size of the resistor on the main board to 3.0K ohm, and then 3.6K ohms instead of the original 1K ohm, the effective gain on the phototransistor was increased. This had the effect of delaying the transition to a logic low level until more of the LED was covered, and increasing the maximum voltage drop per step to about 1.06V when the 3.6K resistor was used.

The sensor was not able to drive the output voltage low when a 4.7K resistor was tested. It may be possible to increase the gain of the system further by increasing the current to the LED, but since the current limiting resistor is only 100 ohm it's being driven respectably hard already.

Although increasing the gain of the phototransistor improved the accuracy of the triggering dramatically, this method was not infallible. The voltage provided by the sensor still lingers in the undefined voltage range of the driver chip input for about 20 steps, making it possible for the state change to be triggered erratically. In this configuration, the reference flag was typically triggered within +/-1 step of previous test but occasionally could be as much as +/-6 steps different.

This amount of discrepancy will not cause the brewer to fail, but during calibration, it would be necessary to repeat tests with discrepancies greater than 1.5 steps. On two occasions a 69 step discrepancy was observed.

It was noted that multi-board electronics I/O boards, provided by International Ozone Services, conditioned the optical switch output signal with an inverting Schmitt trigger (74HC14N) before it reached the driver chip. The Schmitt trigger provides a properly conditioned logic level to the driver chip, eliminating the undefined logic levels entirely.

A circuit containing the same type of conditioning circuit as in the IOS board was constructed and wired ahead of the existing circuitry on #195 (Figure 2.). With this adapter in place the results were accurate to within +/- 1 step. This performance was observed on both micrometers on #195 and on #204.

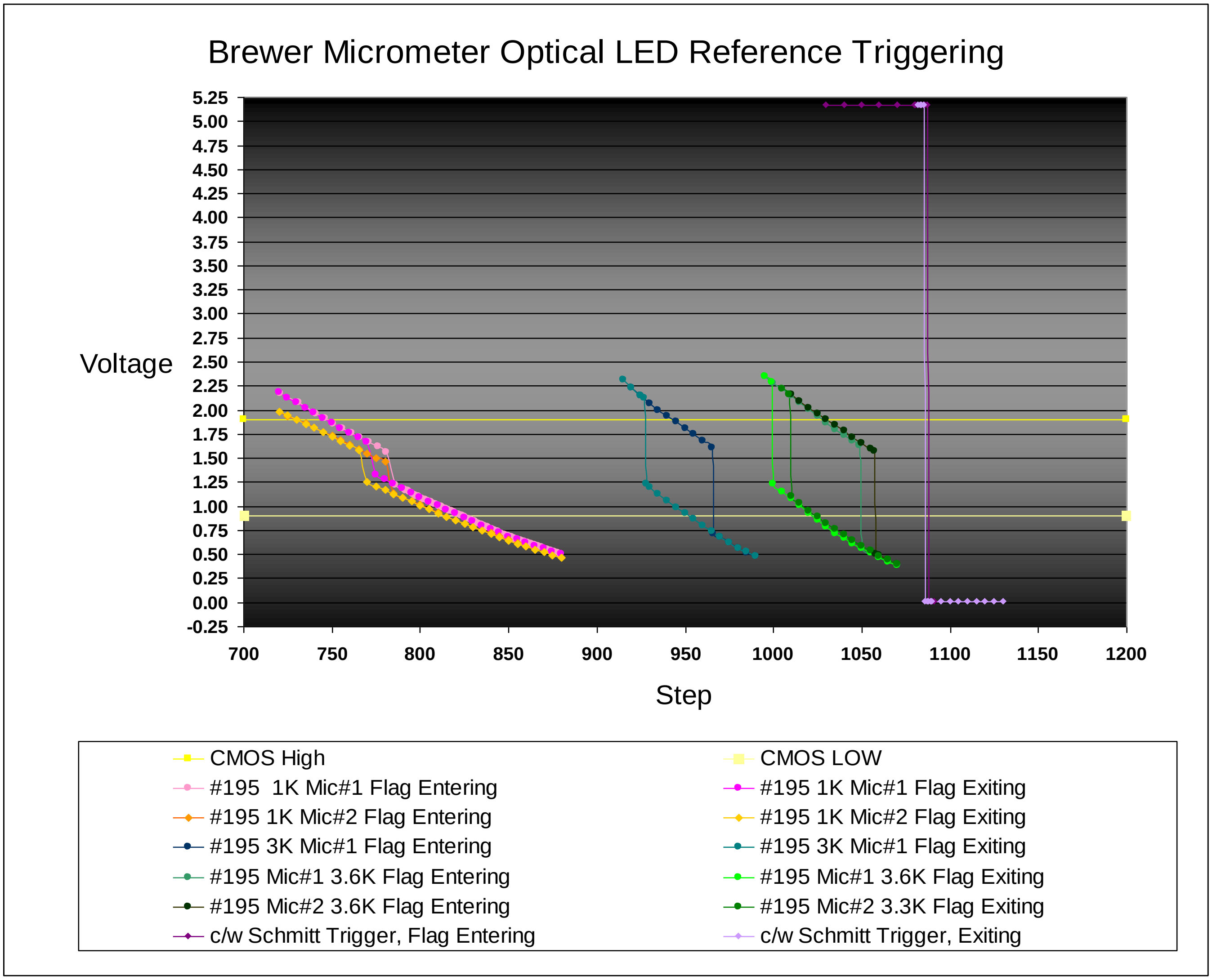


Figure 1

For these tests the Brewer was placed in Teletype mode and the grating arm flag moved to just outside the LED. The zero position was then reset. The grating arm flag was then moved into the sensor in small increments and the input voltage measured at the driver pin each time for various configurations.

Conclusions

For most of the optical switches within the Brewer the supplied circuitry is adequate. However this is not the case for the micrometer optical sensors with their greater requirement for precision, and an adaptor of the type in figure 2. is needed.

If the surface mount version of the Schmitt trigger was utilized, it is likely the manufacturer could provide a small male/female adapter that could be inserted between the header of the board and the ribbon cable going to the micrometers. Two adapters per Brewer would need to be supplied and could easily be mailed out to Brewer customers with this version of electronics in their Brewers.

It should be noted that the adapter installation will shift the micrometer offset considerably (~150 steps). A procedure to ensure the micrometer position before the installation, a description on how to note this difference and what changes need to be made to the constants and configuration file would have to accompany the adapters when sent to the customer.

Subsequent production runs of Brewer boards should contain the circuitry, thereby eliminating the need for these adapters for future sales.
With the adapter added to the micrometer circuit and the optical switches not blocked, the Schmitt trigger will be providing 5V to both pin18 and 20 of the logic chip (see Figure 3). Given the 1K ohm pull down resistors on the main board presently in place, a 10 mA output current passes through the Schmitt trigger. This current is below the 25 mA limits of the chip, however on future production, the pull down resistors should be increased to 10K ohm resistors to reduce possible stress on the chip.

Figure 2

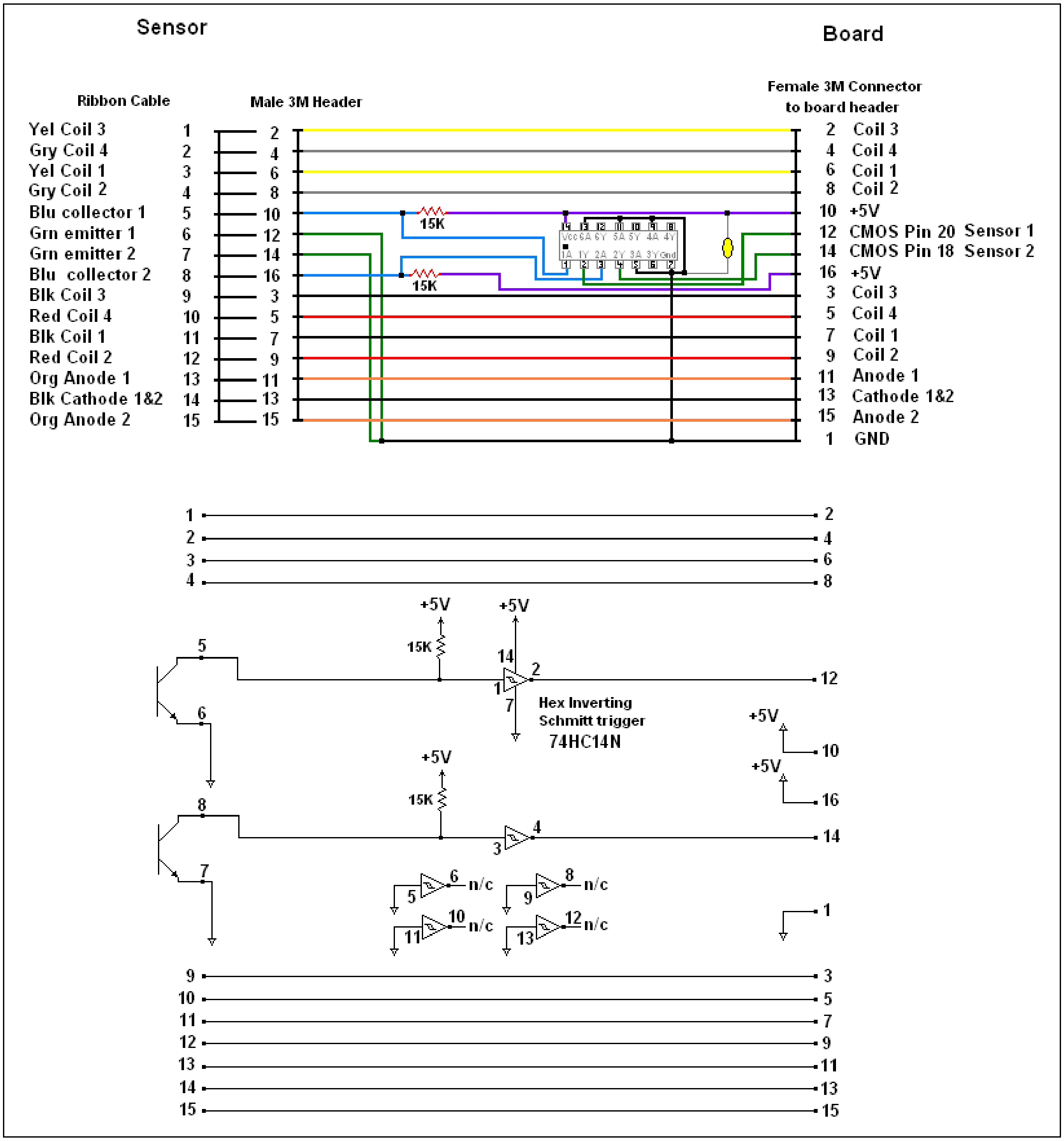
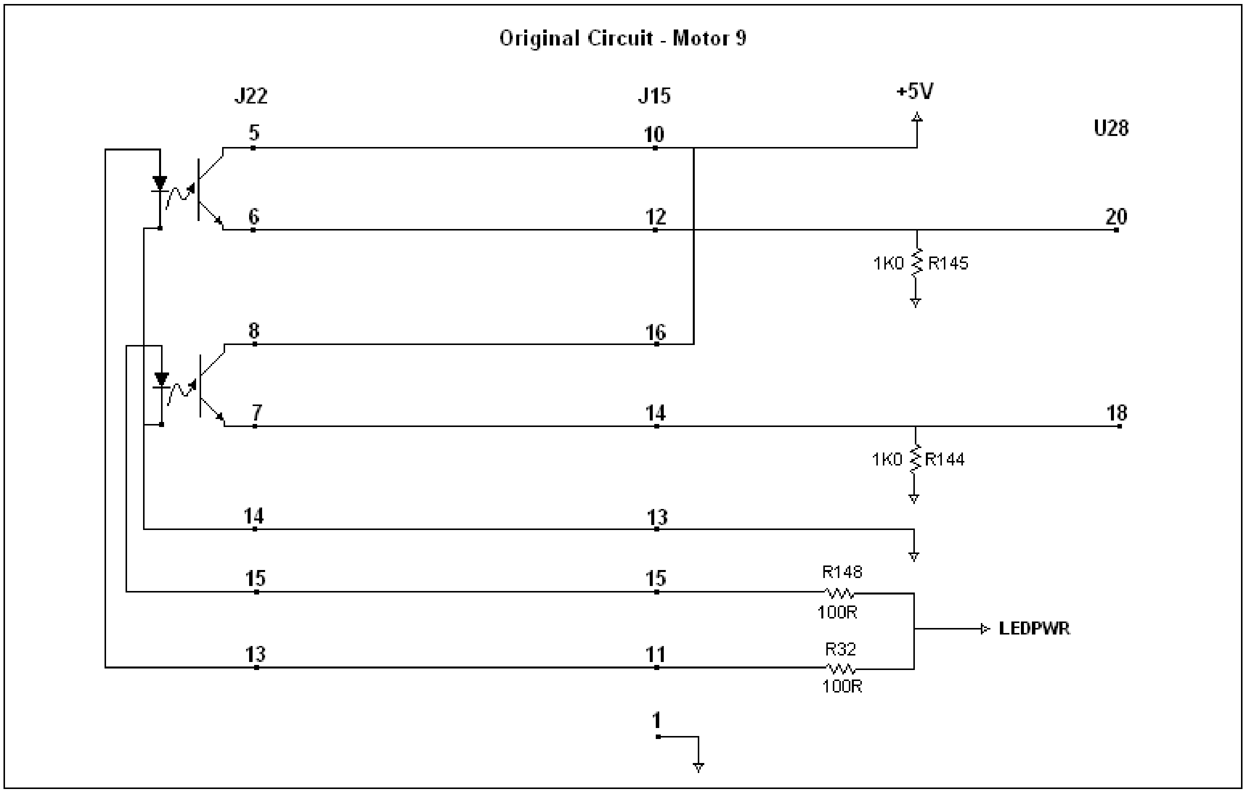

Sensor
Board
Ribbon Cable
Male 3M Header
Female 3M Connector
to board header
Yel Coil 3
Gry Coil 4
Yel Coil 1
Gry Coil 2
Blu collector 1
Grn emitter 1
Grn emitter 2
Blu collector 2
Blk Coil 3
Red Coil 4
Blk Coil 1
Red Coil 2
Org Anode 1
Blk Cathode 1&2
Org Anode 2
15K
15K
2 Coil 3
4 Coil 4
6 Coil 1
8 Coil 2
10 +5V
12 CMOS Pin 20 Sensor 1
14 CMOS Pin 18 Sensor 2
16 +5V
3 Coil 3
5 Coil 4
7 Coil 1
9 Coil 2
11 Anode 1
13 Cathode 1&2
15 Anode 2
1 GND
+5V
15K
Hex Inverting
Schmitt trigger
74HC14N
n/c

Figure 3



Original Circuit - Motor 9
J22
J15
+5V
U28
5
10
6
12
20
1K0
R145
8
16
7
14
18
1K0
R144
14
13
15
15
R148
100R
LEDPWR
13
11
R32
100R
1