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1) **INTRODUCTION**

The OEM-1 Electronic Module is comprised of basically four subsystems:

i) The signal processing and display,

ii) The stepper motor controls,

iii) The chopper controls,

iv) The DC-DC inverter.

Each of these subsystems will be discussed in detail within this Instruction Manual.

The OEM-1 module controls the sample wheel so that the relative transmittance of the samples can be compared to the clear aperture position. The 3-1/2 digit DVM displays the clear aperture signal level as well as the ratio of the remaining sample positions relative to the clear aperture position. The sample wheel position is decoded so that the signals and ratios can be correlated to the data. The OEM is automatically reset to the \( I_0 \) on initial turn-on and can be reset to the "0" position by actuating a front panel switch. The sample wheel can be interrupted to change samples or induce a longer integration time if desired by a front panel command. Integration times from 1 - 50 seconds are provided at the front panel. BCD data for external interfacing is provided.
II) SPECIFICATIONS

OEM Electronics

Analog Divider Accuracy    \( \pm 0.25\% \) for \( I_o > 100 \text{ mV} \)
Ratio Accuracy    \( < 0.4\% \); \( I_o = 10 \text{ V} \)
DVM Accuracy    \( 0.05\% \) Reading \( \pm 0.05\% \) F.S.
DVM Temp. Coefficient    \( \pm 0.005\% \) R/°C
DVM F. S. Sensitivity    19.99 V
DVM Resolution    10 mV
DVM Input Impedance    1 Mohm
DVM Digital Outputs    Parallel BCD, TTL Compatible, 1-2-4-8 Code
DVM Reading Rate    Up to 10 /sec
System Sample Time    1, 2, 5, 10, 20 and 50 sec
Maximum Input    + 10 VDC
Input Polarity    Positive
\( I_o \) Analog Output    + 10 V Max
\( I_n / I_o \) Analog Output    + 10 V Max.
\( I_n \) Analog Output    + 10 V Max
Number of Sample Positions    8
Position Indicators    Front Panel LED Indicators. One for each position.
Position Data    Parallel BCD, TTL Compatible
Data Ready

TTL Compatible; one at DVM reading
and one ANDed function of DVM
+ Sample Timer Rate

Chopping Frequency

≈ 15 Hz

D/A Linearity

0.05% (25°C) of full scale
0.075% (0-70°C) of full scale

Power Requirements

+28 VDC, 130 W (Max.)

Dimensions

5-1/4" x 19" x 17³
III ) CIRCUIT DESCRIPTION

The OEM-1 has three printed circuit boards;

i) The Signal Processing and Chopper Electronics, PCB-080,

ii) The "Sequencer and Controller" board, PCB-078,

iii) The Power Supply board, PCB-079.

The functions of these boards are described in the following text.

A) SIGNAL PROCESSING AND CHOPPER

The light source is modulated by a stable chopper network consisting of a DC motor, the chopper blade, the rate detector, and the speed controller. The controller output is proportional to the error signal generated by the difference between the rate feedback and a stable internal reference signal.

The modulated light is detected by the EMR photomultiplier tube (PMT) as it passed through the sample wheel apertures. The output of the PMT is channelled into a lock-in amplifier (to be supplied by NASA) which is synchronized to the modulation frequency of the chopper wheel. The chopper reference output signal is available at the OEM-1 front panel, labelled Chopper Monitor. The output of the lock-in amplifier must be positive with a maximum amplitude of +10 V.

For optimum ratio accuracy, the clear aperture signal, $T_0$, should be as close to +10 VDC as possible. The lock-in amplifier is attached to the OEM electronic module via the buffer amplifier. The output of the buffer is made
available at the front panel, labelled $I_n$. This output monitors the voltage of the lock-in signal and provides an analog output for each sample wheel position. The buffer output is connected to the analog divider and to the DVM (digital voltmeter) input relay. The DVM input relay is in the $I_o$ position only when the sample wheel is in the clear aperture position. The clear aperture signal $I_o$ is digitized and displayed on the 3-1/2 digit DVM. The BCD output $I_o$ of the DVM is stored in the storage resistors until the system is either manually reset or the sample wheel has moved all the way around back to the $I_o$ position. A 3-1/2 digit D/A converter is used to convert the digital $I_o$ information back into the analog domain. The D/A output is maintained stable regardless of the length of the sample time selected. Thus, analog sample and hold amplifiers have been eliminated which would otherwise cause ratio errors due to the finite droop in their outputs.

Thus, the D/A output provides a stable and accurate $I_o$ reference level for the analog divider. This output is also available at the front panel labelled $I_o$.

After the $I_o$ has been digitized, stored and converted back to the analog domain, the DVM input relay is switched to the $I_n/I_o$ position as the sample wheel indexes to a new position. Thus, the analog divider now has two inputs:

i) The stable, stored $I_o$ level and,

ii) The different level corresponding to a new aperture position.
The output of the analog divider is digitized and displayed on the DVM.

The ratio \( \frac{I_n}{I_o} \), where \( I_n \) is the signal corresponding to the seven other aperture positions \( n = 1 - 7 \), is displayed sequentially as the stepper motor drives the sample wheel around to the initial \( I_o \) position. When the \( I_o \) position is reached again, the DVM selector switch is commanded to the \( I_o \) position. The new \( I_o \) value is digitized, stored and converted, as before, to provide a new \( I_o \) reference for the next revolution of the sample wheel.

If for any reason the \( I_n \) signal is greater than the \( I_o \) signal, the front panel Error light will illuminate. This could happen, for example, if the lock-in sensitivity was changed in the middle of the sample wheel indexing process. The front panel Overload indicator will illuminate if the signal input ever exceeds +10 VDC. These two indicators functions are also available in TTL levels for digital processing to indicate erroneous data.

Whenever the power is initially turned on or a reset command is given, the system will automatically seek the \( I_o \) position and store a new \( I_o \) value for the ratio comparison. The DVM’s BCD outputs are available along with data ready transfer pulses and sample wheel position data. These outputs can be connected to external peripheral equipment for further storage and/or processing. The DVM’s digital outputs include the \( I_o \) value and the ratio \( \frac{I_n}{I_o} \quad (n = 1 - 7) \).
B) SEQUENCER AND CONTROLLER

The control subsystem performs all the functions to properly correlate the sample wheel position and the signal being processed. To best understand the operation, refer to Figure 1 and Figure 2 for the following discussion.

When the unit is first turned on, a "power-on reset" command is initiated which enables the stepper motor index clock. This clock drives the stepper motor, via the motor driver circuitry, which in turn spins the sample wheel. In Figure 2, position 4 was initially assumed. The stepper motor continues to index until the "0" ($I_0$) position is reached. Position sensors are used to distinguish the $I_0$ position from the other positions. During this indexing process, the system registers are reset to zero to eliminate initial errors.

When the $I_0$ position is reached, the $I_0$ position sensor goes high and the "0" front panel light goes on. This enables the sample timer whose time interval can be selected at the front panel. The $I_0$ position is maintained for the preselected sample time interval. On the leading edge of the subsequent sample timer output pulse, a couple of things happen:

1) A data ready (transfer) pulse is generated so that the digitized $I_0$ data from the DVM can be stored in external peripheral equipment, and

2) the DVM's BCD data is transferred into the storage register and stored until the next $I_0$ position is reached.
The D/A converter therefore maintains the stable analog signal at the input of the analog divider for the remaining cycle.

On the sample timer's output trailing edge, the stepper motor is commanded to index to the next (1) position. When the "1" position (referring to I1 aperture) is reached, the "1" position light comes on. In addition, the DVM input relay is actuated to the I1 / Io position. This switch position is maintained until the next Io position is reached. Thus, the DVM displays the ratio of I1 / Io. The digitized I1 / Io information is strobed out to peripheral equipment when the leading edge of the next sample timer output pulse appears. This allows the digital output to be available only after the end of the integration time generated by the sample timer. The lock-in amplifier time constant should be selected in accordance with the sample timer setting. If desired, however, the digital output can be transferred at the DVM's reading rate (up to 10 readings/sec) since two data ready TTL levels are provided. One comes directly from the DVM and the other is an ANDed function of the DVM and the sample timer logic. The ANDed data ready level occurs after the motor indexes to a new position and the sample timer interval has expired. The position data decoder will always provide the necessary information to correlate the signal data with the position data.

This process continues sequentially and automatically until the next Io position is reached. A new Io value is again displayed and stored and the indexing process continues, as before. The time interval between the
sample positions is controlled by a front panel switch with 1, 2, 5, 10, 20 and 50 second positions. Each position is displayed at the front panel by an illuminated LED indicator light.

The indexing process may be indefinitely held in the desired position by actuating the Interrupt switch.

This switch disables the sample timer. This switch can be used to stop the wheel without resetting it to the $I_0$ position. Use this switch to stop the wheel when a new sample is to be installed or use it to integrate longer than the sample rate clock settings allow. If pressed while the stepper motor is indexing, the sample wheel will continue to the next position. The stepper motor has 15° indexing increments, thus three motor clock pulses are required to index the sample wheel to the next aperture position.

When the Interrupt switch is deactivated, the sample wheel will advance to a new position and continue at the selected sample rate.

If the Reset switch is actuated, the stepper motor will index until the "$0" position is reached. The storage register and the position data counter will be reset to zero. Therefore, by using the reset and/or the Interrupt switches, the operator may manually control the operation and select and maintain any position as long as desired. The front panel positional information as well as visual display of the $I_o$, $I_n$ and $I_n/I_o$ ratio values provide a functional instrument which is ready to use. Analog outputs for $I_o$, $I_n$ and $I_n/I_o$ are provided. The rear panel provides for the power supply input of +28 VDC, protection fuses, digital outputs and the OEM module interfacing connector.
C ) **POWER SUPPLY**

The OEM-1 requires +5 V, +15 V, -15 V, and the incoming +28 VDC for operation. The +5 V and ±15 V sources are generated and regulated by PCB-079. The board provides stable DC outputs with line and load regulation of about 0.01% on all outputs. Both the ±15 VDC outputs are capable of supplying 100 mA, whereas the +5 VDC output can supply up to 2 A. The -15 VDC output is achieved by utilizing a 10 kHz oscillator which drives an inverter transformer. The output of this transformer is rectified, filtered and regulated at -15 VDC. The +5 VDC and +15 VDC are current limited at 2 A and 100 mA respectively.
IV ) OPERATING INSTRUCTIONS

A ) FRONT PANEL

The front panel contains the control switches, the position, overload and error indicators, the digital display, signal input, the chopper monitor output, and three analog output monitors. Each of these functions will be discussed in the following text.

Power On: This switch applies the +28 VDC to the system. No warm-up time is required.

Reset: This switch when actuated will cause the sample wheel to index continuously until the \( I_0 \) wheel position is detected. When the \( I_0 \) position is reached, the sample wheel will proceed at a rate governed by the Sample Time switch.

The Reset Light will come on when the power is initially applied to the system unless the sample wheel is already in the \( I_0 \) position. Therefore, the OEM-1 will command the sample wheel to seek out the \( I_0 \) position when the unit is first turned on or whenever this switch is actuated.

Interrupt: This switch can be used to stop the sample wheel indefinitely at any position desired. If actuated, however, during an indexing cycle, the sample wheel will continue the next position and then stop. This function allows for sample replacement or longer integration times than provided by the
front panel Sample Time switch. When this switch is deactivated, the sample wheel will immediately advance to the next position. If this switch is depressed after the reset command is initiated, the $I_o$ position will be reached and maintained. To index to, and hold the next position, simply deactivate the Interrupt switch and immediately activate it again.

Sample Timer (seconds): This rotary switch selects the integration time of the sample position. The times provided are 1, 2, 5, 10, 20, and 50 seconds. The timer starts when the sample wheel reaches a new aperture position. At the end of the timer cycle, a data ready strobe is generated and "ANDed" with the DVM data ready TTL level. This ANDed data ready signal is provided at the digital output connector. The sample wheel indexes to a new position at the end of the timer cycle.

Position Indicators: There are eight LED indicators that show the wheel position. When the Reset light is on, these LED's may be invalid. However, when the $I_o$ position is reached the "O" light will illuminate, thus resetting the position counter to the proper state. As the sample wheel indexes, these LED's will sequentially illuminate to show the correct sample position. The position is also available in BCD format at the CP2 connector on the rear panel.

Digital Display: This 3-1/2 digit DVM has a full scale sensitivity of ±19.99 V. The decimal point is fixed between the first and second MSB digits, e.g. 1.000. In the $I_o$ position the DVM reads the lock-in output directly. The $I_o$ signal should be as close to ±10 V as possible for maximum
ratio accuracy. In the $I_1 \rightarrow I_7$ positions, the ratio $I_n / I_o$ is displayed where $n = 1 \rightarrow 7$. The DVM display is provided in BCD, TTL compatible levels at CP2 on the rear panel. The DVM data ready strobe is also provided if readings at the DVM reading rate are desired.

**Overload:** This LED indicator will come on if the signal input exceeds +10 VDC. The overload condition is also available in digital form at CP2 on the rear panel.

**Error:** This LED indicator will illuminate if the $I_n$ signal is greater than the clear aperture position signal. This function is also available in digital TTL compatible form at CP2 on the rear panel.

**Signal Input:** This floating BNC is to be connected to the NASA supplied lock-in amplifier. The output of the lock-in amplifier should be close to +10 V in the $I_o$ position for the best ratio accuracy. The overload light will come on if the input voltage exceeds +10 V. Do not apply a negative input polarity.

**Chopper Monitor:** This floating BNC provides the chopper reference for the lock-in amplifier. The output is 50% duty cycle and is a TTL output level.

$I_o$: This floating BNC provides an analog output of the stored $I_o$ signal. This signal remains stable over the complete sample wheel indexing cycle. When a new $I_o$ position is reached, this $I_o$ signal level may change to correspond to the new $I_o$ signal level. Do not load this output down, use equipment with at least 10 kohm input impedance when measuring this output.
**I₀**: This floating BNC connector essentially provides the lock-in output (same as signal input) signal at the front panel. However, this output is after the buffer amplifier and is the exact voltage that is applied to the analog divider circuitry. The signal input and the \( I₀ \) output will vary by the amount of offset and attenuation contributed by the buffer amplifier. Use at least 10 kohm input impedance measuring equipment.

**\( I_n/I₀ \)**: This floating BNC provides the output directly from the analog divider. This analog signal is directly coupled internally to the DVM in the \( I_1 \rightarrow I_7 \) positions. Use at least 10 kohm input impedance measuring equipment.

**B ) BACK PANEL**

The back panel provides the input power connections, fuses, and the connectors for digital outputs and OEM housing interfacing. Each will be briefly discussed.

**Input Power Barrier Strip**: The OEM-1 requires an +28 VDC input. A two terminal barrier strip is provided to interface the OEM-1 to an external power supply. Make sure the external supply is properly connected, otherwise damage to the OEM-1 may result.

**F1**: This 5A fuse is the main line fuse and protects the OEM-1 from system overloads and short circuits.
F2: This 1/2 A fuse protects the chopper motor.

F3: This 1-1/2 A fuse protects the DC power supply PCB-078.

F4: This 1/4 A fuse protects the photomultiplier tube power supply.

CP1: This 24 pin cannon connector provides all the interfacing necessary between the sample wheel assembly and the OEM-1 electronic chassis. See Table I for the pin assignments.

CP2: This 24 pin ribbon connector provides all the BCD, TTL compatible data line necessary to interface with the external peripheral equipment. See Table II for the pin assignments.
V) CALIBRATION PROCEDURE

A) SAMPLE TIMER CALIBRATION

There are six single turn trim-pots on the sequencer and controller printed circuit board, PCB-078, which allow calibrating the sample timer.

The trimpots are labelled "1S" through "50S" corresponding to their respective timer positions. To calibrate, follow this procedure:

i) Using an oscilloscope of the interval counter, look at pin 9 of U15, and pin 3 of U5.

ii) Select the desired sample timer position and allow the sample wheel to index. Adjust the appropriate trim-pot so that the time between the pulses at these pins corresponds to the selected time position.

B) CHOPPER SPEED ADJUSTMENT

The chopper speed adjustment is located on the "Analog Divider and Chopper" printed circuit board, PCB-080. Follow this procedure to adjust the chopper speed.

i) Remove the power supply printed circuit board, PCB-079, for access to the speed adjustment.
i ) Make sure this board is supported and insulated from the surrounding circuitry so it does not short out.

ii ) Adjust trim-pot labelled " P41, Chop. Rate " on PCB-080 while observing the chopper monitor BNC output. If this pot is adjusted to an excessively low speed, the chopper wheel will pulse irrationally, if adjusted too high, the speed regulation will be affected. A chopping frequency of about 15 Hz is desired for proper stability.

C ) DAC OFFSET AND FULL SCALE ADJUSTMENT

These adjustments also include the DAC output amplifier balance adjustment. Follow these steps for correct DAC adjustments.

i ) Remove the power supply board, PCB-079, for access to the DAC and the trim-pots. Insulate this board from the surrounding circuitry.

ii ) Allow the sample wheel to index to the $I_0$ position. Actuate the interrupt switch so that the wheel can be manually turned for the following steps.

iii ) With the sample wheel in the $I_0$ position, check pins 12, 13, 14, 15 of U3, U4 and U5 and pin 15 of U2 to make sure the
storage resistors are reset to zero. If they are, use a 4-1/2
digit DVM with a resolution of 100 μV and observe pin 30 of
3-1/2 digit DAC. This DAC output can be zeroed by
adjusting the trimpot labelled " R4, Offset Adj. ". Adjust R4
so that the DAC is as near to zero as possible. Connect the
DVM common lead to the analog ground on PCB-080.

iv) With the DAC zeroed as close to zero as possible, observe
the output of U6 at Pin 6. Adjust the trim-pot labelled
" U6 Bal." so that it reads the same as pin 30 of the DAC.
Thus, pin 6 of U6 should also read very close to zero volts.

v) With a stable external power supply, apply +10.00 VDC to
the signal input BNC. The DVM should read 1.000
(corresponding to +10.00 V). Make sure the DVM reads
exactly 1.000. Now, manually turn the sample wheel to the
I1 position. Pin 15 of U2 should now be a logic 1, and
pins 12, 13, 14 and 15 of U3, U4 and U5 should be a logic
0. Adjust the trim-pot labelled " R5, F.S. Adj. " reads
+10.000 V on the 4-1/2 digit DVM.
VI) TROUBLESHOOTING PROCEDURE

A few brief suggestions listed below may help in locating system problems.

This list is not intended to cover all the possible symptoms and causes, but it should cover some of the most likely ones. Refer to the indicated schematics when specified.

All voltages are referred to chassis common.

<table>
<thead>
<tr>
<th>SYMPTOM</th>
<th>PROBABLE CAUSE &amp; SOLUTION</th>
</tr>
</thead>
</table>
| 1) No system power | a) Check F1 and replace if necessary. Investigate the cause of failure.  
b) Make sure the input DC lines are properly connected. |
| 2) The position indicators show the wrong position | a) If the wheel is obstructed this will cause a wrong count.  
b) A varying +28 VDC input may slow the stepper motor sufficiently to cause timing problems. Use a solid +28 VDC source. |
| 3) The sample timer is not calibrated. | a) Recalibrate as discussed in Chapter V, A. |
| 4) The DVM ratio readout is in error and/or may exceed 1.000. | a) At small $I_o$ signal input levels the DAC accuracy will reduce the accuracy of the ratio measurement. For the best accuracy, keep the $I_o$ signal level as close to +10 V as possible.  
b) The accuracy of the analog divider falls off steeply for $I_o < 100$ mV. |
5) The chopper rate is erratic or drifts randomly
   a) If the chopper rate trim-pot R41 on PCB-080 is adjusted too low or too high a loss of regulation will occur. Select a rate of about 15 Hz.
   b) A rapidly varying +28 VDC input may cause random variations in the chopping frequency.

6) The ratio output inaccuracy seems to be excessive
   a) Recalibrate the DAC and its associated amplifier U6, by the procedure discussed in Chapter V, C.

6) For best results, keep the signal level as close to +10 V as possible.

7) The chopper motor is not running
   a) Check F2

8) No Photomultiplier output is detectable
   a) Check F4
   b) Do not damage the PMT by flooding it excessively with the lamp source.

9) The stepper motor does not stop at the correct wheel position (detent)
   a) Tighten the set-screws in the shaft-to-wheel coupler assembly
   b) Adjust the detent to match the sample wheel grooves
   c) Adjust the pulse width of U13
      \[ T_w = 1.1 \left( \frac{R49}{C33} \right) \] so that the trailing edge of the pulse occurs after the sample wheel stops oscillating (after being pulsed) and before the next motor step command is determined by U13 Pin 5.
# TABLE 1

CP 1, OEME TO OEMCP INTERFACE

<table>
<thead>
<tr>
<th>PIN #</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Open</td>
</tr>
<tr>
<td>B</td>
<td>Open</td>
</tr>
<tr>
<td>C</td>
<td>Open</td>
</tr>
<tr>
<td>D</td>
<td>Open</td>
</tr>
<tr>
<td>E</td>
<td>Chopper LED Anode</td>
</tr>
<tr>
<td>F</td>
<td>Chopper LED Cathode &amp; Chopper Photo-transistor emitter</td>
</tr>
<tr>
<td>G</td>
<td>Chopper Photo-transistor collector</td>
</tr>
<tr>
<td>H</td>
<td>Photomultiplier P.S.; +28 V</td>
</tr>
<tr>
<td>J</td>
<td>Photomultiplier P.S.; Ground</td>
</tr>
<tr>
<td>K</td>
<td>$I_o$ LED Anode</td>
</tr>
<tr>
<td>L</td>
<td>$I_n$ LED Anode</td>
</tr>
<tr>
<td>M</td>
<td>$I_e$ &amp; $I_n$ LED cathodes &amp; $I_o$ &amp; $I_n$ Photo-transistor emitters</td>
</tr>
<tr>
<td>N</td>
<td>$I_o$ Photo-transistor collector</td>
</tr>
<tr>
<td>P</td>
<td>$I_n$ Photo-transistor collector</td>
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<tr>
<td>R</td>
<td>Ground</td>
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<tr>
<td>S</td>
<td>Ground</td>
</tr>
<tr>
<td>T</td>
<td>Ground</td>
</tr>
<tr>
<td>U</td>
<td>Chopper motor shield return</td>
</tr>
<tr>
<td>V</td>
<td>Stepper motor shield</td>
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<tr>
<td>W</td>
<td>Chopper motor (L)</td>
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<tr>
<td>X</td>
<td>+28 VDC Chopper motor (H)</td>
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<td>Y</td>
<td>+28 VDC Stepper Motor (H)</td>
</tr>
<tr>
<td>Z</td>
<td>Stepper Motor (L)</td>
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</tbody>
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### TABLE II

**CP2, DIGITAL OUTPUTS**

<table>
<thead>
<tr>
<th>PIN</th>
<th>FUNCTION</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Data Ready (OEM + DVM)</td>
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<tr>
<td>2</td>
<td>Position BCD: 4</td>
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<tr>
<td>3</td>
<td>Position BCD: 2</td>
</tr>
<tr>
<td>4</td>
<td>Position BCD: 1</td>
</tr>
<tr>
<td>5</td>
<td>Error</td>
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<td>6</td>
<td>Analog Overload</td>
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<tr>
<td>7</td>
<td>Read Enable</td>
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<tr>
<td>8</td>
<td>Data Ready (DVM)</td>
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<td>9</td>
<td>+ Polarity</td>
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<td>DVM Overflow</td>
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<td>BCD: 1000</td>
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<td>BCD: 4</td>
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<td>22</td>
<td>BCD: 2</td>
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<td>23</td>
<td>BCD: 1</td>
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<td>24</td>
<td>Digital Ground</td>
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</table>
CHOPPER MONITOR

+28V

position sensor

SAMPLE WHEEL

STEPPER MOTOR

+5V

reference

*photodetector

*SAMPLE WHEEL

*SOURCE POWER SUPPLY

*LIGHT SOURCE

*SPEED CONTROLLER

*SAMPLER

STEPPER MOTOR DRIVER

SYSTEM SEQUENCER & CONTROLLER

DECODER DRIVER

DECade COUNTER

POSITION INDICATORS

+5V

0 1 2 3 4 5 6 7

RESET

motor index clock

SAMPLE TIMER

ERROR

ANALOG OUTPUT

+5V

ANALOG DIVIDER

SAMPLE

(SEC)

clear

interrupt

data ready

ORIGINAL PAGE IS OF POOR QUALITY.
ANALOG DIVIDER & CHOPPER
PCB-080
Q3 IS MOUNTED OFF PCB-079 ON AN EXT. HEATSINK.