STARLIGHT-1 STELLAR PHOTOMETER

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SECTION I. General Information

1.1 Introduction

Photoelectric photometry is the measurement of the intensity of a light source by electrical means. In astronomical applications, the light source is usually a star of variable or constant magnitude, an asteroid, or a comet. Until recently, the cost and technical complexity of good photoelectric equipment had limited photoelectric photometry to the professional observatories and a few amateurs with extensive electrical background.

The STARLIGHT-1 has been designed to provide everyone - amateurs, professionals, colleges, high schools - the capability of making the highest quality photoelectic measurements without concern for electronics, cooled housings, or expensive ancillary equipment. No other equipment is required in order to obtain results of publishable quality. Our customers include as many professional astronomers as amateur astronomers; in fact, the only thing "amateur" about the STARLIGHT-1 is its selling price! You will soon have the satisfaction of realizing that you have purchased the finest stellar photometer available from a commercial source. You could have paid thousands of dollars more without obtaining half of the features available on the STARLIGHT-1.

We recommend that you read this instruction manual completely before operating your STARLIGHT-1 Photometer. If you are new to stellar photometry, we also recommend that you read one or more of the following books on the subject:

1. "Photoelectric Astronomy for Amateurs", by F.B. Wood, Macmillan Publishing Company, New York, 1963.

2. "Photoelectric Photometry of Variable Stars", by D.S. Hall and R.M. Genet, 1981. (Available through EMI Gencom Inc.).

3. "Astronomical Photometry", by A. Henden and R.H. Kaitchuck, Van Nostrand Reinhold, May 1982.

If you would like to share your interest in stellar photometry with other professional and amateur astronomers, we recommend that you join the International Amateur - Professional Photoelectric Photometry (I.A.P.P.P.) organization. Information may be obtained from Mr. Russel M. Genet, Fairborn Observatory, 1247 Folk Road, Fairborn, Ohio, 45324.

1.2 DESCRIPTION

The STARLIGHT-1 consists of 3 basic parts:

1) The photometer head (sometimes referred to as "HEAD" in this manual) which detects light through your telescope and converts it into a useful electrical signal.

2) The interconnecting cable which carries the ECL signal to the photon counter, and supplies low voltage to the dc-dc power supply in the photometer head.

3) The photon counter (sometimes referred to as "COUNTER") which controls the counting interval and processes the signal into a digital, TTL, analog, or multiplexed BCD, START, STOP, and RESET input/output for computer interface.

The photometer head contains the power supply, photomultiplier tube, Fabry lens, diaphragm and filter turrets. See figures 14-16 on pages 47-49. The photometer head is described in detail in Section 3.3.

The photon counting unit is a complete instrument in itself, which can be used with any detector system capable of operating in the single photoelectron mode. It is of extremely rugged design to allow continuous transportation to and from observing sites. It has a carrying handle which also serves as a tilt bar for adjusting the front panel to the optimum viewing position. A complete description of the counter can be found in section 3.1 and 3.2.

1.3 SPECIFICATIONS

MECHANICAL

Photometer Head:
- Dimensions: 6.5"W x 4.5"H x 7.2"L
- Weight: 5 lbs. 7 oz. (including eyepiece)
- Mounting: 4 threaded mounting holes, 10-32 on 5" x 6" centers. 1¼" O.D. eyepiece adaptor is standard 2" O.D. eyepiece adaptor available on request. Other sizes are available on special orders.

Photon Counter:
- Dimensions: 12.13W x 3.94 x 9.3D (without handle and feet) 13"W x 4.3"H x 9.3"D (with handle and feet)
- Weight: 11 lbs.
- Cable: 10-ft. long is standard. Extra length is available.

OPTICAL SYSTEM

Focal Length: f/5.0 or longer focal length telescopes. Optical system contains field lens and Fabry lens.

Aperture Sizes: 22" 57" 110" 164" 275"

Standard Set A: .020, .052, .0995, .1495, .250 and full open with illuminated reticle.

11" 22" 35" 44" 220"

Standard Set B: .010, .020, .0313, .040, .199 and full open with illuminated reticle.

Non-Standard: Custom sizes can be made to order.

Filters:
- U: 1 mm Shott UG-1
- B: 1 mm Shott GG-400 1 mm Shott BG-25
- V: 1 mm Shott OG-515
- O: Opague for use as protective shutter
- R: Unused position in standard unit
- I: Unused position in standard unit

Photomultiplier Tubes:

Standard: EMI 9924A
- Background: 200 c.p.s. at 22°C typ., 500 c.p.s. maximum at 22°C.
- Spectral Range: 3100 Å to 6700 Å
- Peak Response: 4200 Å

Non-Standard: Contact EMI GENCOM for other types.

ELECTRICAL

Power: 110-120/220-240 V, 50-60 HZ Switch Selectable 25 Watts

Connectors:
- Head: 9-pin 'D' type
- TTL: BNC
- Analog: Binding Post
- Input/Output: 25-pin 'D' type

PERFORMANCE

DIGITAL:
- Dead time: 1.2×10^{-7} seconds (120 nsec.) typical
- Gate time: 10, 1.0, 0.1, 0.01 seconds
- Unit Count: 10^8 maximum counts before overflow
- Accuracy: 50 ppm typical at 22°C

Analog:
- Range: 10^3, 10^4, 10^5, 10^6 counts/volt, +4.0 volts max.
- Response: 1 second on all ranges
- Linearity: within 1% on all ranges
- Dead time: 50µs at 10^3 c/v
  5 µs at 10^4 c/v
  500 ns at 10^5 c/v
  120 ns at 10^6 c/v

TTL: +2.4 volts minimum, 50 n second

Input/Output (multiplexed control & BCD data lines):

EOM/READY	Reset/Digit Select
BCD-1	Start/Digit Select
BCD-2	Stop/Digit Select
BCD-4	Control
BCD-8	Ground

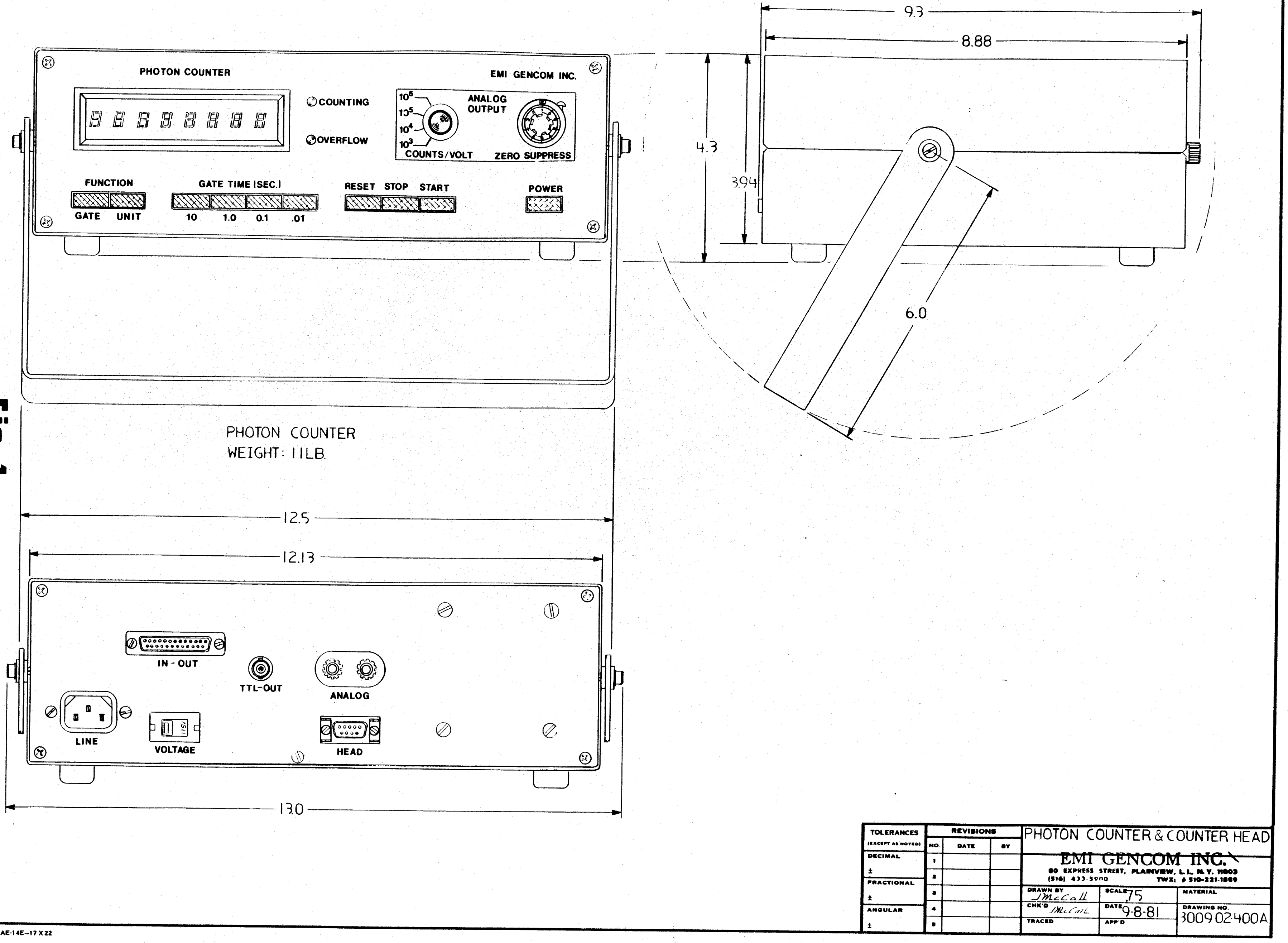

PHOTON COUNTER
EMI GENCOM INC.
COUNTING
OVERFLOW
ANALOG OUTPUT
COUNTS/VOLT
ZERO SUPPRESS
FUNCTION
GATE
UNIT
GATE TIME (SEC.)
10
1.0
0.1
.01
RESET
STOP
START
POWER
PHOTON COUNTER
WEIGHT: 11LB.
12.5
12.13
13.0
IN - OUT
TTL-OUT
ANALOG
LINE
VOLTAGE
HEAD
9.3
8.88
4.3
3.94
6.0
TOLERANCES
(EXCEPT AS NOTED)
DECIMAL
FRACTIONAL
ANGULAR
REVISIONS
NO.
DATE
BY
PHOTON COUNTER & COUNTER HEAD
EMI GENCOM INC.
80 EXPRESS STREET, PLAINVIEW, L.I., N.Y. 11803
(516) 433-5900
DRAWN BY J McCall
SCALE .75
MATERIAL
CHK'D J McCall
DATE 9-8-81
DRAWING NO. 3009 02 400A
TRACED
APP'D

Fig. 1

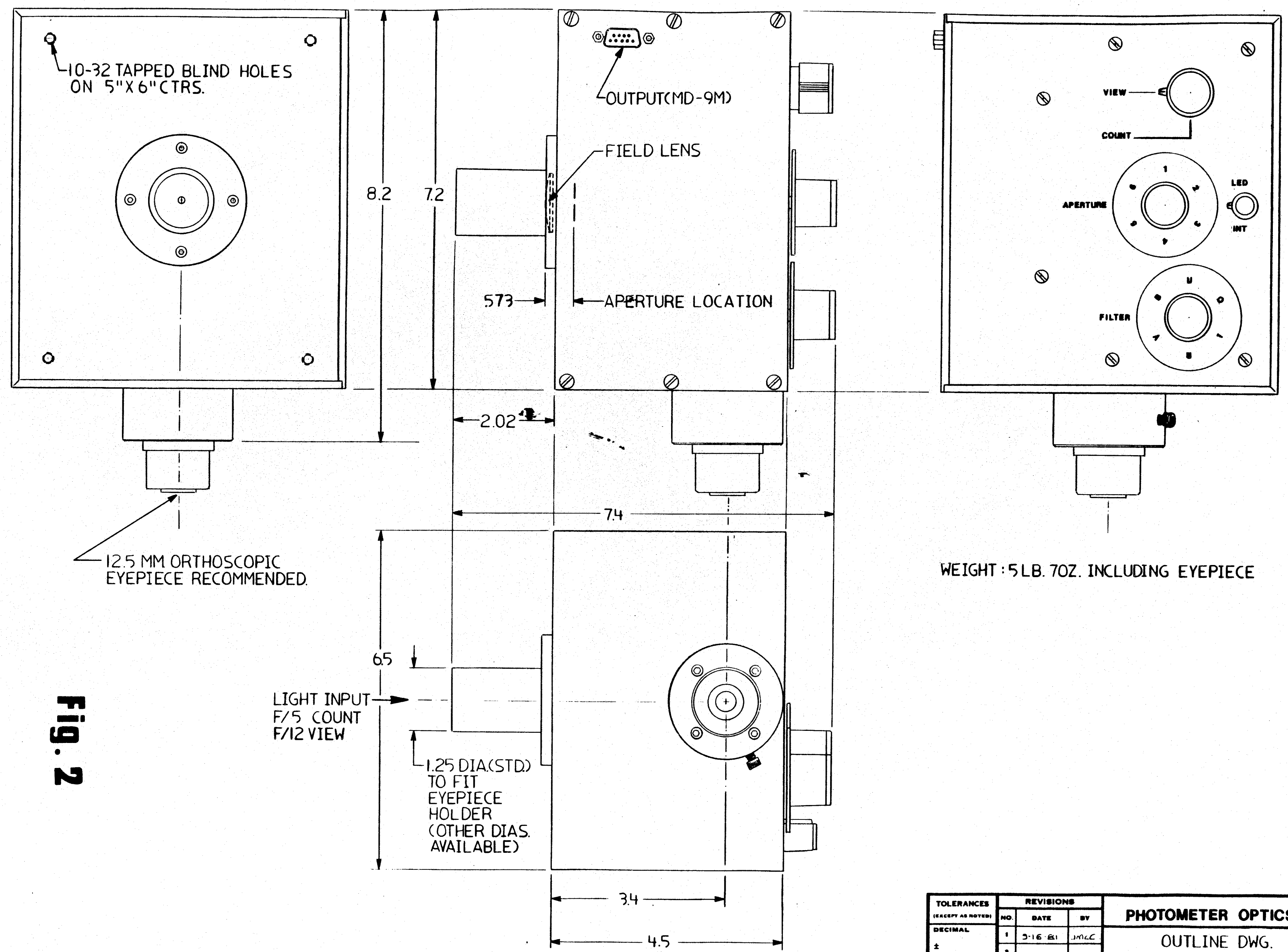


Fig. 2

TOLERANCES (EXCEPT AS NOTED)	REVISIONS			PHOTOMETER OPTICS HEAD		
	NO.	DATE	BY	OUTLINE DWG.		
DECIMAL ±	1	5-16-81	JMcC			
FRACTIONAL ±	2					
	3			DRAWN BY J McCall	SCALE .75	MATERIAL
ANGULAR ±	4			CHK'D J McCall	DATE 9-10-81	DRAWING NO. 3009-01-402B
	5			TRACED	APP'D	

TELEDYNE POST 18AE-14E-17X22

1.4 ACCESSORIES

As mentioned in section 1.1, the STARLIGHT-1 is a complete instrument, requiring no other equipment other than your telescope to provide extremely accurate photoelectric measurements. However, certain accessories are available which either add convenience or sophistication to your data collection.

1.4.1) 12.5 mm Meade Orthoscopic Eyepiece:

Since our reticle is located in the diaphragm turret (which provides the greatest convenience and accuracy), it allows great freedom in selection of a post viewing eyepiece. Since you probably already have a set of eyepieces, we could see no reason to supply you with another and increase your photometer cost. The post viewer eyepiece magnifies the aperture, thus allowing easy location of the star in the diaphragm. Any eyepiece within the 10 mm to 21 mm focal length range should provide the necessary magnification. If you do not wish to use one of your own, you may purchase one from us or any eyepiece manufacturer.

1.4.2) RC-1 Remote Control Box:

This accessory provides greatly increased operating convenience for persons who are not controlling their photometer by computer. The RC-1 consists of a hand-held box which contains Start, Stop, and Reset buttons, and a 10-foot long cable which plugs into the 25-pin Input/Output port on the rear panel. This device allows you to remain at your telescope and photometer head while making measurements - an invaluable feature when there is no one to assist you.

1.4.3) Photomultiplier Tubes:

The EMI 9924A supplied with your STARLIGHT-1 is the best photomultiplier tube available for UBV measurements. If you wish to extend your measurements into the red and near infrared spectral regions, EMI Gencom can supply EMI 9798A and D161A photomultipliers which are plug-in replaceable. The EMI 9798A is an S-20 tube with red response to 8500Å, but it has typically 10,000 c.p.s. at 22°C. The EMI D161A has an S-1 response which is sensitive to 11,000Å. Both tubes require cooling in order to be useful, but the EMI 9798A might be used on bright stars without cooling.

Note: The filters supplied with the STARLIGHT-1 are for use only with EMI 9924A photomultipliers. If the tube type is changed, new filters may be added to the "R" and "I" filter wheel position. The High Voltage control will also need adjustment. It is recommended that this be done in our factory.

1.4.4) Filters:

The filter wheel in your STARLIGHT-1 has two unused positions. You may insert any .820 inch diameter into these locations. Special filters may be purchased either through EMI Gencom or through a filter manufacturer.

1.4.5) Non-Standard Cable Lengths:

We can supply interface cables up to 25 feet in length.

1.4.6) AD-100:

The AD-100 is an amplifier/discriminator which allows the STARLIGHT-1 counter to be attached (by BNC connector) to any other photometer head which is capable of single photoelectron detection.

1.4.7) "Photoelectric Photometry of Variable Stars"

by D.S. Hall and R.M. Genet.

1.4.8) Mounting Flanges:

It is generally recommended that the user design his own mounting flange. However, if we are supplied with a detailed sketch of what you require for your particular telescope, we will supply a custom mounting system. (See section 2.4.)

1.4.9) Apertures:

We can supply additional standard aperture sets or individual apertures to customer specifications.

Accessories which may be available at a future date include digital printer with time display, computer interface boxes for certain model microcomputers (some models such as the Commodore Pet do not require additional interface electronics), computer interface cables, PMT cooling system, and chart recorders. An order form is included at the rear of this manual.

Section II INSTALLATION

2.1 Unpacking and Inspection

Your STARLIGHT-1 has been carefully calibrated, tested, and inspected for electrical and mechanical performance before it arrives in our Shipping Department. Upon arrival in shipping it is given a visual inspection to ensure that the equipment conforms to your order. The unit is then wrapped in plastic, placed inside specially formed styrofoam packing material, and shipped in a 200-lb. rated carton.

Upon receipt, inspect your instrument carefully for damage and contents.
NOTE: If any accessory item appears to be missing, check the packing list before calling us. It is possible that it was (or will be) shipped separately.
If damage is found, file a claim with the carrier and notify us as to the situation.

NOTE: It is recommended that you retain all packing material. This will be useful if the instrument ever needs to be returned to us, or if you are required to transport your unit to a distant observing site.

The STARLIGHT-1 has been shipped with the line voltage setting in the 110-120 V position. If 220-240V line voltage is to be used, PLEASE SWITCH THE LINE VOLTAGE SETTING ON THE REAR PANEL IMMEDIATELY!

2.2 LOCATION and HANDLING PRECAUTIONS

Both the Head and Counter of your STARLIGHT-1 has been designed to be extremely rugged, but as with any precision instrument, it should be handled with care and respect. The STARLIGHT-1 has been shipped with the filter turret in the "0" (opague shutter) position. Please be sure that it remains in this position at all times when not in use. This will prevent accidental exposure of the photomultiplier tube to intense light.

The photometer head could be damaged if it is dropped onto a hard surface; and the most likely time for this to happen is during the installation onto your telescope (see section 2.4). If possible, have someone help you during this procedure.

TEMPERATURE:

The STARLIGHT-1 should operate to specifications within a temperature range of $-15^{o}C$ ($5^{o}F$) to $+50^{o}C$ ($122^{o}F$). If your observatory falls below $0^{o}C$, you may want to cover the instrument in order to keep it as warm as possible. If the temperature in the observatory should exceed $50^{o}C$, the photometer should be moved to a cooler location.

HUMIDITY:

Even though we have taken great care to protect the photomultiplier/base assembly from humidity, extensive exposure to a humid environment may cause your background count rate to increase by more than an order of magnitude. If your observatory is not protected against humid weather, and if you do not intend to use the STARLIGHT-1 for a few days, we recommend that you remove the head from the telescope and place it in a dry location. Section 6.1.1 gives further information on this subject.

PMT CARE:

Your photomultiplier tube (PMT) is quite rugged for being such a sensitive device. They can be safely exposed to roomlight if there is no voltage applied to the dynodes. They can be subjected to an amazing amount of shock and vibration without damage. They can even sometimes survive a roll off the table (not a recommended practice)! With proper care, the EMI 9924A inside your stellar photometer will provide many years of excellent service. The standard rules which ensure long life are:

1) Avoid exposure to ambient light, especially when the high voltage is applied.
2) Avoid exposure to heat of more than 60°C (140°F).
3) Avoid excessive operating voltage. (Your PMT voltage has been factory set).
4) Do not drop.

If you do not remove the PMT from its chamber, and if you remember to put the filter wheel in the "0" position when the photometer is not in use, you will probably not have to worry about PMT damage. (See section 6.1).

2.3 Line Voltage and Power Requirements

The STARLIGHT-1 should be operated at 110-115V or 220-240V, 50-60 Hz. The input voltage selection switch is located on the back panel of the counting unit. The power requirement is 25 watts.

2.4 Installation of the Photometer Head

The location of the post viewer eyepiece and control dial has been chosen to provide optimum convenience for most telescope designs. Consideration of your final eyepiece location should be given before the mounting adaptors are designed.

The 1¼ inch O.D. (or other custom size) telescope adaptor tube should be secured to the telescope focusing assembly by either a locking screw or a locking clamp. The telescope adaptor tube is strong enough to easily support the photometer head without additional mounting brackets; however, if it is possible to also use mounting brackets, we would certainly recommend their usage - especially in situations in which the photometer will be operated by unskilled personnel.

Two simple "U" or "L" shaped brackets can be made from aluminum or steel. One side of the bracket should be bolted to the 10-32 tapped holes on the photometer head and the other side bolted to tapped holes in your telescope. The dimensions of the mounting brackets should be determined by first focusing the photometer on a star while using only the telescope adaptor as a mounting support (see section 3.3.2). This will provide the proper telescope to photometer distance to be figured in your mounting assembly dimensions.

Many other designs of mounting flanges and mounting brackets are possible, but DO NOT drill any additional holes into the photometer head. Any alteration of the photometer head or improper mounting of the photometer head will invalidate the warranty.

SECTION III.

OPERATING INSTRUCTIONS

3.0 Controls and Indicators

Refer to figure 3a for front panel controls and indicators. (Page 12).

1. AC power switch
2. START starts counter
3. STOP stops counter
4. RESET resets counter
5. .01 selects .01 sec gate time
6. .1 selects .1 sec gate time
7. 1.0 selects 1.0 sec gate time
8. 10 selects 10 sec. gate time
9. UNIT selects unit count mode (external gate time)
10. GATE selects gate count mode
11. Displays counts accumulated
12. Indicates unit is counting
13. Indicates counter overflow (10^8 counts - 1 max.)
14. Selects conversion rate for analog output
15. Zero suppress cancels background counts in analog output

Refer to figure3b for rear panel controls and indicators

16. AC power line receptical
17. AC line voltage select switch
18. Connector to photometer HEAD
19. Analog output (1 sec time constant)
20. TTL output (will not drive more than 12" of cable).
21. Computer or remote input/output connector.
22. Repeat/Single Switch

FRONT PANEL

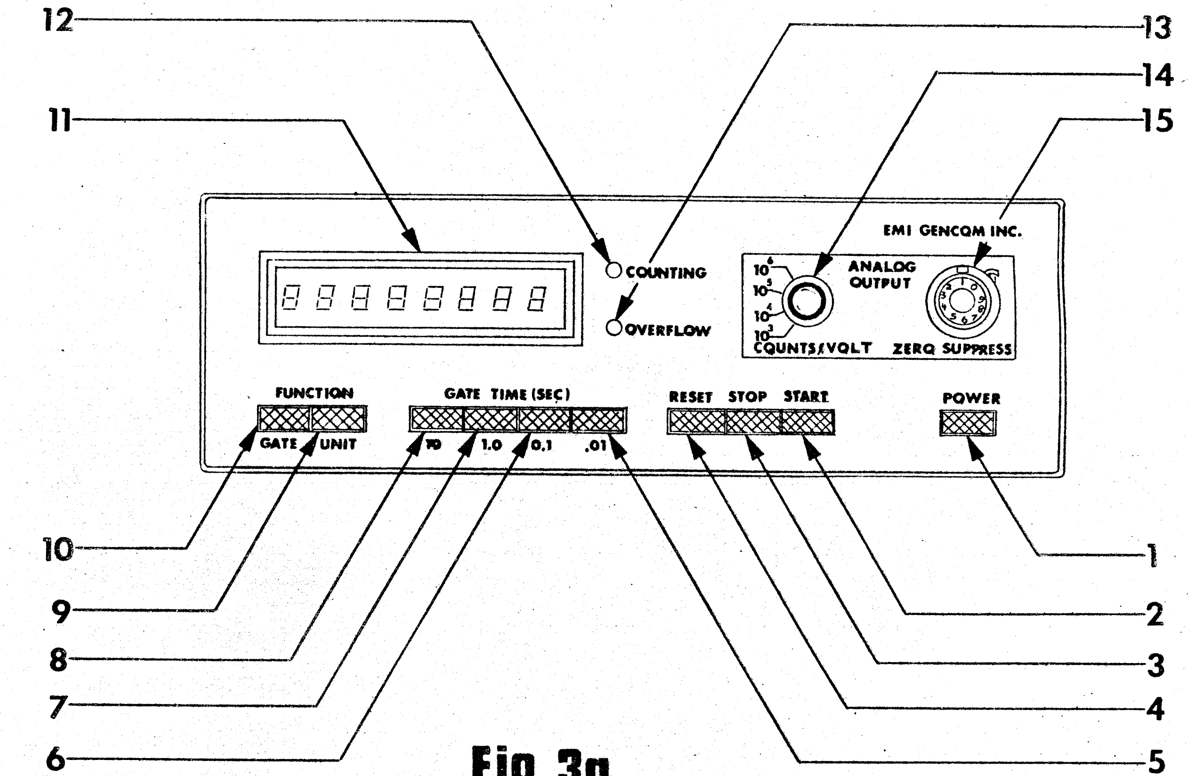


Fig. 3a.

REAR PANEL

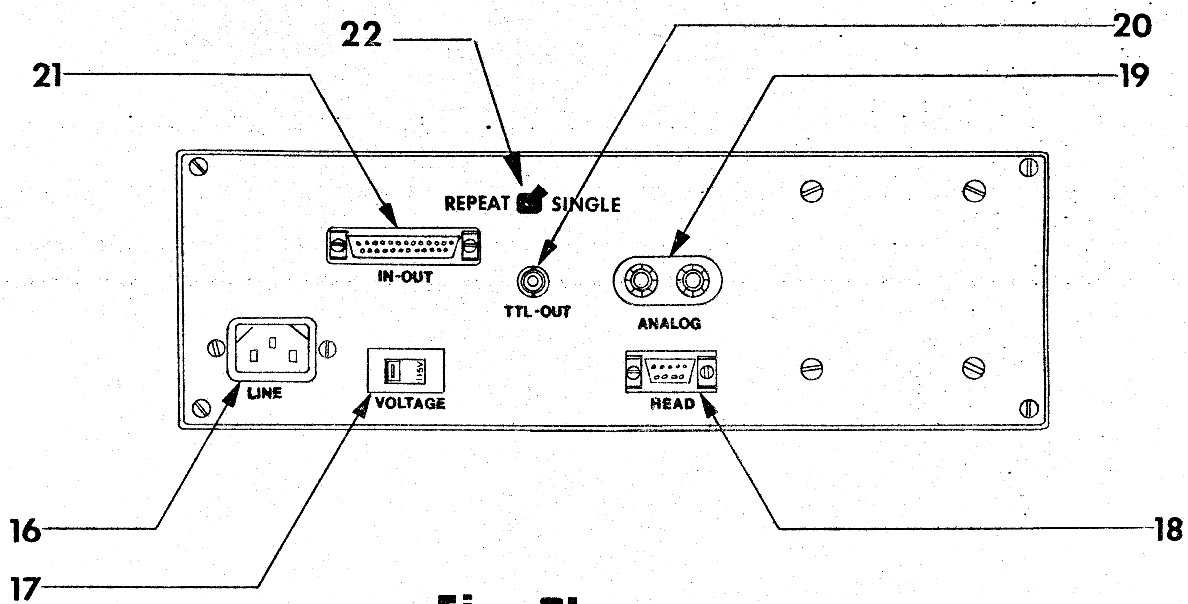


Fig. 3b.

Section III OPERATING INSTRUCTIONS

Refer to figure 3 for location of controls, inputs, etc. (Page 12).

3.1 Counter Rear Panel

3.1.1) Serial Number:

The serial number of your instrument is located on the blue and silver label. You should refer to this serial number in all correspondance relating to your stellar photometer.

3.1.2) Line Voltage Input:

A line cord has been supplied with your photometer. Units sold outside the U.S.A. are supplied with line cords which are terminated with European color coded wires. They should be connected to the counter through the input designated "LINE".

3.1.3) Voltage Selector:

Units are shipped in the 115V position. If you intend to use 220-240 volts, the position of this switch should be reversed.

3.1.4) Head Input:

The 9-pin interconnecting cable from the photometer head should be attached to the photon counter at this input.

3.1.5) Analog:

Two binding posts will provide an analog output for use with a chart recorder or analog meter.

3.1.6) TTL-Out:

A BNC connector is provided to a direct access to a TTL signal.

3.1.7) In-Out:

The 25-pin 'D' in/out connector serves two purposes. First, it provides an I/O Port for direct interface to a microcomputer (see Section 3.6). Second, it is to be used as the input for the model RC-1 remote control box. Obviously, they cannot be utilized at the same time, but a remote control is not required if a computer is controlling the counting interval.

3.1.8) Repeat/Single: See section 3.9, page 24 for proper use.

3.2 Counter Front Panel

3.2.1) Digital Display:

The STARLIGHT-1 has an 8 digit, LED digital display which is labelled "COUNTS". This displays the actual number of photoelectrons which are produced by the photocathode of the EMI 9924A PMT* The number of photoelectrons produced is directly proportional to the number of photons received from the star being measured. If more than 10^8 counts are received, the "OVERFLOW" indicator will light.

*assuming all are collected at the anode. Actual collection efficiency is approximately 95%.

3.2.2) POWER:

The power switch is located on the lower right portion of the front panel. It is pushed to turn on and off the photometer system.

3.2.3) START:

The "START" button will start the counting interval when pushed.

3.2.4) STOP:

The "STOP" button will stop the counting interval when pushed. If the counter is in "GATE" mode, the counting interval will stop automatically after the preselected gate time interval has elasped.

3.2.5) RESET:

The "RESET" button will reset the display to zero counts when pushed.

3.2.6) MODE:

There are two MODE switches:

GATE: When this button is pressed, the photometer will count the signal during the user selected gate time after the "START" button is pressed.

UNIT: When the STARLITGHT-1 is in the UNIT FUNCTION MODE, it will commence counting when the START button is pressed, and continue to collect counts until the user presses the STOP button. This counting mode is useful when long counting intervals are required, or when an interfaced microcomputer is controlling the counting interval.

3.2.7) GATE TIME:

The four push-buttons select counting intervals of 10, 1, 0.1, or 0.01 seconds. The counter must be in the GATE FUNCTION MODE for these gate times to be applicable.

3.2.8) COUNTING Indicator:

The counting indicator will light whenever the photon counter is collecting counts from the detector (photometer head). This indicator will light whenever the START button is pressed. This indicator is valuable since in the GATE MODE, the display will hold the previous count until the next measurement is completed. Thus, the COUNTING light is the only indication that a measurement is in progress.

3.2.9) ANALOG OUTPUT:

The STARLIGHT-1 provides a post discriminator analog output which is completely independent of all other forms of data output. The two analog output controls, COUNTS/VOLT and ZERO SUPPRESS, allow the user to control the analog output from the photon counter.

NOTE: If the analog output is always a 4 volt maximum and the counting and overflow LED's do not light, check the cable connection at J4 (figure 12).

3.3 Photometer Head Controls

(See figure 4, Page 16)

3.3.0) Controls and Indicators

1. Telescope adaptor tube
2. Output (9-Pin)
3. Top panel
4. Postviewer eyepiece
5. Front panel
6. Flip prism control
7. Aperture (Diaphragm) Turret control
8. LED backlight ON/OFF/Brightness Control
9. Filter Turret Control
10. Nylon eyepiece set screw

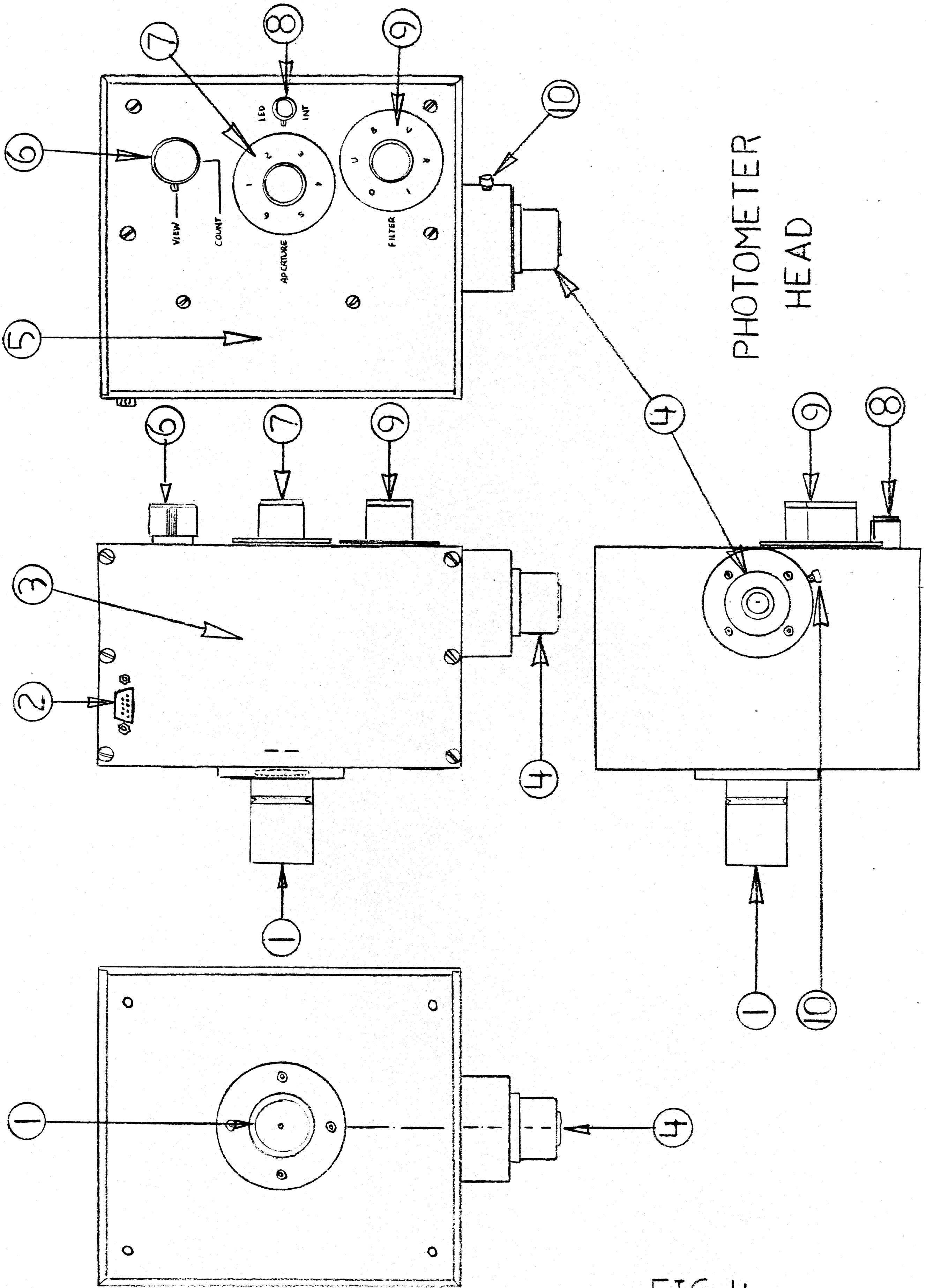

PHOTOMETER HEAD
1
2
3
4
5
6
7
8
9
10
VIEW
COUNT
APERTURE
FILTER
LED
INT

FIG. 4

3.3 Photometer Head Controls

See figure 4 for control locations

3.3.1) OUTPUT:

A 9 pin 'D' connector output is located on one side of the photometer head. The interconnecting cable from the photon counter should be inserted into this input.

3.3.2) POSTVIEWER EYEPIECE HOLDER:

A postviewer eyepiece holder is located on the "top" end panel. Your eyepiece should be inserted into this fixture and focussed on the apertures and reticle (which are parfocal). When the apertures and reticle are in focus, tighten the nylon set screw which is located on the side of the eyepiece holder. The eyepiece will ALWAYS remain in this position.

NOTE! DO NOT USE THIS EYEPIECE TO FOCUS ON YOUR STAR FIELD. ALL STAR FIELD FOCUSSING IS DONE BY YOUR TELESCOPE RACK AND PINION FOCUSSING ASSEMBLY, WHICH WILL MOVE THE ENTIRE PHOTOMETER HEAD INTO THE CORRECT FOCUS POSITION! (See section 6.2.7 page 46 for adjustments).

HINT: It is sometimes easiest to focus the postviewer eyepiece if you first turn on the backlight LED (section 3.3.3) to illuminate the aperture (or reticle). Then move the eyepiece until the edge of an aperture (or reticle) is in sharp focus.

3.3.3) LED/INT:

This switch turns on and off the internal LED and also controls the LED intensity. The unique design of this system provides exceptional backlighting of the aperture plates and excellent reticle illumination. An added convenience feature is that the LED will be automatically turned off when the flip prism is turned to the "COUNT" position (see section 3.3.4). This allows you to set the LED brightness to the desired level and leave it untouched during the night's observing. It also prevents accidential exposure of the PMT to the LED light, which would result in erroneous readings.

3.3.4) VIEW/COUNT SWITCH:

This is a two position switch which will place the flip prism into either the VIEW position or COUNT position. In the VIEW position, starlight is diverted to the post viewer microscope eyepiece; in the COUNT position, starlight is allowed to pass throught the filters and Fabry lens, and into the photomultiplier tube. It is recommended that the prism be left in the VIEW position when the photometer is not in use. This will help to protect your PMT from ambient light.

3.3.5) APERTURE:

The APERTURE control turns the aperture turret to the desired position. There are 6 aperture positions available with the following apertures depending upon the set you ordered:

Position #	Set A	Set B
		ARC SECONDS
1	Illuminated Reticle	Illuminated Reticle
2	.020 inch 22"	.010 inch 11"
3	.052 57"	.020 22"
4	.0995 1'49"	.0313 34"
5	.1495 2'44"	.040 43"
6	.250 4'35"	.199 3'[illegible]"

The set you choose depends upon the desired field of view, telescope focal length, and telescope tracking accuracy. See Graph 1 on page 27.

A red LED will illuminate the Aperture turret setting. It will always be lit when the Head is connected to The Counter and the power is "on". If the LED is not lit, you should check your cable connections. See section 6.4.5.

Each of the 6 aperture turret positions has two positive detented locations. One detent will place the aperture or reticle in the exact center of the field of view. The other detent will offset the aperture or reticle to one side of the field of view. This "offset" position may be used to obtain your sky background measurements while the star being measured is located in the center of the field.

NOTE: Before using the "offset detent" for sky background measurements, make sure that there is no star located in that position.

You should practice setting your aperture locations for a few minutes until you "get the feel" of the aperture turret positions and detents. You will soon become familiar enough with the control that you will be able to confidently switch from the center of the field to the offset position (and vice versa) without switching the flip prism to the VIEW position (NOTE: This requires accurate telescope tracking).

3.3.6) FILTER:

The filter turret operates in the same way as the aperture turret except that there is only 1 detent for each position which locates the filter in the center of the optical path. The filters in the 6 positions are as follows:

Position	Filter
U	Ultraviolet Channel (1 mm Shott UG-1)
B	Blue Channel (1 mm Shott GG-400, 1 mm Shott BG-25)
V	Visible Channel (1 mm Shott OG-515)
R	Open (See Appendix 1, page 59)
I	Open
0	Opague filter (shutter)

The filter turret should always be turned to the "0" position while the photometer is not in use. This will protect the PMT from exposure to ambient light.

The "R" and "I" positions are left open. Any other .820 inch diameter user selected filter may be placed into these positions (see section 6.2.3).

We have designed the STARLIGHT-1 Head so that the filter turret is positioned in the optical path behind the flip prism. This provides 3 very important features:

1. The light viewed through the eyepiece has not been filtered, thus allowing the faintest possible stars to be located.

2. The filters are not located near the focal plane, so dust particals, etc, on your filters will not show up as local irregularities in your measurements.

3. Since you do not have to turn the filter turret to an "open" position to observe very faint stars, there will be less movement of the controls on the photometer head. This will increase measurement efficiency and provide less chance of moving the star out of the diaphragm field.

3.4 Turn-On and Check-Out Procedure

3.4.1) WHEN YOU FIRST RECEIVE YOUR INSTRUMENT:

You should turn-on and check-out your STARLIGHT-1 as soon as possible after it is received. This procedure should be done before you mount the Head onto your telescope.

A. Set the photometer Head (eyepiece up with controls toward you) and Counter on a flat table top. Do not connect the interface cables.

B. Plug the line cord into the Counter and wall power outlet after checking that the VOLTAGE switch is set to the correct rating (see sections 3.1.2 and 3.1.3).

C. Put the Counter into GATE Mode (3.2.6) and GATE TIME to 10 seconds. Press the POWER button, wait 5 seconds and press the START button. The display should read "0000" and the COUNTING indicator should light.

D. After 10 seconds the COUNTING indicator will go off and the display will still read "0000". Now press the 1.0 sec GATE TIME. The display should read "000". Press the 0.1 second GATE TIME. The display should read "00". Press the .01 second GATE TIME. The display should read "0". This demonstrates a convenient method of telling which gate time you are in while in complete darkness. If "000" is displayed after pressing RESET, you know you have a 1.0 second gate time, and so forth.

E. Turn off your power by again pressing the POWER switch. Connect the Head to the Counter using the White interconnecting cable. Remove the eyepiece holder protective cover and place your eyepiece into the holder.

   NOTE: KEEP THE TELESCOPE ADAPTOR TUBE COVER IN PLACE. Check to see that the flip prism is in the VIEW position (3.3.4)

F. Turn on the Counter. The two LED lights under the FILTER and the APERTURE turret wheels will light. Turn the FILTER turret to the "0" position and focus the eyepiece as described in section 3.3.2.

G. Turn off the LED/INTENSITY switch (if it has been turned on during step F), cover the entire Head with a dark cloth, set the gate time to 1.0 second , and press the start button. At the end of 1 second you will have a reading displayed on the counter. This is your PMT dark count. It will typically be 200 c.p.s. at 22^{o}C (72^{o}F). If the dark count is over 500 c.p.s. at this temperature, check to see that the aperture backlight LED is off and that the photometer head is well shielded from ambient light. Try a few more measurements. If the count rate remains over 500 c.p.s. leave the photometer in the dark for a couple of hours with the power on. If the dark count remains unchanged refer to section 6.4.6. (If your room temperature is greater than 22^{o}C, your dark count will normally be higher). These are highly selected tubes and should have very low dark count. The dark count measured here in the factory is located on the test page at the rear of this manual. It is not uncommon for an EMI 9924A PMT to have less than 100 c.p.s. at room temperature. The dark count will decrease when the temperature is lowered.

H. If you have completed all of the above steps and have found no problems, you may install your photometer as described in section 2.4.

3.4.2) ROUTINE INSTRUMENT TURN-ON AND CHECK-OUT:

Your STARLIGHT-1 should be quickly checked out before each observing session. This will quickly tell you if anything has changed since your last measurements. Use the following 30 second procedure.

A. Set the FILTER turret to "0"
B. Set the APERTURE turret to "2"
C. Set the prism to VIEW
D. Turn off the LED backlight (This step may be eliminated)
E. Set the GATE TIME to 1 second and MODE to GATE
F. Turn on the Counter and press START
G. Check for the following:

1. The photometer Head panel LED's should light.
2. The Counter display should read a dark count which is typical for the dark count for your particular instrument.

If items 1 and 2 are normal, proceed with your measurement program. If not, turn to sections 6.1 and 6.4.

3.5 Operating Modes

The STARLIGHT-1 counter can be operated in two different modes. The GATE mode and the UNIT mode.

In the GATE mode the user can pre-select a desired gate time of 10, 1.0, .1, .01, sec. In this mode, after hitting the start switch, the counter will accumulate counts for the period selected. At the end of this period, the display will indicate the number of counts accumulated in that gate time.

In the UNIT mode the counter will continiously update the display with accumulated counts until a stop command is given. This mode of operation is useful when gate times of greater then 10 sec are required.

For the user who intends to interface the counter to a microcomputer, both modes can be used. In the GATE mode the counter will 'inform' the computer as to when an end of measurement has occurred. In the UNIT mode the computer will stop the counter. This mode is useful when it is necessary to have the microcomputer time out the counter.

3.6 Computer Interfacing

Located on the rear panel of the STARLIGHT-1 is a 25 pin connector. Pins 1-11 are used to interface the counter to a microcomputer system. As supplied the unit can be directly interfaced to a parallel port; the user only needs to provide the support software to drive the interface. All levels are standard TTL.

Two modes of operation are necessary to control the counter by a computer. The first mode is the 'READ DATA' mode and the second is the 'COUNTING' mode. Pin 9 of the I/O connector controls the operating mode of the counter. A logic one on pin 9 will put the counter in the 'READ DATA' mode and a logic zero on pin 9 will put the counter in the 'COUNTING' mode.

In the 'READ DATA' mode (logic 1, pin 9) Pins 6, 7, 8 will select the desired digit to be read into the computer. Data will be available on pins 2, 3, 4, and 5 of the I/O connector when the data ready signal goes high (available on pin 1). Since the data ready line will be high for only 250us/digit it is necessary to latch the BCD data for each digit in that time. The following table shows the decoding required for each digit.

Fig. 5 Digit Address Decoding

Pin # 6	7	8	9	Digit Selected
0	0	0	1	1 (LSD)
0	0	1	1	2
0	1	0	1	3
0	1	1	1	4
1	0	0	1	5
1	0	1	1	6
1	1	0	1	7
1	1	1	1	8 (MSD)

NOTE: Pin 9 is the control bit. Must be high to address data.

As stated before a logic 0 at pin 9 will put the counter in a 'COUNTING MODE'. When the counter is in this mode pins 6, 7, and 8 will no longer be digit select lines, but will be the reset, start, and stop control respectively. In order to assure reliable command from the computer, the reset, start, and stop pulse must be a minimum of 20 MS.

At the end of a selected gate time an end of measurement (EOM) signal will be available at pin 1. This signal can be used to inform the computer when to change modes and read data.

The following table summarizes the control lines available at the 25 pin I/O connector.

Fig. 6 Input/Output Control Lines

Pin #	Read Data	Counting
1	Digit Ready	End of Measurement
2	BCD-1	X
3	BCD-2	X
4	BCD-3	X
5	BCD-4	X
6	Digit Select (LSB)	Reset
7	Digit Select	Start
8	Digit Select (MSB)	Stop
9	Logic 1 for Read data	Logic 0 for Counting
11	Digital Ground	Digital Ground
25	Protective Ground	Protective Ground

Figure 7 represents a typical flowchart of the computer interface algorithm. This is a general design and is not intended to be the only method for driving the interface. The users' individual requirements will dictate the software necessary to drive the interface.

Flow Chart: Computer Interface

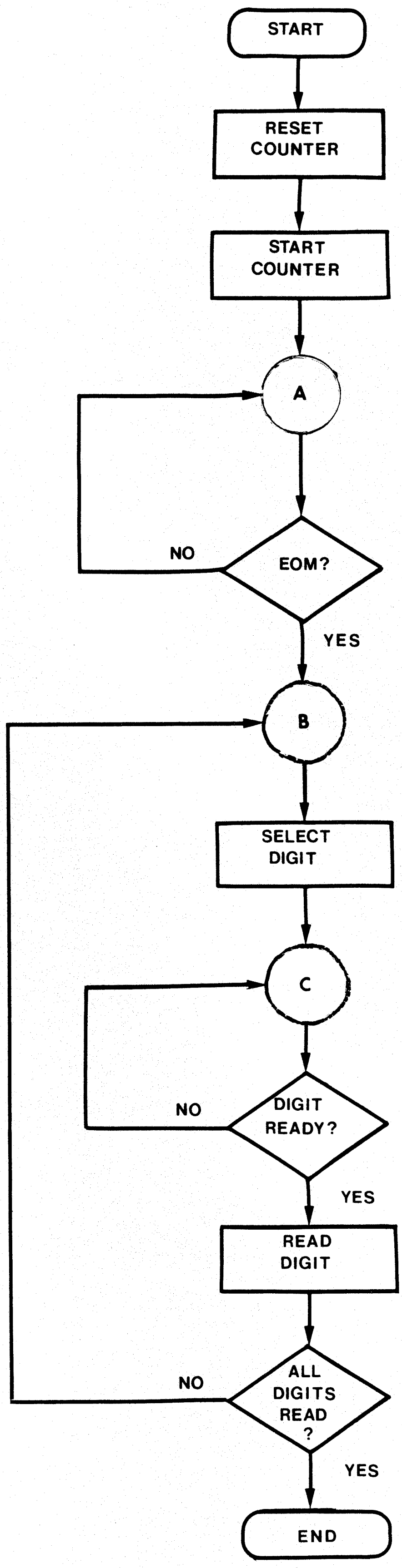


Fig. 7

3.7 Analog Output

A post discriminator analog output has been provided for those users who desire to use a chart recorder, etc. instead of or in conjunction with the digital output.

The analog output will provide a maximum +4 volt output, which is suitable for most chart recorders. The pen or needle can be zeroed utilizing the ZERO SUPPRESS located on The STARLIGHT-1. The STARLIGHT-1 also provides 4 ranges of counts per volt which can accomodate a signal of up to 4×10^6 counts per second.

The analog response time is 1 second on all ranges. Note the typical dead times in section 1.3. The analog output operates independently of all other outputs.

3.8 TTL Output

A rear panel TTL output is provided for users who desire direct signal access. This buffered 50 nanosecond TTL output may be coupled to a frequency counter, microcomputer, or other TTL compatible instrument. It provides a continuous data update which is independent of the gate times and digital display.

3.9 Repeat/Single

This switch allows you to repeat a measurement automatically when operating the counter in any one of the four gate times. When in the "single" position, the counter will stop counting and display the counts after the counting interval has been completed. Another measurement can be made by pressing the START button.

In the "Repeat" position, once you press the START button the measurements will continue until you press the STOP button. For example, if the gate time is 10 seconds, every 10 seconds a new measurement will be displayed on the front panel. The completed measurement will be displayed until the next measurement has been completed. This will give you 10 seconds to write down the measurement (If you are not using a computer, chart recorder, printer, etc.) before the next mearurement appears on the display. When you have completed your sequence of measurements press the STOP button. When you have located your next object to be measured, press the START button and you will again obtain repeated measurements.

Section IV. DATA COLLECTION AND REDUCTION

4.1 Differential Photometry

The STARLIGHT-1 will provide very accurate measurements of stellar magnitudes by means of "Differential Stellar Photometry". A very complete discussion of this technique of stellar photometry may be found in "Photoelectric Photometry of Variable Stars" by Hall and Genet, chapters 6 to 14. We will not attempt to repeat this information in this manual, but there are several points which we want to discuss in more detail later in this section.

One question everyone asks is, "What is the faintest stellar magnitude that is measurable with my telescope?" Results from our prototype units have demonstrated that if you can see the star and if your telescope can accurately track on that star, then it can be accurately measured by the STARLIGHT-1. You will find that your sky background and telescope performance will be the limiting factor. A good telescope mount and drive is very important! The STARLIGHT-1 can produce measurements with .001 magnitude standard deviation under good conditions, and 0.01 magnitude accuracy can easily be achieved.

4.2 Aperture Choice

The aperture set installed in your photometer head should provide a reasonable range of fields of view. The actual field of view is dependent upon the focal length of your telescope. Graph 1 gives the fields of view for telescopes between 40 and 180 inches of focal length. For other focal lengths, use this formula:

$$\text{F.O.V. (arc sec)} = 206{,}265 \, \frac{d}{f}$$

where "d" is the aperture (diaphragm) diameter, "f" is the focal length of the telescope, and F.O.V. is the field of view in arc seconds. (See page 27).

NOTE: f and d must be in the same units. EMI Gencom can supply custom aperture sizes on request.

4.3 Spectral Response

It is critically important that your stellar magnitude measurements relate to measurements which have gone before or will come after yours. This can be accomplished by calibrating your photometer to give the same magnitude vs. color readings on certain selected stars as was assigned to them by the person originating the standard system. These "standard stars" have been assigned magnitudes which were obtained when measured in a particular spectral bandwidth with a particular detector system.

It is almost impossible to obtain a photodetector and a set of filters which correspond at all wavelenghts <u>exactly</u> to the spectral response of the original equipment; but, it is possible to come close enough so that a small factor can be applied to your INSTRUMENT MAGNITUDES to make them agree to the STANDARD MAGNITUDES within a reasonable degree of accuracy. This small multiplication factor is commonly referred to as the transformation coefficient.

The UBV Standard System is the most widely used standard photometric system. The U or ultraviolet band pass peaks at 3600Å and is approximately 1000Å wide, the B or blue band pass peaks at 4200Å and is approximately 2000Å wide, and the V or visible band pass peaks at ca. 5400Å and is also approximately 2000Å wide.

This is obviously a wide band photometric system which allows an appreciable amount of light to reach the detector, making it quite suitable for amateur sized telescopes.

The EMI 9924A photomultiplier tube has excellent response for the UBV system. Graph 2 shows the typical 9924A spectral response (without filters) and the spectral response curves of the UBV channels. The pyrex window of the 9924A provides a UV cutoff which matches the U channel spectral curve. This allows the use of only one filter to obtain the desired U channel band pass. The 9924A filter corrected curves have not been placed on the graph since each particular tube would be slightly different, and because they generally match the standard UBV curves so well that in most areas you would have overlapping curves. (See page 28).

If you are unfamiliar with the procedure for determining the transformation coefficients for your STARLIGHT-1 photometer, we recommend that you read chapters 10, 12 (section K), and chapter 13 (section J), of "Photoelectric Photometry of Variable Stars" by Hall and Genet. Please note that since the digital readout of the STARLIGHT-1 has a range of 0 to 10^8 counts (more if you count the number of overflow passes), there is no need to adjust gain settings. For this reason, and because of the inherent accuracy of the digital readout, we recommend that you use the digital output mode to obtain your transformation coefficients. You should use three 10-second measurements for each reading in your sequence of measurements.

4.4 Measurement Technique

Measurement techniques are discussed in chapter XII of "Photoelectric Photometry of Variable Stars", by Hall and Genet. After one or two observing sessions you will learn how to operate your STARLIGHT-1 in the most efficient manner. It may be wise to have someone assist you on your first night out with the instrument. The following hints may be helpful:

1. Keep the counter as close to the head as possible. This will help to prevent strain on the interconnecting cable when you either:

   A. Trip over the cable or
   B. Forget about the cable while you are moving your telescope to point to the opposite part of the sky. You may find that a 25-foot cable is a "necessary" accessory.

2. Keep the backlight LED always "ON" and at the desired brightness level. There is no need to turn it off before each measurement since this is done automatically by the internal microswitch.

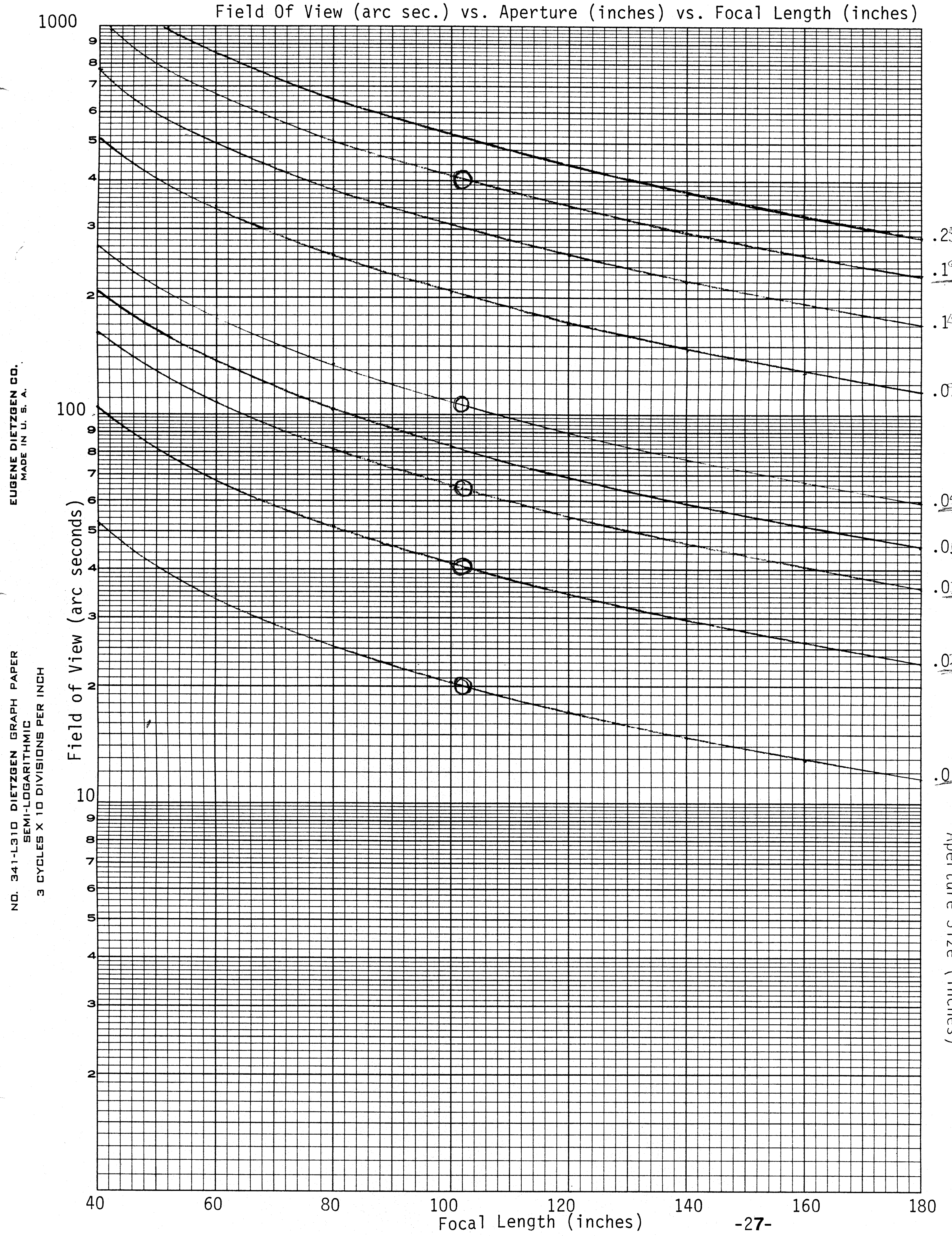
3. The STARLIGHT-1 will display one measurement and immediately begin the next measurement if you keep the START button pressed. This is easiest to do if you are using the RC-1 Remote Control.

4.5 Deadtime Correction

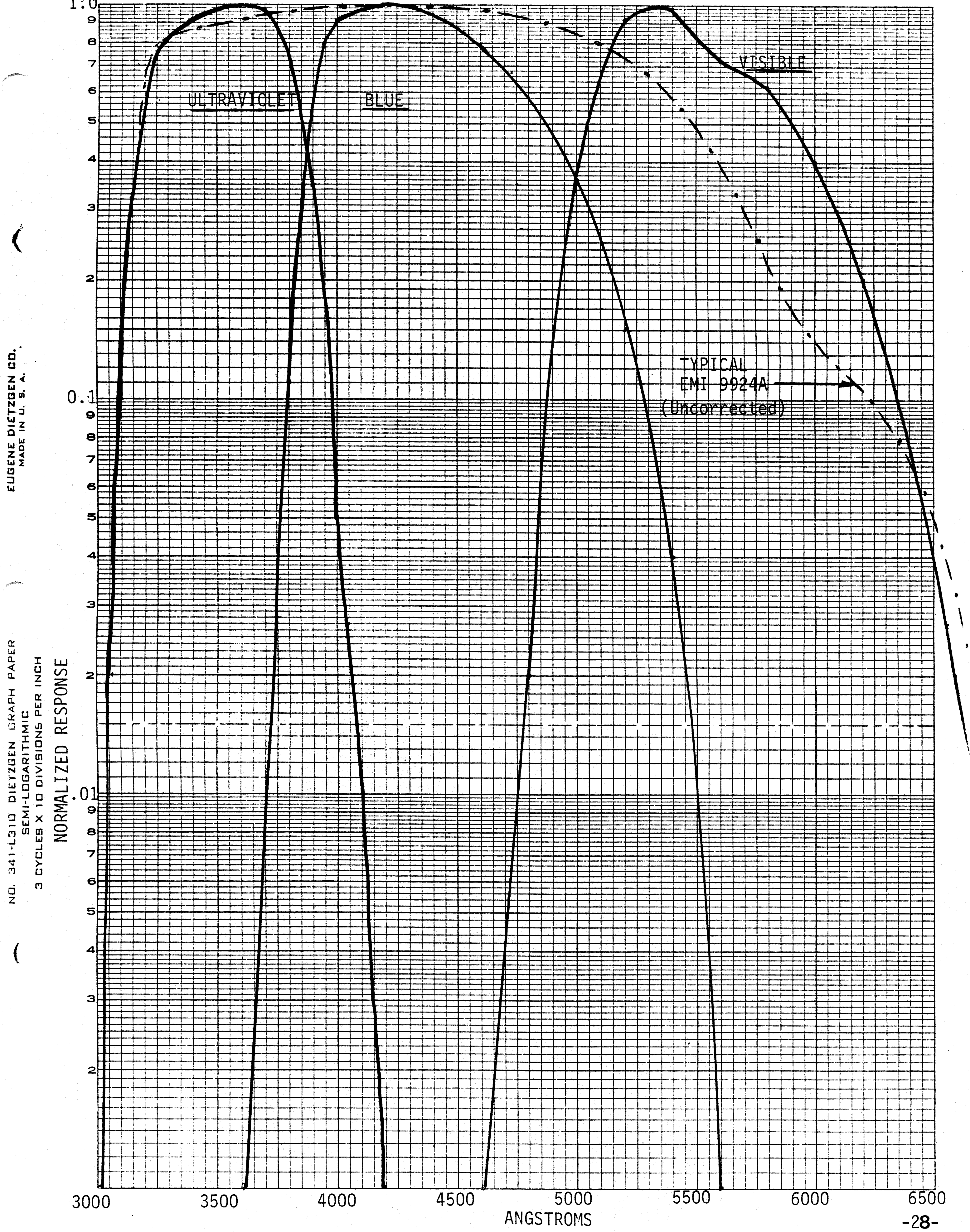
The STARLIGHT-1 uses photon counting (pulse counting) techniques to measure the brightness of a light source. This method yields an improvement in signal-to-noise ratio over dc measurements by a factor of $\sqrt{2}$ when measuring very low light levels. The brighter the star, the more photons will strike the photocathode of the PMT, and the more photoelectron pulses will be produced. Some stars may be bright enough to produce more photoelectrons than the counting electronics can resolve and count as individual pulses. This pulse pair resolution time or DEAD

GRAPH 1

Field Of View (arc sec.) vs. Aperture (inches) vs. Focal Length (inches)



STANDARD UBV AND EMI 9924A SPECTRAL RESPONSE CURVES GRAPH 2



TIME will result in a recorded count rate which is less than the actual count rate; therefore, all measurements should be corrected for the dead time of your instrument. This includes your computer, TTL, and analog outputs as well as the digital display output.

The STARLIGHT-1 has a dead time, d, of between 100 and 130 nanoseconds. Maximum accuracy of your readings can be obtained by determining the exact dead time of your particular instrument. This can be accomplished by the following method:

1. Take the average of three 10-second measurements on a number of standard stars of different but known magnitudes. Record each average count rate, n, vs. the actual magnitude. Use the V filter for this procedure.

2. A plot of log n vs. magnitude should give a straight line. The brighter stars will have a much higher count rate and their points will fall below the line due to an increasing number of pulses from the photomultiplier tube which have failed to be counted in the photon counter due to the pulse pair resolution (dead time) of the counting electronics. (See graph 3, page 31).

3. Use the formula:

$$d = \frac{N-n}{n^2}$$

Where "d" is the dead time in seconds, "n" is the observed number of counts per second (remember to divide the 10 second count rate by 10), and N is the true number of counts per second for the star of the corresponding magnitude as taken from your log n vs. magnitude plot.

NOTE: Your straight line plot of counts verses magnitude should be obtained from standard stars which give less than 10^5 counts per second. All count rates should be of the star only, i.e. subtract out the sky background reading.

Example: Suppose that 5 standard stars of known magnitude are measured and each has an average count rate (average of 3 10-second measurements) of less than 10^5 c.p.s. and covers the range of 1,000 to 100,000 counts. We have arbitrarily let these be associated with stars between magnitude 5 and 11 (see graph #3, note that part of the curve below magnitude 8 has been cut off). We can draw a straight line through these points as shown. Several bright stars are measured to see how the measured counts deviate from the true counts due to the dead time. A second magnitude star gave 2,900,000 c.p.s. instead of the 3,700,000 counts per second that we should get according to our straight line. Using the above formula we get:

$$d = \frac{3.7 \times 10^6 - 2.9 \times 10^6}{(2.9 \times 10^6)2} = \frac{8 \times 10^5}{8.41 \times 10^{12}} = 9.512 \times 10^{-8} \text{seconds}$$

i.e. dead time = 95.12 nanoseconds

The number of counts received from a star of a particular magnitude obviously depends upon the size of your mirror or lens, the filter used (if any) and the aperture size. Although the instrument dead time is independent of all these variables, the aperture, filter, etc. should not be changed during this procedure.

If your telescope is not too large and you are not looking at stars brighter than about magnitude 4, you may very well be able to use the 100 n sec dead time figure without significant loss in accuracy. Table 1 shows the percent error due to dead time and the standard Poisson counting statistical error for various count rates. Notice that as the count rate increases the dead time error increases but the % statistical error decreases. At approximately 5×10^4 c.p.s. the dead time error is equal to the $1/\sqrt{n}$ error (ca. 250 counts).

Table 1

TRUE COUNT RATE/sec.	DEAD TIME of 100 n sec. measured counts/sec	% error	POISSON Statistics $\sqrt{N}$ error	% error
1,000	999.9	0.01	±31.6	3.16
5,000	4997.5	0.05	70.7	1.41
10,000	9990	0.01	100	1.0
50,000	49,750	0.5	223	0.45
100,000	99,020	1.0	316	0.32
500,000	477,225	4.55	707	0.14
1,000,000	916,080	8.39	1.000	0.10
2,000,000	1,708,000	14.6	1,414	0.07
5,000,000	3,660,300	26.8	2.236	0.045
10,000,000	6,180,340	38.2	3,162	0.032

4.6 Atmospheric Extinction, etc.

Atmospheric extinction, seeing, diffraction, dispersion, scintillation and sky brightness are explained in detail in "Photoelectric Photometry of Variable Stars", by Hall and Genet, chapter IX. Although differential photometry will minimize these effects,we recommend that you become thoroughly familiar with them.

4.7 DIGITAL READOUT

The digital readout is extremely simple to use. There is no need to adjust your readings for amplification factors, zero level, gain, or anything else except for Dead Time as explained in section 4.5.

Let us look at an example in which we obtained the following readings for the variable star (Rv), for the variable star sky background (Rvs), comparison star (Rc), and comparison star sky background (Rcs), using the sequence Rcs, Rc, Rvs, Rv, Rv, Rv, Rvs, Rc, Rcs:

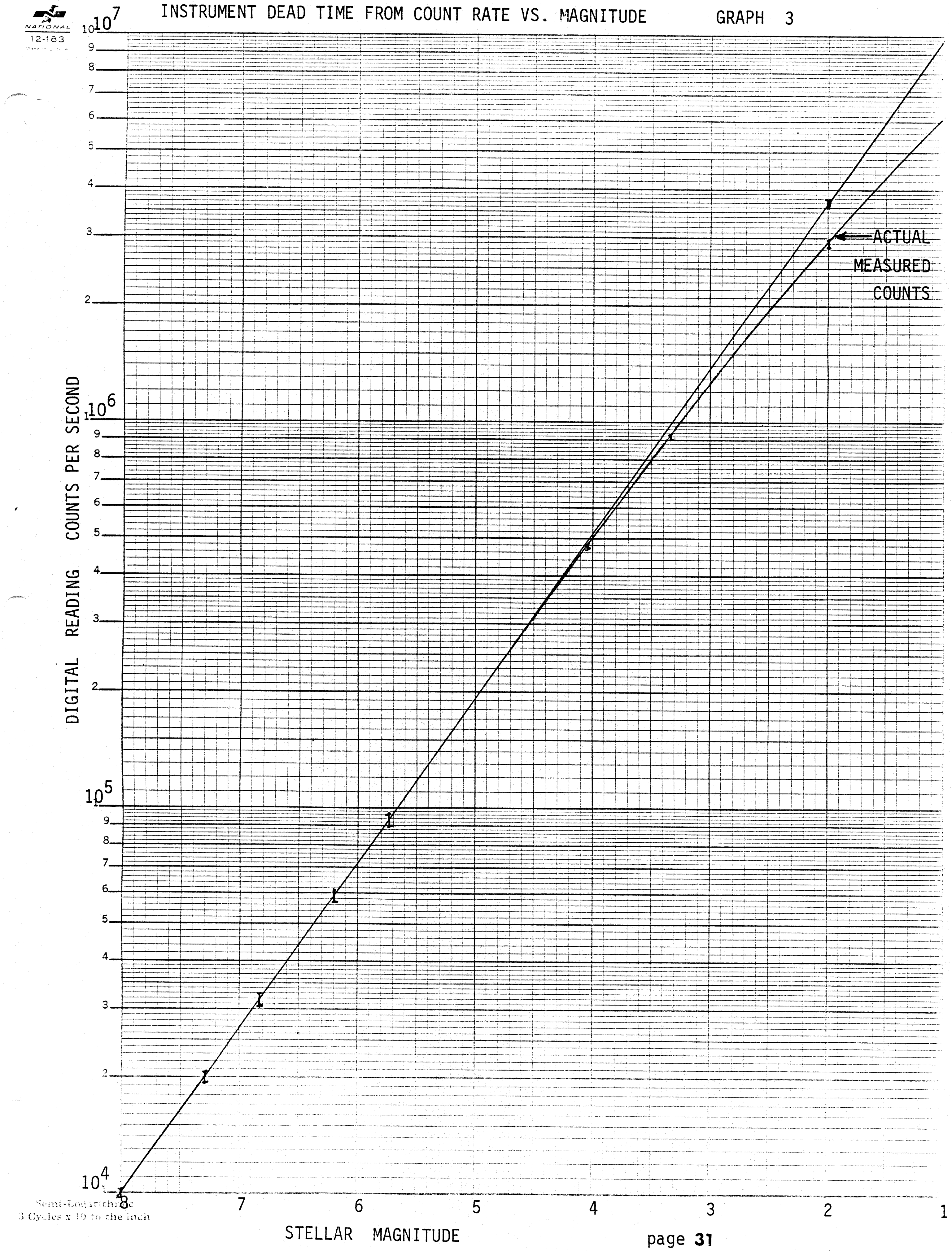
ITEM MEASURED		COUNTS	AVERAGE COUNTS
Rc	=	97,000 ; 97,500	97,250
Rcs	=	2050 , 2028	2,039
Rvs	=	2000 , 1974	1,987
Rv	=	105,275 ; 107,300; 106,800	106,458

The dead time corrected readings are found using the formula:

$$D = R(1 + Rd)$$

where "d" is the instrument dead time (10^{-7} sec),"R" is the measured readings, and "D" is the dead time corrected readings corresponding to the R value for each item measured.

INSTRUMENT DEAD TIME FROM COUNT RATE VS. MAGNITUDE GRAPH 3



$$
\begin{aligned}
Dc &= 98{,}196\\
Dcs &= 2{,}039\\
Dvs &= 1{,}987\\
Dv &= 107{,}591
\end{aligned}
$$

Notice that the count rate on the sky background is the same when corrected for dead time. It should not be necessary to make dead time corrections for count rates under 45,000.

The net counts ,C, on the variable and comparison stars is:

$$
\begin{aligned}
Cv &= Dv - Dvs = 105{,}604\\
Cc &= Dc - Dcs = 96{,}157
\end{aligned}
$$

The Raw Instrumental Differential Magnitude M is:

$$M = m\ (\text{variable}) - m\ (\text{comparison})$$

Where $m\ (\text{variable}) = -2^m.5 \log_{10} Cv$

And $m\ (\text{comparison}) = -2^m.5 \log_{10} Cc$

The digital readout has many advantages over any other form of data display. The most notable are:

A. The readings are an exact number with an exact average and exact error which is equal to $\sqrt{\text{counts}}$. The error in our variable star reading is $\sqrt{107{,}591} = 328$ counts, or 0.3%. Notice that a 200 c.p.s. background not only cancels out from the readings, but it is not even significant for stars which have over 100,000 c.p.s. output.

B. The sky background readings are never lost in the grass at the edge of a chart recorder. No matter how small the tube background plus the sky background count rate is, it is still an exact number to be subtracted from the star count rate.

C. There is no need to change scales, amplification factors, gain or anything else to accomodate a large dynamic range of brightness.

D. There is no need to purchase additional expensive analog equipment.

4.8 Analog Output

An analog output is provided for those users who have a chart recorder and want to record their measurements in this fashion. Three features should be noted:

A. The STARLIGHT-1 provides full chart recorder scale control from its front panel.

B. The analog output is post amplifier/discriminator i.e. you are still photon counting and must still apply dead time corrections.

C. The analog output can perform in conjunction with all other output modes, i.e. you can record digital readings at the same time!

If you must change your counts/volt setting in order to scale sky background and star readings appropiately on the strip chart paper, then when you reduce the data you must divide the readings by the same amplification factor (see chapter XIII, Hall and Genet for further information).

4.9 Computer Data Reduction

Section 3.6 describes the basic technical details for interfacing the STARLIGHT-1 directly to a computer. Your data may be reduced by computer whether or not it is directly interfaced to a computer. A sample program has been provided for your reference.

The following program is a modification of a program written by Mr. Orville Brettmen, of Chicago, Illinois, which is in turn a modification of the program written by Mr. Russell Genet - "A Photoelectric Data Reduction Program in BASIC for Microcomputers", I.A.P.P.P. Communications No. 2, September 1980, p. 23-28. In this article, Mr. Genet describes how he transcribed a FORTRAN program developed by Dr. Douglas S. Hall and Mr. Greg Henry of Dyer Observatory into BASIC so that it might be used with common microcomputers.

The program was developed for a Radio Shack TRS-80 model I, Level II BASIC. Slight changes will make it useful for the Appel and Commodore computers, etc. The program is for measurement with a V filter channel only, but can be easily expanded to include multichannel photometry.

If any of our STARLIGHT-1 users have designed their own programs which they think would be helpful to other users, we would be happy to pass on this information in our Operator's Manuals and newsletters with proper credit given to the orignator. This data reduction program begins with Line 5 and ends with Line 4090. There are several points to be made before you begin programming:

Line 10 - This provides double digit accuracy on TRS-80 microcomputers. Other systems will require this statement to be omitted or changed.

Line 15, 16 - These might be changed according to the capabilities of your computer. The "CLEAR" statement is sometimes written "CLR".

Lines 60, 70, etc. - The "L PRINT" statement provides for a printed output on a chart recorder. Other systems such as Commodore use "PRINT #" to output to an external device.

Lines 80, 100, etc. - The USING "xxx.xxx" format is a feature of the TRS-80. Please check your manual for your system format procedure.

Line 1020 - The statement "FIX(CY)" takes the integer part of CY. Some computers would use "INT(CY)".

Lines 3040, 3080, etc - The Commodore does not use an "ELSE" statement. Check your computer user's manual.

Line 130 - The "EL" and "KV" for your particular STARLIGHT-1 should replace the values given here.

Line 440 - This should be corrected to its own line number and <u>not</u> follow the REM statement of line 435.

Line 582 - DT should be set equal to your own instrument dead time. The exponent symbol may vary from system to system.

We provide this program as a general guideline for your use, and we do not guarantee accuracy or a complete, debugged program. Please do not call us for answers to programming questions.

```
5 REM **PEP PGM AS ADAPTED FROM BRETTMAN/GENET/HALL**
10 DEFDBL A-Z
11 DIM A$(65),X(100),Y(100)
15 CLEAR 5000
16 DIM M(1000,5)
30 INPUT"   NAME OF OBSERVATORY.";NO$
40 INPUT"   LONGITUDE.";LN
50 INPUT"   LATITUDE.";LA
60 LPRINT CHR$(142)NO$
70 LPRINT"LONGITUDE = ";
80 LPRINT USING"###.#####";LN
90 LPRINT"LATITUDE = ";
100 LPRINT USING"###.#####";LA
110 REM**EL = TRANS. COEFF. FOR V BAND
120 REM**KV = EXTINCTION COEFF. FOR V   BAND**
130 LET EL=.027 :LET KV=.25
140 LPRINT"EPSILON=";
145 LPRINT USING"#.###";EL
150 LPRINT"EXTINCTION=";
155 LPRINT USING"#.###";K
160 LET I=1
170 REM**INPUT DATA ON STARS**
180 PRINT"INPUT DATA ON STAR PAIR#";I
190 INPUT" STAR NAMES";SN$
200 INPUT"  VARB RA HR,MIN";V1,V2
210 INPUT"  VARB DEC. DEG,MIN";V3,V4
220 INPUT"  COMP RA. HR,MIN";C1,C2
230 INPUT"  COMP DEC. DEG,MIN";C3,C4
240 INPUT"  EPOCH";EP
250 INPUT"  PERIOD";PD
260 INPUT"  DELTA (B-V)";DC
270 INPUT"  COMP V MAG";CV
280 LPRINT SN$
290 LPRINT"VAR RA=";V1"HR";V2"MIN","VAR DEC=";V3;"DEG";V4;"MIN"
291 LPRINT"COMP RA=";C1;"HR";C2;"MIN","COMP DEC=";C3;"DEG";C4;"MIN"
300 LPRINT"EPOCH=";EP,"PERIOD=";PD,"DELTA(B-V)=";DC,"COMP V=";CV
310 LET J=1
320 REM**INPUT JULIAN DATE AND COMPUTE  SOLAR CORRECTION**
330 PRINT"  INPUT DATA ON  ";SN$;" FOR  NIGHT NUMBER";J
340 INPUT" JULIAN DATE (LAST 4 INTEGERS)";JD
350 VR=(V1+V2/60)*15/57.2957795
360 VD=(V3+V4/60)/57.2957795
370 CR=(C1+C2/60)*15/57.2957795
380 CD=(C3+C4/60)/57.2957795
390 TH=(4.8686153+.0172497*(JD-3874))
400 R=(1-.016719*.01679)/(1+.01679*COS(TH-4.956105))
410 S1=R*COS(TH)*COS(VR)*COS(VD)
420 S2=R*SIN(TH)*SIN(.409273)*SIN(VD)
430 S3=COS(.409273)*COS(VD)*SIN(VR)
435 REM**LET SC BE THE SOLAR CORRECTION*440 SC=-.005775*(S1+S2+S3)
450 LPRINT"JULIAN DATE =";JD,"SOLAR CORRECTION=";
460 LPRINT USING"#.#####";SC
470 LET K=1
480 LPRINT
481 LPRINT"RAW JD  DEL MAG  JH  STD V   ORB PH  MEAN X  STD MAG"
490 PRINT "INPUT DATA ON";SN$;"JD=";JD;"OBSERVATION NO.";K
500 INPUT"  FRACTIONAL JD";JF
501 REM**ENTER STARLIGHT-1 COUNTING INTERVAL IN SECONDS**
505 INPUT"  COUNTING INTERVAL(SEC)";CI
510 INPUT"  COMP COUNT #1 ";C5
520 INPUT"  SKY COUNT #1  ";S4
530 INPUT" VAR COUNTS #1,2&3";V5,V6,V7
540 INPUT" SKY COUNT #2";S5
550 INPUT"  COMP COUNT #2 ";C6
560 LET AV=(V5+V6+V7)/3*CI
```

```
570 LET AS=(S4+S5)/2*CI
580 LET AC=(C5+C6)/2*CI
581 REM**COMPUTE DEAD TIME (DT) CORRECTED COUNT RATES "N"**
582 LET DT=10↑-7
583 LET NV=AV*(1+AV*DT)
584 LET NS=AS*(1+AS*DT)
585 LET NC=AC*(1+AC*DT)
590 LET RV=NV-NS
600 LET RC=NC-NS
610 LET DR=-2.5*(LOG(RV/RC)*.434295)
700 REM**JH IS HELIOCENTRIC JD, JF IS   FRACTION OF JD**
1000 LET JH=JD+JF+SC
1005 REM**CY IS CYCLE OF ECLIPSING BINARY**
1010 LET CY=(JH+2440000-EP)/PD
1015 REM**PH IS THE PHASE OF THE ECLIPSING BINARY**
1020 LET PH=CY-FIX(CY)
1025 REM**SI IS SIDERIAL TIME, SA IS SIDERIAL ANGLE**
1030 LET SI=24*((JH-3407.7489)/365.2422-LN/360+1.002738*(JF-.5))
1040 LET SA=SI*15/57.2957795
1045 REM**COMPUTE VARIABLE AND COMPARISON HOUR ANGLES**
1050 LET VH=SA-VR
1060 LET CH=SA-CR
1065 REM**COMPUTE SINE AND COSINE OF LATITUDE**
1070 LET SL=SIN(LA/57.2957795)
1080 LET CL=COS(LA/57.2957795)
1085 REM**COMPUTE VAR.,COMP.,DIFFERENTIAL,& MEAN AIR MASS**
1090 LET VX=1/(SL*SIN(VD)+CL*COS(VD)*COS(VH))
1100 LET CX=1/(SL*SIN(CD)+CL*COS(CD)*COS(CH))
1110 LET DX=VX-CX
1120 LET MX=(VX+CX)/2
1125 REM**DS=STD V DEL MAG,DR= INSTR. V DELTA MAG.**
1130 LET DS=DR+EL*DC-KV*DX
1135 REM**COMPUTE VISUAL MAGNITUDE OF THE VARIABLE STAR**
1140 LET V=DS+CV
2000 FOR N=1 TO 5
2010 IF N=1 THEN M(K,N)=DX
2020 IF N=2 THEN M(K,N)=DS
2030 IF N=3 THEN M(K,N)=RV
2040 IF N=4 THEN M(K,N)=RC
2050 NEXT N
3000 LPRINT USING"######.####";JF,DR,JH,V,PH,MX,DS
3010 REM**CONTROL SECTION**
3020 PRINT" ANOTHER OBSERVATION THIS JD & THIS STAR ?"
3030 INPUT" 1=YES   ,   0=NO";X
3040 IF X=1 THEN 3050 ELSE 3060
3050 LET K=K+1: GOTO 490
3060 PRINT" ANOTHER JD FOR THIS STAR?"
3070 INPUT" 1=YES   ,   0=NO;X
3080 IF X=1 GOTO 3090 ELSE 3100
3090 LET J=J+I: GOTO 320
3100 PRINT" ANOTHER STAR?"
3110 INPUT" 1=YES   ,   0=NO;X
3120 IF X=1 THEN 3130 ELSE 4000
3130 LET I=I+1 : GOTO 170
4000 PRINT" DO YOU WISH TO LOOK AT THE
4010 INPUT" 1=YES   ,   0=NO;X
4020 IF X=1 GOTO 4040 ELSE 4030
4030 STOP
4040 LPRINT"DIF.AIR MASS. DELTA M(ST.V) VAR RAW  COMP RAW HELIO JD"
4050 FOR W=1 TO K
4060 FOR N=1 TO 5
4070 LPRINT M(W,N)
4080 NEXT N
4085 LPRINT
4090 NEXT W
```

SECTION V. PRINCIPLES OF OPERATION

5.1 General Discussion

Referring to figure 8 , light impinges upon the window of the PMT after it travels through the diaphragm, filters and Fabry lens. About 33% of the photons that hit the photocathode (which is deposited on the inside surface of the window) will produce a photoelectron. Each photoelectron is accelerated through the dynodes, producing 4 to 6 secondary electrons for each impinging primary electron. The PMT gain is adjusted to be 4 million (4×10^6) at the anode, thus creating a pulse of charge equal to (1.6×10^{-19} coul) (4×10^6) = 6.4×10^{-13} coul. This pulse is spread over a period of about 3×10^{-8} seconds (Full Width Half Maximum pulse width of a EMI 9924A), to provide 6.4×10^{-13} coul./3×10^{-8}sec = 2.13×10^{-5} amps.

The Amplifier/Discriminator is set to a 50 ohm input impedance and 1 mv threshold. We can see that if we multiply our 2.13×10^{-5} amp signal by 50 ohms we obtain a 1.07 mv pulse, which is sufficient to trip the amp/disc and allow us to detect a single photoelectron!

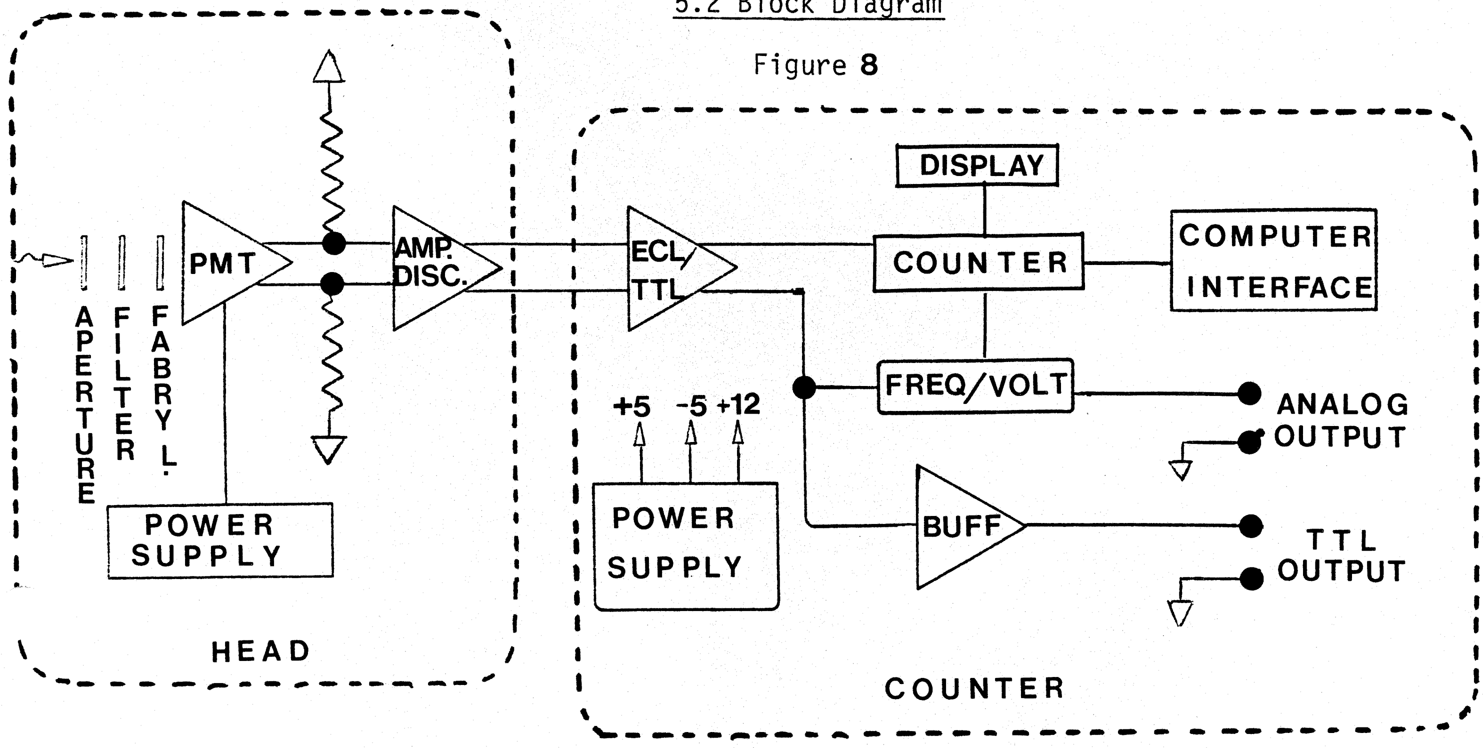
For every input pulse, the photometer head will output an ECL differential pulse which is received in the Counter and translated to TTL level pulses by a line receiver and ECL to TTL translator. The output of the translator goes to a TTL buffer, frequency to voltage converter, and the main counter. The TTL buffered output is available to the user via a rear panel BNC connector.

The frequency to voltage converter changes input frequency to a voltage which is selectable over a 4 decade range. The output of the frequency to voltage converter is available via a 5 way binding post on the rear panel.

The main counter shifts in serial TTL data for a pre-determined time and then displays this data. A 25-pin computer interface connector allows computer control of the counter. The power supply generates the required voltage for all the modules from an AC power line.

5.2 Block Diagram

Figure 8



SECTION 3.3 CIRCUIT ANALYSIS

The STARLIGHT-1 circuit can be broken down into 7 sections: DETECTOR, AMPLIFIER/DISCRIMINATOR, LINE RECEIVER/TRANSLATOR, COUNTER, COMPUTER I/O CIRCUIT, FREQUENCY TO VOLTAGE CONVERTER and, POWER SUPPLY. This discussion will describe the function of each section and then the purpose of the main components of each. With this information it should be possible to localize and repair any problems that may occur in the photon counter.

5.3.1 DETECTOR

The detector section consists of the filters, diaphragms, optical assembly, photomultiplier tube, and PMT power supply. It is designed to receive and process the incoming starlight into a useful electrical signal. The output of the detector is a charge pulse orginating from the light source or background noise. See figures 9 and 10, pages 39 and 40.

5.3.2 AMPLIFIER/DISCRIMINATOR

The circuit for the Amplifier/Discriminator can be found in figures 9 and 10. U1 is a device that generates a single output pulse of a defined width for every input pulse over the threshold (1MV). The pulse width output of 50NS is set by R3 and C3, this output is a complimentary ECL output on pins 15 and 16. The RCL combination of R4, C5 and L1 set the bandwidth of the amplifier.

5.3.3 LINE RECEIVER/TRANSLATOR

The purpose of the LINE RECEIVER/TRANSLATOR is to change the complimentary ECL input to a single ended ECL output and then to a TTL level. The circuit for this can be found in figure 11. The complimentary output of the amplifier/discriminator is fed to the input of U1. U1 is a line receiver with a single ended output (Pin 2), the output of the line receiver in turn goes to a comparator which has a complimentary TTL output. Resistor R3 and R4 set the input threshold level of the comparator.

5.3.4 COUNTER

Intergrated Circuits U6, U13, U14, U15 provides all the functions of the counter - i.e. high frequency oscillator, decade time base, 8 decade data counter and latches, 7 segment decoder, digit multiplexed and segment drivers. Y1 is a crystal which provides a fundamental 10 MHz operating frequency for the counter. This signal is available at pin 38 of U6. Trimer capacitor C25 is used to adjust the oscillator frequency.

The store function which goes low when the counter is updating the display is used to put the counter in a hold mode. This is accomplished by edge triggering on the store signal and setting an RS flip flop (U13) which in turn puts the HOLD line (Pin 39 , U6) in a high state which stops the counter. The counter will not start again until the START switch is depressed which will reset the RS flip flop. See figures 11 and 12.

5.3.5 COMPUTER I/O

U6 provides a multiplexed BCD output which is buffered by U10 and U11 and is available on pins 2-5 of J8. In order to know which digit is on the BCD Buss D1-D8 are level shifted, buffered (Q1-Q8, U7, U10), and then fed to a multiplexer (U8). The digits are addressed via pins 7, 8, and 9 of J8, when the control line (Pin 9, J8) is high. A data ready signal will then be available on pin 1 of J8 when the selected BCD digit is on the buss.

When the control line is low (Pin 9, J8) a Reset, Start, and Stop command can be applied via pin 7, 8, and 9 of J8 to U12; in addition, when the control line is low, an end of measurement signal is available on pin 1 of J8. See figures 11 and 12.

5.3.6 FREQUENCY TO VOLTAGE CONVERTER

The frequency to voltage converter gives an analog representation of the count rate of the amplifier/discriminator. This is accomplished with integrated circuits U3, U4, U5.

U3 is a one shot which has its pulse width output set by the range select switch SW3. The output of the one shot is fed to an intergrated U4 which has a time constant of one second. The output voltage of the intergrator is amplified by U5 and is available to the user on the rear panel 5 way binding posts.

5.3.7 POWER SUPPLY

The power supply supplies a regulated +5 volts, -5 volts, and +12 volts required by the counter. This is accomplished by a dual secondary winding on the transformer, 3 full wave rectifiers and filter capacators. The unregulated outputs of the capacitors are fed to the appropriate voltage regulators to deliver the regulated +5, -5, +12 volts as needed by the circuits. The transformer is of the dual primary type thus allowing operation at either 115/230 volts.

NOTE: SEE SECTION 6.2.7 AND 6.3.3 FOR PARTS LISTS.

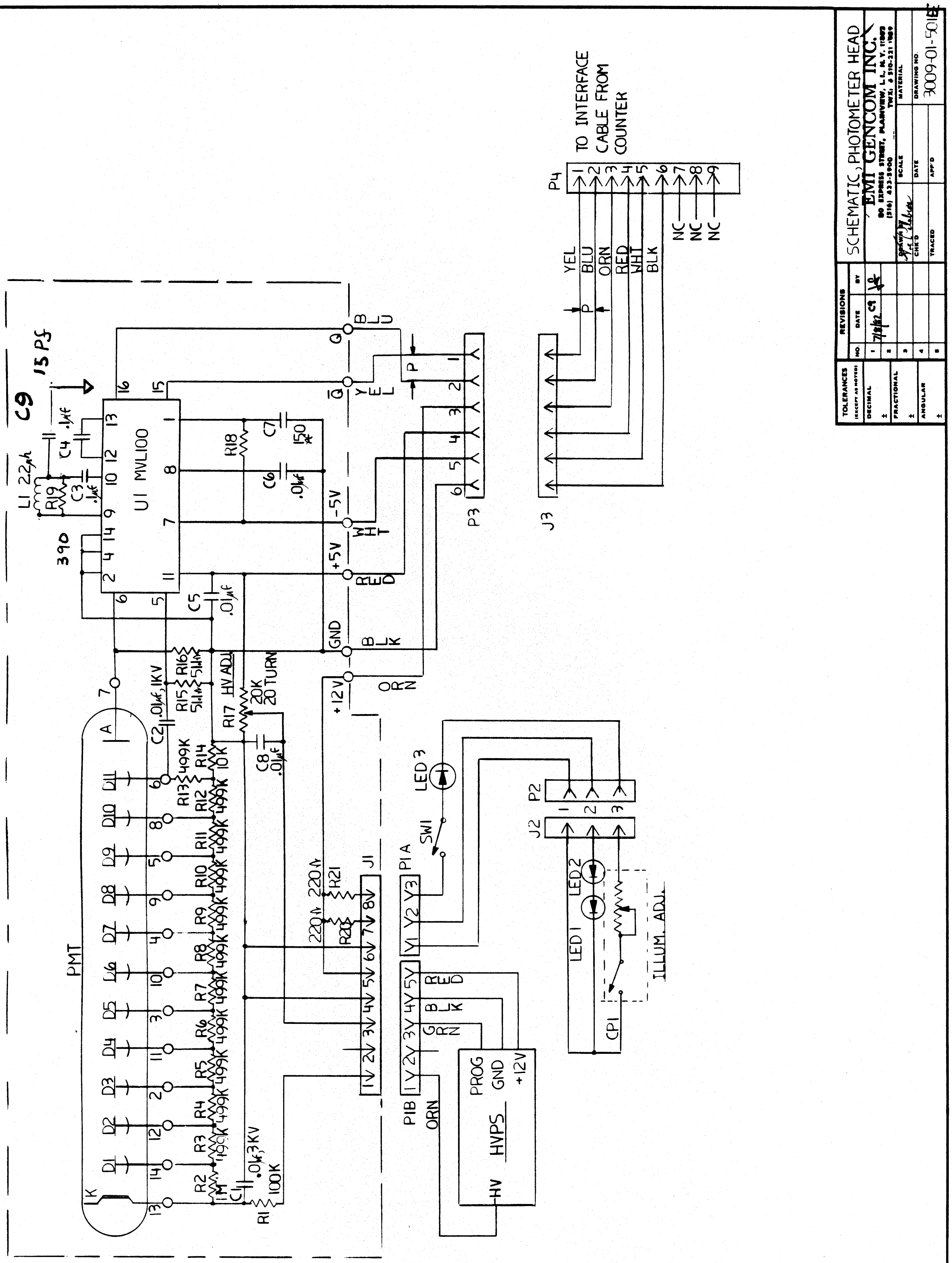
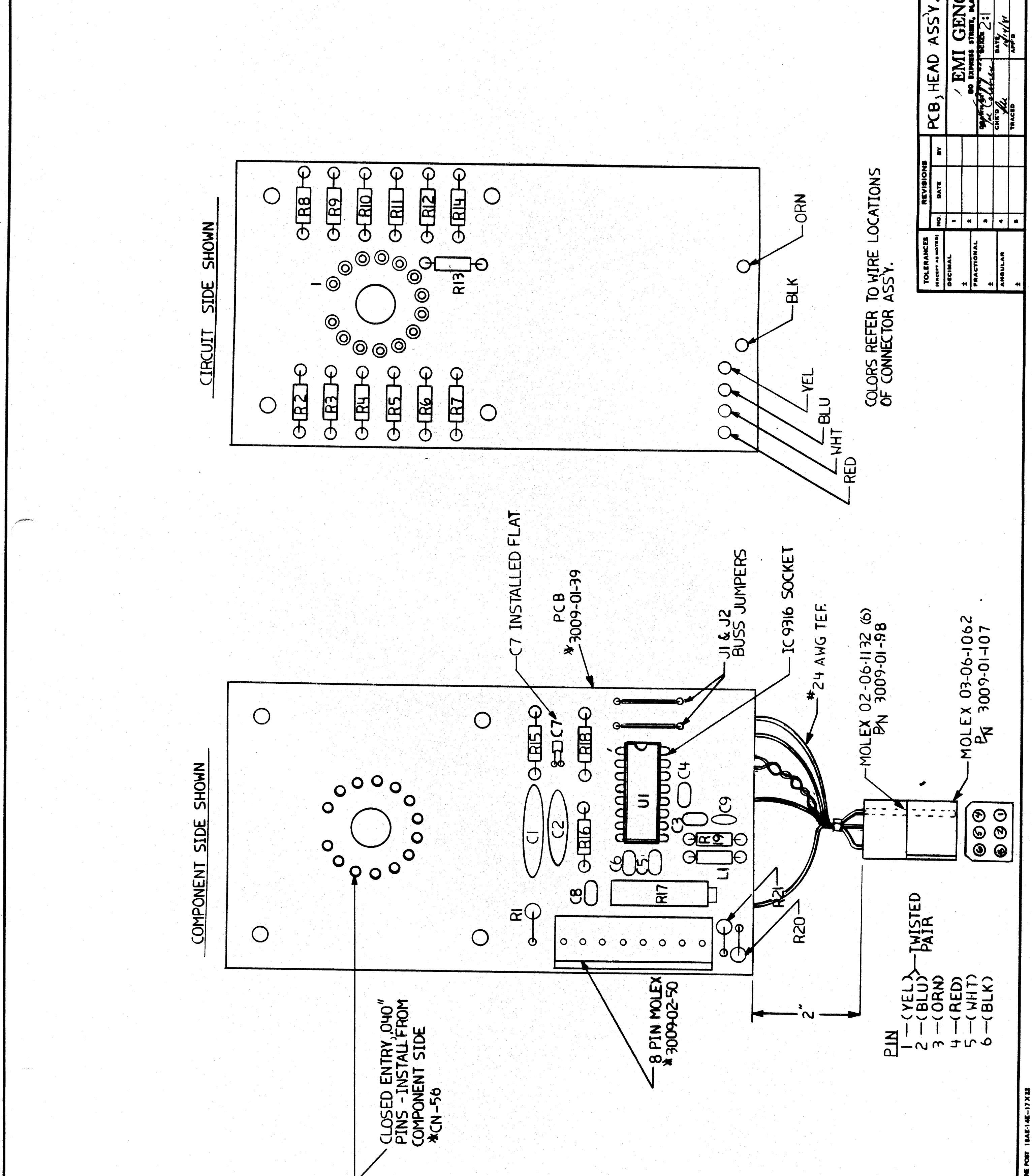
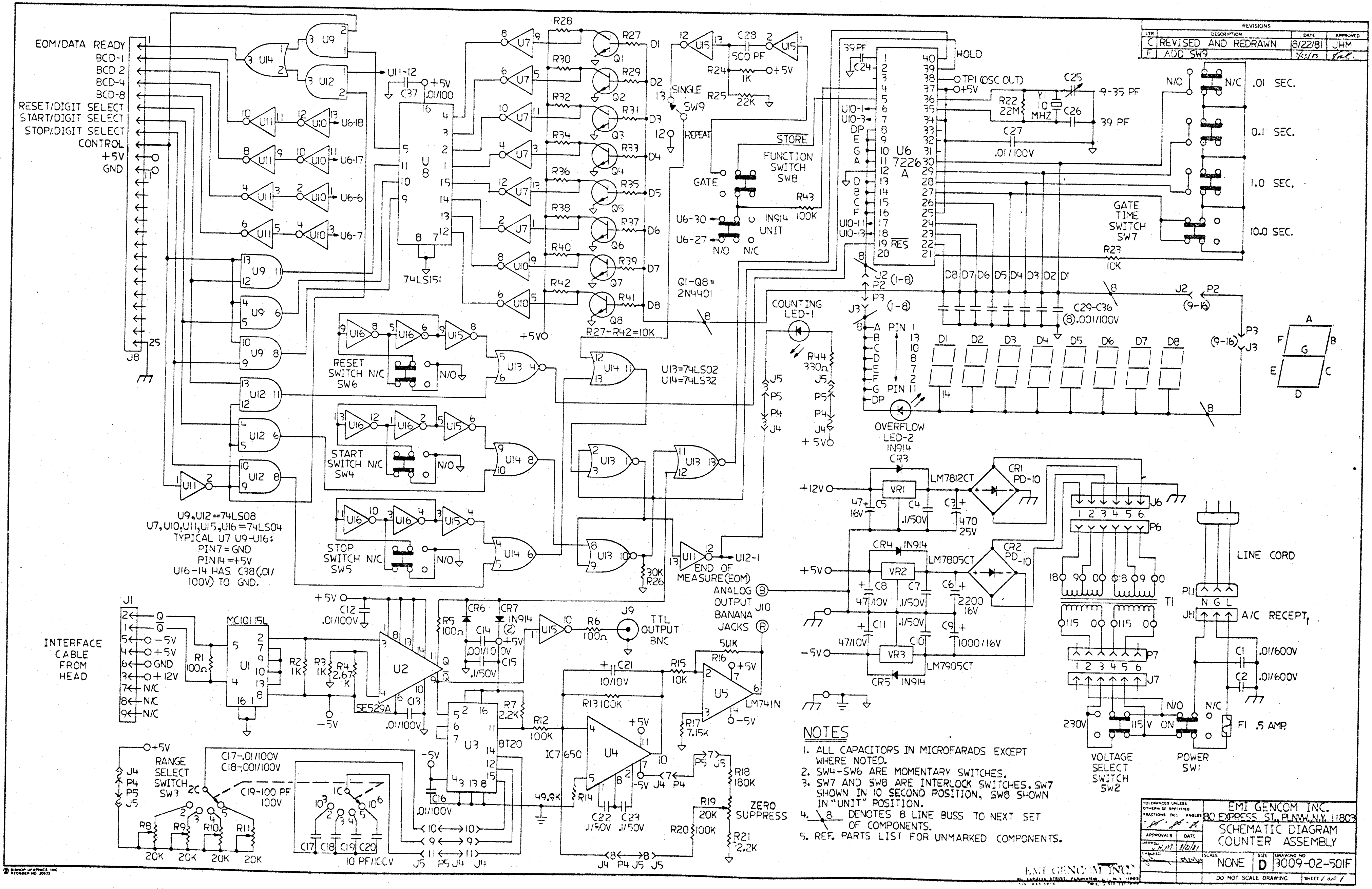

SCHEMATIC, PHOTOMETER HEAD
EMI GENCOM INC.
3009-01-501E
TO INTERFACE
CABLE FROM
COUNTER
P4
YEL
BLU
ORN
RED
WHT
BLK
NC
NC
NC
J3
P3
U1 MVL100
L1 22μh
C9
15 PF
390
R18
C7
150
C6
.01μf
C5
.01μf
-5V
+5V
GND
+12V
C2 .01μf, 1KV
R15 51.1K
R16 51.1K
R17 HV ADJ
20K 20 TURN
C8 .01μf
PMT
K
A
D1
D2
D3
D4
D5
D6
D7
D8
D9
D10
D11
R13 499K
R14 10K
R1 100K
C1 .01μf, 3KV
J1
R21 220Ω
R20 220Ω
P1A
P1B
SW1
LED 3
LED 1
LED 2
P2
J2
ILLUM. ADJ.
CP1
HVPS
PROG
GND
+12V
HV

Fig. 9


CIRCUIT SIDE SHOWN
R8 R9 R10 R11 R12 R14
R13
R2 R3 R4 R5 R6 R7
ORN
BLK
YEL
BLU
WHT
RED
COLORS REFER TO WIRE LOCATIONS OF CONNECTOR ASS'Y.
COMPONENT SIDE SHOWN
C7 INSTALLED FLAT
PCB *3009-01-39
J1 & J2 BUSS JUMPERS
IC 9316 SOCKET
#24 AWG TEF.
MOLEX 02-06-1132 (6) P/N 3009-01-98
MOLEX 03-06-1062 P/N 3009-01-107
R15 C7 R18 C4 U1 C9 C1 C2 R16 C3 R19 C6 C5 L1 C8 R17 R1 R21 R20
TWISTED PAIR
2"
PIN
1 —(YEL)
2 —(BLU)
3 —(ORN)
4 —(RED)
5 —(WHT)
6 —(BLK)
8 PIN MOLEX *3009-02-50
CLOSED ENTRY .040" PINS - INSTALL FROM COMPONENT SIDE *CN-56
TOLERANCES
DECIMAL
FRACTIONAL
ANGULAR
REVISIONS
NO. DATE BY
PCB, HEAD ASS'Y.
EMI GENCOM INC.
SCALE 2:1
DRAWING NO.
3009-01-307A
Fig. 10



NOTES

1. ALL CAPACITORS IN MICROFARADS EXCEPT WHERE NOTED.
2. SW4-SW6 ARE MOMENTARY SWITCHES.
3. SW7 AND SW8 ARE INTERLOCK SWITCHES. SW7 SHOWN IN 10 SECOND POSITION, SW8 SHOWN IN "UNIT" POSITION.
4. 8 DENOTES 8 LINE BUSS TO NEXT SET OF COMPONENTS.
5. REF. PARTS LIST FOR UNMARKED COMPONENTS.

EMI GENCOM INC.
80 EXPRESS ST., PLNW., N.Y. 11803

SCHEMATIC DIAGRAM
COUNTER ASSEMBLY

SCALE NONE | SIZE D | DRAWING NO 3009-02-501F

DO NOT SCALE DRAWING

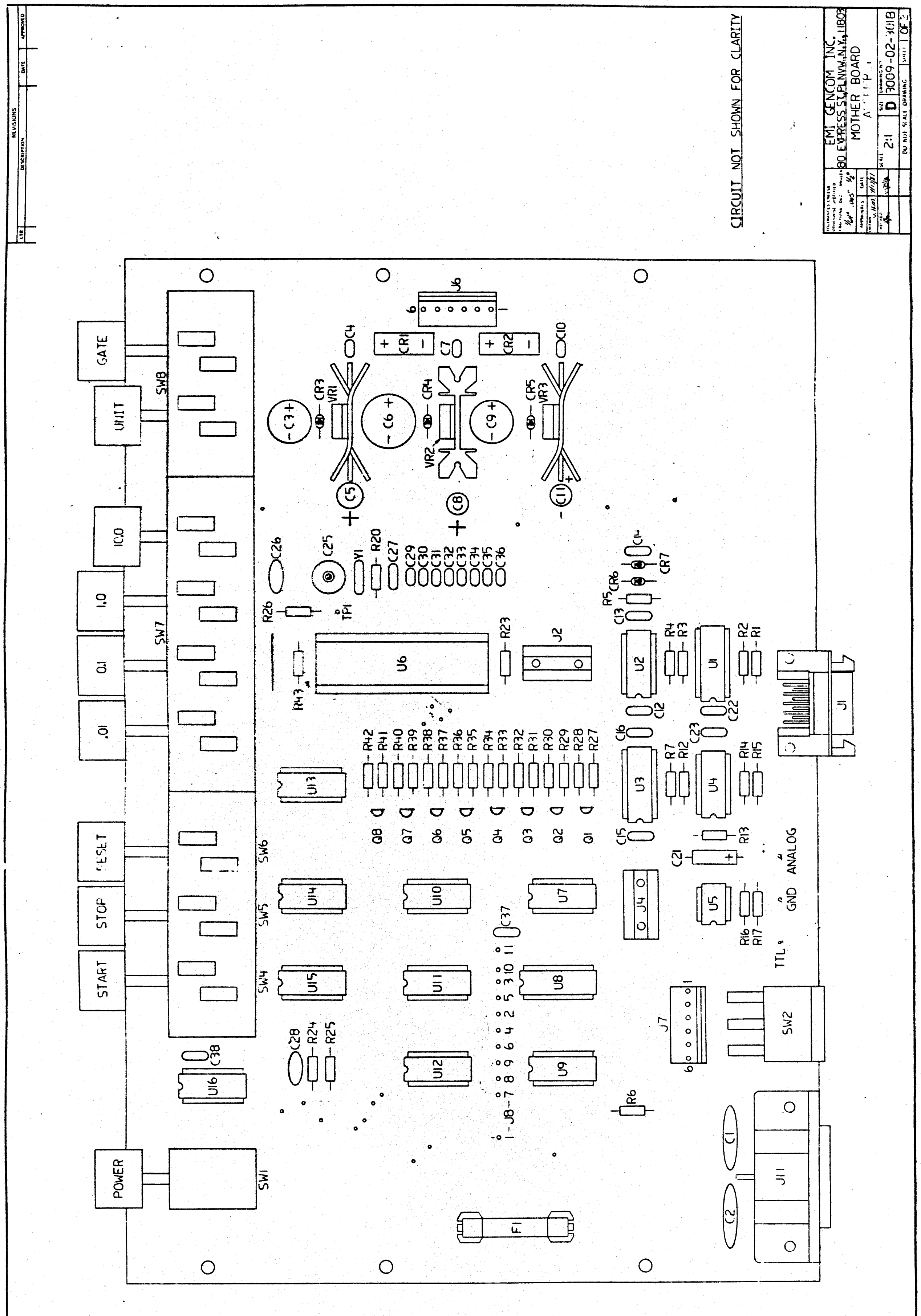
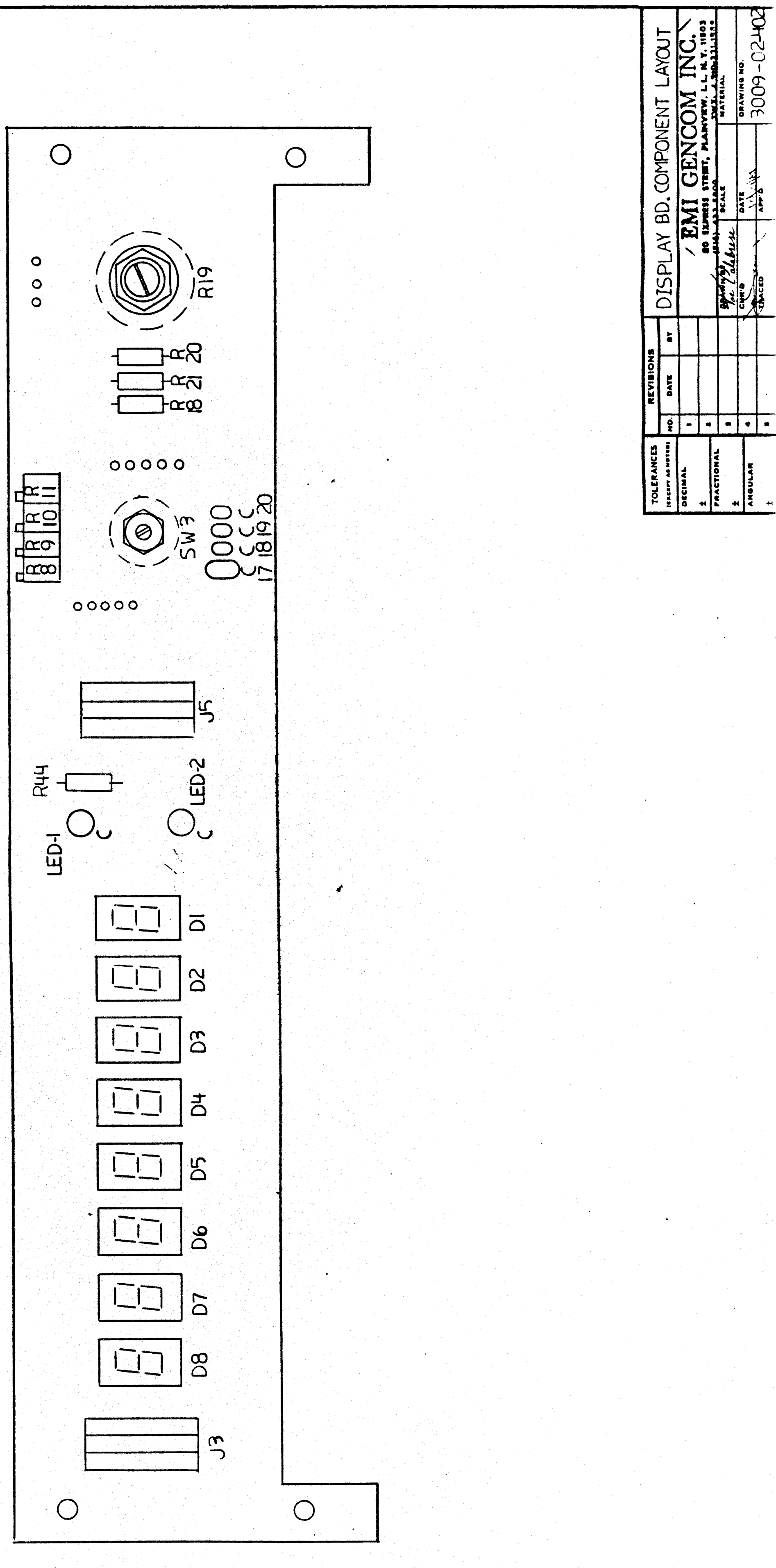

CIRCUIT NOT SHOWN FOR CLARITY
EMI GENCOM INC.
80 EXPRESS ST. PLNVW. N.Y. 11803
MOTHER BOARD
D
3009-02-301B
SHEET 1 OF 2
DO NOT SCALE DRAWING
2:1
REVISIONS
LTR
DESCRIPTION
DATE
APPROVED
GATE
UNIT
SW8
10.0
1.0
0.1
.01
SW7
RESET
STOP
START
SW6
SW5
SW4
POWER
SW1
SW2
F1
J1
J2
J4
J6
J7
J8
J11
U1
U2
U3
U4
U5
U6
U7
U8
U9
U10
U11
U12
U13
U14
U15
U16
VR1
VR2
VR3
CR1
CR2
CR3
CR4
CR5
CR6
CR7
Y1
TP1
Q1
Q2
Q3
Q4
Q5
Q6
Q7
Q8
TTL
GND
ANALOG

Fig. 12



DISPLAY BD. COMPONENT LAYOUT
EMI GENCOM INC.
80 EXPRESS STREET, PLAINVIEW, L.I., N.Y. 11803
TOLERANCES
DECIMAL
FRACTIONAL
ANGULAR
REVISIONS
NO.
DATE
BY
SCALE
MATERIAL
DATE
DRAWING NO.
3009-02402
R19
R20
R21
R18
R8
R9
R10
R11
SW3
C17
C18
C19
C20
J5
R44
LED-1
LED-2
D1
D2
D3
D4
D5
D6
D7
D8
J3

Fig. 13

SECTION VI MAINTENANCE

6.1 Operating Conditions and Precautions

The STARLIGHT-1 is an extremely rugged stellar photometer and should operate indefinitely without the need of repair. To ensure long life and best performance, the following operating conditions and precautions must be observed.

6.1.1 Humidity:

Humidity will probably be the first villain to crop up in your photoelectric measurements. It is a problem with every stellar photometer which has ever been made. Many professional astronomers have had to resort to potting the PMT base in an RTV rubber compound to alleviate this problem. We have not done this because it would make it impossible for you to change the photomultiplier tube if you should ever require a replacement or exchange the PMT for a more red sensitive model, etc.

We have, however, placed the PMT inside a foamed block and put a humidity sealant on the voltage divider board. This will give some protection, but it will not help if the photometer head is left in a very humid environment while it is not in operation. We strongly recommend that you bring the photometer head into a heated shelter when it will not be in use for a few days.

The obvious symptom of humidity is a dramatic increase in your dark count rate. The cure to this problem is in section 6.4.6.

6.1.2 Ambient Light:

Ambient light should not damage your PMT if the photometer is not turned on. However, it is recommended that you always protect the PMT from ambient light by setting the filter turret to the "0" position and by leaving the flip prism in the "VIEW" position when the photometer is not in use. Do not point the telescope at the sun, moon, or street lights - the STARLIGHT-1 was not designed to measure the brightness variations of these objects!

6.1.3 Heat:

The photometer is designed to function in temperature environments up to 50°C (122°F). However we recommend that you remove the photometer head from any environment which may go above 40°C (104°F), as this may increase your dark count during your next observing session.

6.1.4 Cold:

The photomultiplier tube will operate normally even if the temperature drops to -20°C (-4°F); in fact, the dark count will improve by a factor of 10. The intergrated circuits are specified to 0°C (32°F) and seem to work normally at lower temperatures. The PMT and PMT power supply produce heat under normal operation, as the photon counter components. Thus, the normal operating ambient temperature can be reduced further.

We recommend that if the temperature drops to -5°C (23°F) or below, you devise a cover for the counter and head which would contain and perhaps generate some heat.

The optimum operating temperature would be approximately 0°C (32°F).

6.1.5 Counter Position:

We recommend that the counter be positioned as close to your photometer head as possible to avoid stress to the interconnecting cable. The 25-foot cable option may be necessary for your observatory conditions.

6.2 Photometer Head Maintenance

6.2.1 Opening The Head:

The photometer head has been designed to be basically maintenance free. However, if you need to open the Head, please follow this procedure:

A. Remove the Head from the telescope and place on a flat table and away from strong lights. Remove the interconnecting cable.

B. Remove the 6 screws on the top panel of the head (figure 4, page 16).

C. Loosen the 4 front panel screws which are located toward the panel edge, two on each side. A loosening of 4 to 6 turns should be sufficient. (Figure 16 page 49 shows screws in loosened position). Pull on the top black panel (with 9-pin connector) with left hand while pulling the opposite (bottom) panel in the other direction with your right hand. The bottom and side panels will separate from the top panel. The front panel (with control knobs) will either stay with the top panel or with the bottom and side panels, it does not matter which way. All of the Head assembly is attached to the top panel. Two people can separate the head quite easily - one pulling the top panel, the other holding both side panels.

A good amount of effort may be required to separate the panels. This is because a light tight fit is essential and therefore tolerances are quite close. Once separated, place the photometer on its top panel as shown in figure 15.

6.2.2 Changing Apertures:

The diaphragm turret has been designed to allow easy replacement of the apertures. We recommend that you purchase replacements from our factory to ensure proper dimensions and accuracy. (See figure 16). Remove cover as per 6.2.1. First remove the aperture turret control knob. Then remove the aperture turret cover plate shown in figure 15 (page 48) by removing the 5 screws holding it in place. The aperture turret assembly will easily slide out. Push out the aperture and retaining ring. When replacing the turret, be sure that the detent plungers are riding properly on the circumference of the turret.

It is not recommended that you remove the reticle. If you find that the standard reticle is unsuited to your particular requirements, please contact our factory.

6.2.3 Changing or Adding Filters:

Remove cover as per 6.2.1 Rotate filter turret until the desired filter position is in an accessible area (you may want to first remove the aperture turret as per 6.2.2). Push out the filters and retainers with your thumb but use tissue paper to prevent finger prints on the filters. Replace with new filters.

6.2.4 Adjusting the Plungers/Detent Mechanisms:

After a long period of use, it may be necessary to re-adjust the plunger in order to obtain the proper feel when rotating the turrets. Refer to figure 14.

The pressure exerted by the diaphragm turret plungers is controlled by the single screw shown next to the diaphragm as shown in figure 16. The pressure exerted by the filter turret plunger is controlled by the single allen head screw located at the back end of the plunger block (Shown just behind the head of the arrow in figure 16).

Warning: Do not overtighten these screws as this will increase wear and require too much pressure from the control knobs while you are adjusting the photometer upon your star. They should be tightened just enough to provide positive location at all detented positions.

6.2.5 Replacing the MVL-100 Amp/Disc:

Refer to figures 10 adn 15 for location.

6.2.6 Replacing the Photomultiplier:

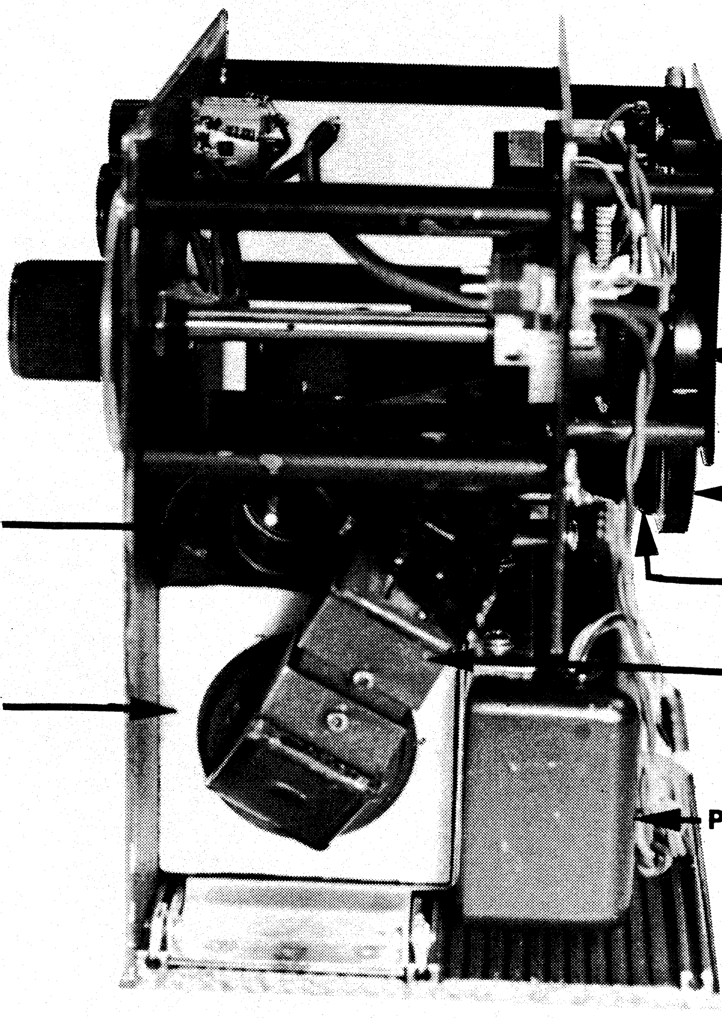
Replacement of the PMT is a rather involved and delicate operation. If you require the PMT to be replaced with the same model or a similar model with a different photocathode, we strongly recommend that you return the photmeter head to our factory (see section 6.5). If it is not possible to return the Head to us, please contact the factory for special instructions.

If any other parts require repair or replacement, please contact our factory for instructions and for parts.

6.2.7 Adjusting the Postviewer Eyepiece:

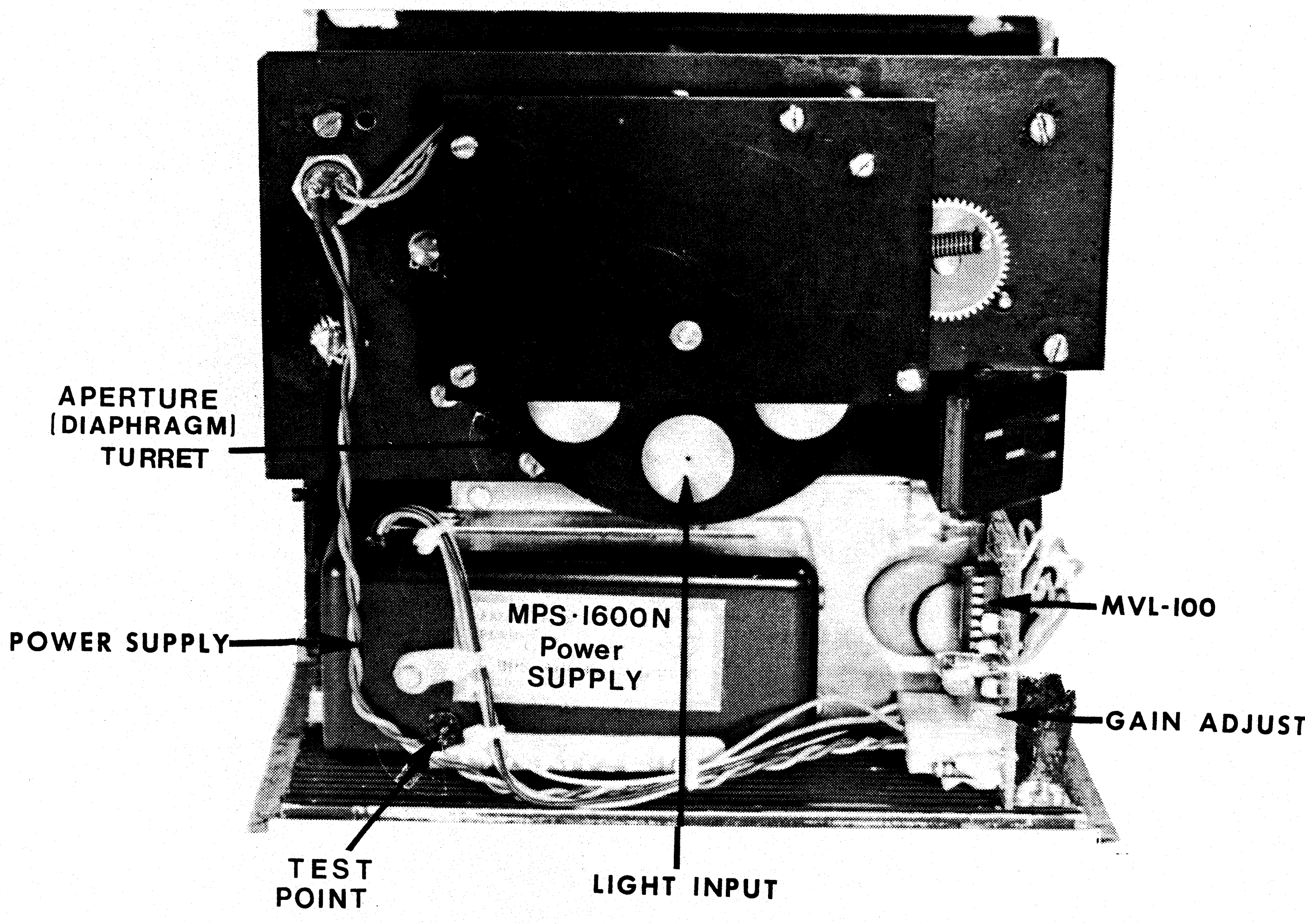
The position of the postviewer eyepiece can easily be adjusted to center the image in the eyepiece. There are 4 screws surrounding the eyepiece and recessed into the eyepiece holder (see part No. 4, figure 4, page 16). Loosen each of the 4 screws only enough to allow the eyepiece holder to be moved. DO NOT remove the screws completely.

When the 4 screws are loosened, the eyepiece holder can be moved 1/4 to 1/2 inch in any direction. This should be enough to allow proper adjustment to the eyepiece position. When the eyepiece is in the proper position, tighten each of the 4 screws.



PHOTOMETER HEAD
SIDE VIEW

FIGURE 14

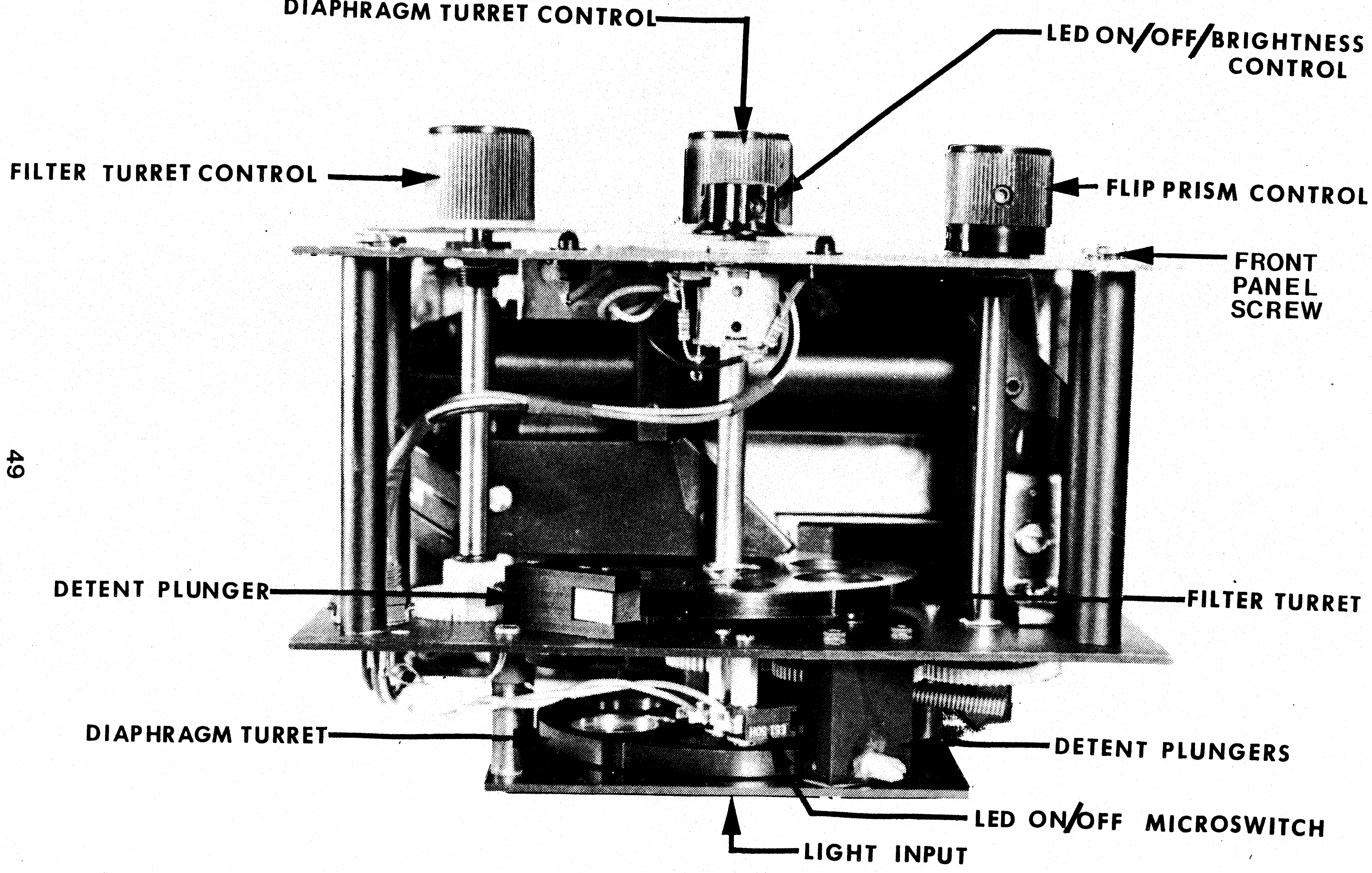


PHOTOMETER HEAD

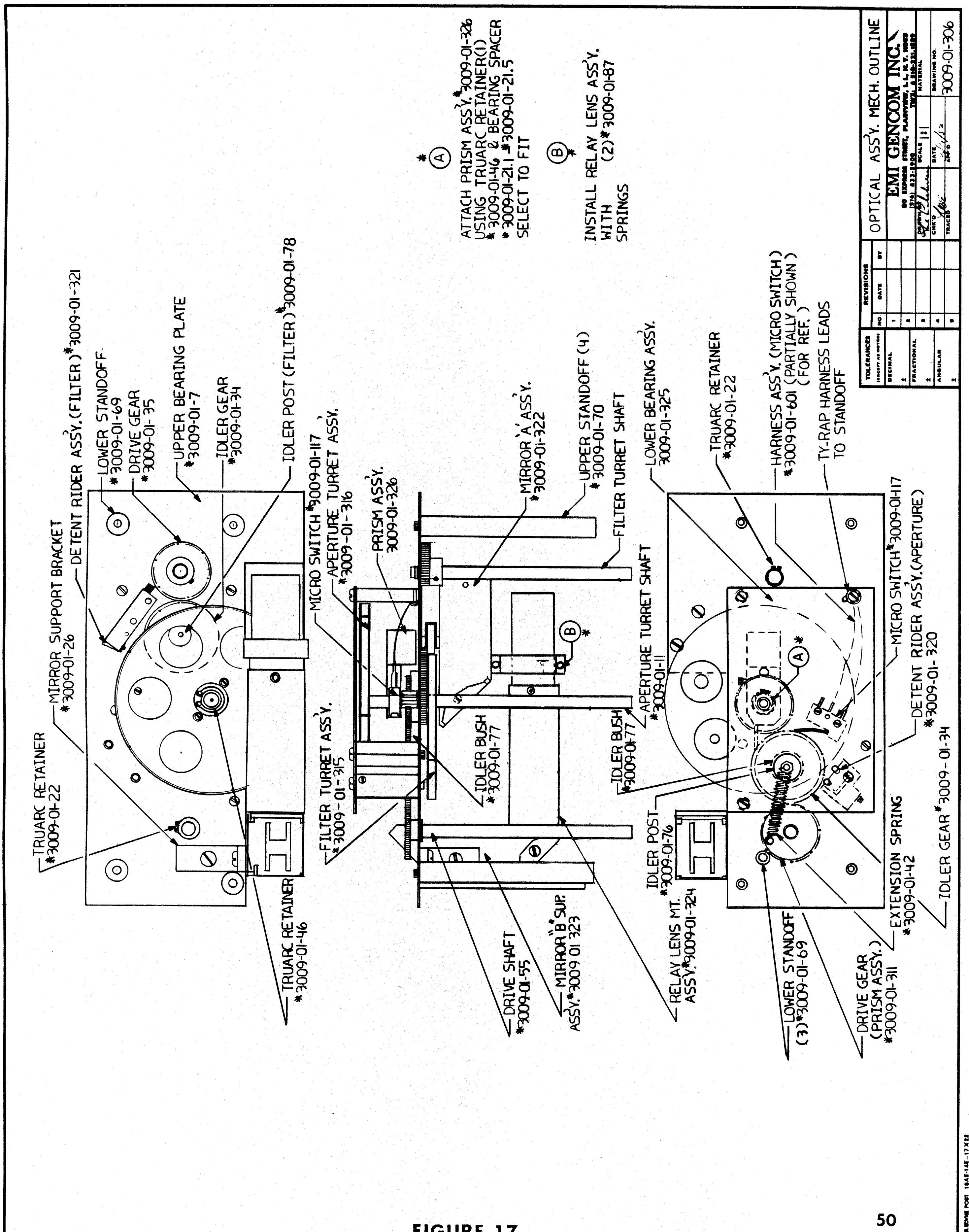
FRONT VIEW

FIGURE 15

PHOTOMETER HEAD



TOP VIEW
FIGURE 16



TRUARC RETAINER *3009-01-22
MIRROR SUPPORT BRACKET *3009-01-26
DETENT RIDER ASS'Y. (FILTER) *3009-01-321
LOWER STANDOFF *3009-01-69
DRIVE GEAR *3009-01-35
UPPER BEARING PLATE *3009-01-7
IDLER GEAR *3009-01-34
IDLER POST (FILTER) *3009-01-78
TRUARC RETAINER *3009-01-46
MICRO SWITCH *3009-01-117
APERTURE TURRET ASSY. *3009-01-316
PRISM ASS'Y. 3009-01-326
FILTER TURRET ASS'Y. *3009-01-315
IDLER BUSH *3009-01-77
DRIVE SHAFT *3009-01-55
MIRROR "B" SUP. ASS'Y. *3009 01 323
RELAY LENS MT. ASS'Y. *3009-01-324
MIRROR 'A' ASS'Y. *3009-01-322
UPPER STANDOFF (4) *3009-01-70
FILTER TURRET SHAFT
APERTURE TURRET SHAFT
APERTURE TURRET *3009-01-11
IDLER BUSH *3009-01-77
IDLER POST *3009-01-76
LOWER BEARING ASS'Y. 3009-01-325
TRUARC RETAINER *3009-01-22
HARNESS ASS'Y. (MICRO SWITCH) *3009-01-601 (PARTIALLY SHOWN) (FOR REF.)
TY-RAP HARNESS LEADS TO STANDOFF
MICRO SWITCH *3009-01-117
DETENT RIDER ASS'Y. (APERTURE) *3009-01-320
IDLER GEAR *3009-01-34
EXTENSION SPRING *3009-01-42
LOWER STANDOFF (3) *3009-01-69
DRIVE GEAR (PRISM ASS'Y.) *3009-01-311
A *
B *
(A) * ATTACH PRISM ASS'Y. *3009-01-326 USING TRUARC RETAINER(1) *3009-01-46 & BEARING SPACER *3009-01-21.1 *3009-01-21.5 SELECT TO FIT
(B) * INSTALL RELAY LENS ASS'Y. (2) *3009-01-87 WITH SPRINGS
OPTICAL ASS'Y. MECH. OUTLINE
EMI GENCOM INC.
TOLERANCES
REVISIONS
DRAWING NO. 3009-01-306

FIGURE 17

6.2.7 Parts List

Ref Designation	Description	Mfg. Part Number	Gencom Part Number
-	Head Assembly	-	3009-01-307A
C1	.01µf/3KV		
C2	.01µf/1KV		
C3, C4	.1µf	Centralab CW20C104K	3009-02-42
C5	.01µf	Centralab CW186103K	3009-02-38
C6	.01µf	Centralab CW186103K	3009-02-38
C7	150pf	Centralab DW15C151K	3009-02-4
C8	.01µf	Centralab CW186103K	3009-02-38
C9	15pf/600V	Sprague DD150	3009-02-45
R1	100K, 1/4W, 1%	-	R100K, 1/4W, 1%
R2	1 Meg, 1/4W, 1%	-	R1M, 1/4W, 1%
R3-R13	499K, 1/4W, 1%	-	R10K 1/4W, 1%
R14	10K	-	R449K
R15, R16	51.1 ohm, 1/4W, 1%	-	R51.1, 1/4W, 1% MF
R17	20K, 20 turn	-	3009-01-83
R18	2.7K, 1/4W, 1%	-	R2.7K, 1/4W, 1% MF
R19	390 ohm, 1/4W, 5%	-	R390, 1/4W, 5% CC
R20-21	220 ohm	-	
L1	Choke 2.2µh	Cambion 550-3399-17-00	
U1	Amp/Disc	LeCroy MVL/100	IC-MVL100
HVPS	HV Power Supply	MPS1600N	MPS1600N
PMT	Photomultiplier Tube	EMI 9924A	EMI 9924A
PCB	Photocircuit Board	Gencom 3009-02-39	3009-02-39

6.3 Photon Counter Maintenance

6.3.1 Test Equipment required

The following list of equipment is recommended should it become necessary to repair or recalibrate the instrument.

1. Frequency counter 10 Mhz.
2. High Stability differential ECL pulse generater
3. 3 1/2 digit Digital Volt Meter (DVM)

6.3.2 Calibration Procedure

Should the counter require calibration or you find it necessary to verify the performance, the following procedure is recommended. Use figures 12, 13 pages 42, 43 for parts placement.

Oscillator Frequency

Connect a frequency counter to pin 38 of U6 and Ground. Adjust C25 for 10 Mhz. oscillator frequency

Analog Output

1. Connect a differential ECL pulse generator across R1 and Ground.
2. Connect a 3 1/2 digit DVM on the analog output.
3. With the Pulse Generator off, adjust the Zero Suppress for Zero volts on the DVM.
4. Turn on the pulse generator and adjust for a frequency of 1000 hertz.
5. Set the range select switch for 1000 counts/sec.
6. Adjust R8 for 1 volt output on the DVM.
7. Set the range select seitch for 10,000 counts/sec.
8. Set the pulse generator for 100,000 Hertz.
9. Adjust R9 for 1 volt output on the DVM.
10. Set the range select switch for 100,000 counts/sec.
11. Set the pulse generator for 100,000 Hertz.
12. Adjust R10 for 1 volt output on the DVM.
13. Set the range select switch for 1,000,000 Hertz.
14. Set the pulse generator for 1,000,000 Hertz.
15. Adjust R11 for 1 volt output on the DVM.

This completes the calibration of the STARLIGHT-1 photon counter.

Note: The cover to the photon counter is easily removed by removing the four hex screws located on the side panels. This still leaves the photon counter fully operational and caution must be observed since high voltage connections will be exposed.

6.3.3 Parts List for Photon Counter

Ref. Designation	Description	Mfr. Part Number	Gencom Part Number
C1, C2	.01uf/600v	Sprague DD6-103	3009-02-46
C21	10uf @ 10V Tant.	Sprague	Q10/10
C9	1000uf/16V.	KSMM-1000-16	3009-02-67
C25	9-35pf, Var.	Erie 011D-9-35	3009-02-47
C26	39pf/1000 Volts.	Sprague DD390	3009-02-44
C28	500pf/1000 Volts	Sprague DD501	3009-02-43
C4, 7, 10, 15, 22, 23	.1uf/50V	Centralab CN20C104K	3009-02-42
C14, C29-C36, C18	.001uf/100V	Centralab CN15A102T	3009-02-38
C6	2200uf/16V	KSET 2200-16 (TOWA)	3009-02-37
C5	47uf/16V	KSET 47-16 (TOWA)	3009-02-36
C8, C11	47uf/10V	KSET 47-10 (TOWA)	3009-02-35
C3	470uf/16V	KSMM 470-25	3009-02-34
C19	100pf/100V	Centralab CN15A101K	3009-02-40
C20	10pf/100V	Centralab CN15A100K	3009-02-39
C17	.01uf/100V	Centralab CN40A103K	3009-02-38
CR3-CR7	1N914 Diode	IN914	D-1N914
CR1, CR2	Bridge Rectifier	EDI P10	3009-02-20
D1-D8	7 Sey. Display	Monsanto MAN71A	3009-02-11
LED-1, LED-2	LED	Dialight S-21-9165	3009-02-16
Q1-Q8	Transistor	2N4401	3009-02-59
R27, R42	10K, 1/4W, 5%		R10K, 1/4, 5%, C
R26	30.1K, 1/4W, 1%		R30.1K, 1/4, 1% MF
R25	R22.1K, 1/4W, 1%		R22.1K, 1/4, 1% MF
R22	22Meg, 1/4W, 5%		R22M, 1/4W, 5%,CC
R17	7.15K, 1/4W, 1%		R7.15K, 1/4, 1% MF

Ref. Designation	Description	Mfr. Part Number	Gencom Part Number
R16	51.1K, 1/4W, 1%		R51.1K, 1/4, 1% MF
R15, R23	10K, 1/4W, 1%		R10K, 1/4, 1% MF
R14	49.9K, 1/4W, 1%		R49.9K, 1/4, 1% MF
R12, R13, R43	R100K, 1/4W, 1%		R100K, 1/4, 1% MF
R7	R2.21K, 1/4W, 1%		R2.21K, 1/4, 1% MF
R4	R2.67K, 1/4W, 1%		R2.67K, 1/4, 1% MF
R2, R3, R24	R1K, 1/4W, 1%		R1K, 1/4, 1% MF
R1, R5, R6, R2	100, 1/4W, 1%		R100, 1/4, 1% MF
R44	330, 1/4W, 5%		R33, 1/4, 5% CC
R21	2.21K, 1/4W, 1%		R2.21K, 1/4, 1% MF
R18	180K, 1/4W, 1%		R180K, 1/4, 1% MF
R8-R11	Pot 20K, 10T	Bourns 3299X-20K	3009-02-14
R19	Pot 20K, 10T	Bourns 35405-1,10K	3009-02-15
SW1	Power Switch	AMF 7P01-3-22N-P2B1	3009-02-19
SW2	AC Select Switch	Switch Craft EP52-PC3	3009-02-31
SW3	Range Switch	Alco Switch MRC-2-55L	3009-02-17
SW4, 5, 6	START/STOP/RESET	AMF 7M03-0-22N-P2B1	3009-02-22
SW7	Gate Time Switch	AMF 7L04-0-22N-P2B1	3009-02-21
SW8	Function Switch	AMF 7L02-0-22N-P2B1	3009-02-23
T1	Transformer	Signal DL36-1	3009-02-76
U1	Line Receiver	Mot MC10115P	IC-MC10115P
U2	Comparitor	Sig. ME529A	IC-529A
U3	One-shot	Sig. 8T20N	IC-8T20N
U4	OP - Amp	Intersil 17650	IC-7650
U5	OP- Amp	Mat 741N	IC-741N
U6	Counter	Intersil 7226A	FC-7226A
U7, U10, U11, U15, U16	Inverter	TI 74L502N	IC-74L502N

Ref. Designation	Description	Mfr. Part Number	Gencom Part Number
U8	Multiplexer	TI 74L5151N	IC-74L5151N
U9, U12	AND GATE	TI 74L508N	IC-74L508N
U13	NOR GATE	TI 74L502N	IC-74L502N
U14	OR GATE	TI 74L532N	IC-74L532N
VR1	+12 Regulator	NAT. LM7812CT	IC-LM7812CT
VR2	+5V Regulator	NAT. LM7805CT	IC-LM7805CT
VR3	-5V Regulator	NAT. UA7905	IC-UA7905
Y1	Crystal 10 Mhz.	CTS Knights ISI-002-10Mhz.	3009-02-10
F1	Fuse	.5A Slowblo (115V) .25A Slowblo (230V)	

6.4 TROUBLE SHOOTING

6.4.1 NO POWER TO THE PHOTON COUNTER OR NO DISPLAY

This will be evident when the digital display does not light when in the GATE mode or when the counting LED does not light.

Check the following:

1. Push start button.
2. Power outlet has voltage (a likely cause when extension cords are being used).
3. Fuse - located on the mother board inside the photon counter, F1 figure 12. 1/2 A for 115 and 1/4 A for 230V operation.

If there is still no power or display, please contact our factory per section 6.5.

6.4.2 UNUSUAL OR INTERMITTENT DISPLAY

Check connection J2 (Figure 12).

6.4.3 NO POWER TO THE PHOTOMETER HEAD

This will be obvious if the position or backlight LED's do not light. The photon counter will record a count rate of "000" for a 1-second measurement.

Check the following:

1. That there is power to the photon counter. (If no power, see section 6.4.1)
2. That the white interconnecting cable is properly connected to both the photometer head and the photon counter.
3. Open the photometer head as per section 6.2.1. Check the 8-Pin Molex connector P/N 3009-02-50 for proper contact. Check for proper contact with all wires and connector P/N 3009-01-107, 6-Pin molex. See Figure 10.

If there is still no power to the Head, contact our factory per section 6.5.

6.4.4 POWER TO THE HEAD (LED'S LIGHT), BUT NO COUNT RATE RECEIVED (DISPLAY ALL ZERO'S) DO THE FOLLOWING:

CONTACT OUR FACTORY FIRST!

1. Open the photometer head as per section 6.2.1.
2. Check resistor values. You may need to remove some Humiseal to make proper contact.
3. Check for proper contact between the 4-Pin power supply connector and the 8-Pin Molex connector.
4. Check that voltage is reaching the PMT by:

   A. Disconnect the PMT from the optical assembly by removing the three screws in the "PMT Optical Path" assembly shown in figure 14.
   B. Place black electrical tape over the opening to the PMT window in order to shield the PMT from ambient light.
   C. Connect the HEAD to the COUNTER and turn the photometer "ON".

D. Use a voltmeter to check the voltage between pin 13 on the PCB and ground. Pin 13 is found by counting clockwise from pin 1, which is labeled on the PCB (See figure 10, Circuit side). You may use the unpainted bracket which holds the PMT/PCB assembly as a ground point. It is located directly in front of the PCB and attached to the top panel. Your meter should read the voltage written on the label attached to the power supply.

If the correct voltage is read on the meter, then replace the MVL-100 as this is the likely cause of the problem.

If the voltage is more than 100 volts away from the setting on the label, please contact our factory before making any voltage adjustments. Improper adjustment could damage the PMT.

If no voltage is read on pin 13, begin step E.

E. Check that the PMT power supply (MPS1600N) is supplying an output voltage by measuring the voltage between the test pin and ground. The test pin is located in the lower left hand (figure 1 corner on the front of the power supply near the label. It will read 1/1000th of the actual output, i.e. a 1-volt reading for 1000V output.

If a proper reading is obtained, read the voltage from pin 1 of the 8-Pin connector (Circuit side) to ground. This should also read the proper high voltage. If not, check the orange HV wire connection in the 4-pin connector.

If the proper reading is not obtained from the MPS-1600N power supply, check the voltages between the red and black wires (+12V) and Green and black wires (+5 volts).

If all of the above procedures fail to locate the problem, please contact our factory for instructions as per section 6.5.

6.4.5 LED'S IN HEAD DO NOT LIGHT, BUT COUNTS ARE RECEIVED.

Check that proper contact is being made between the 3-pin connector and 8-pin connector(figure 9).

6.4.6 LARGE INCREASE IN DARK COUNTS

The mose likely cause for this problem is humidity on the HEAD components. To cure this problem, follow these steps:

1. Remove the HEAD to a warm and dry location.
2. Open the HEAD by separating the top panel from the side panels, a distance of 1/2 to 1 inch only. See section 6.2.1
3. Remove the postviewer eyepiece .
4. Use a hair dryer or fan to blow air into the eyepiece holder opening.
   NOTE: If using a hair dryer, use only the "low" setting and without high temperture. Extreme heat will damage the PMT! If possible use a "cool" setting. Do not use a "High" fan setting. The "Low" setting is sufficient whether the hair dryer or fan is used.
5. Every 10 minutes turn off the dryer or fan, cover the HEAD with a dark cloth, connect the counter, and measure the dark count.

If the humidity problem is severe, you may need to blow dry air into the HEAD for a couple of hours.

Another method of reducing the dark noise is to turn on the photon counter with the HEAD attached and in complete darkness. The photometer should be left this way for 4 to 24 hours. Measurements should be made at several times during this interval to determine the dark count level.

If the dark count does not return to an acceptable level, please contact the factory as per section 6.5.

6.4.7 PHYSICAL DAMAGE AND MISC. PROBLEMS

Please contact the factory per section 6.5. Do not attempt to trouble shoot the the problem yourself. Any signs of unauthorized repair or mishandling may invalidate your warranty.

6.5 FACTORY REPAIR

If you should have any problems with your STARLIGHT-1, it is best to immediately contact our factory. This is also true for the items discussed in section 6.4 Many repairs require the knowledge and equipment which may not be available to most of our customers.

To contact our factory either call us at: 516-433-5900

Telex us at: TWX 510-221-1889

or

Write to us at: EMI GENCOM INC.
80 Express Street
Plainview, NY 11803

If your photometer must be returned to us, please ship it inside the original packing material. If this packing material is not available, please use extreme care in packing with the materials you have available.

RETURNS SHOULD BE SENT TO GENCOM PREPAID AND FULLY INSURED!

We will make every effort to return your photometer to you in the shortest possible time. If your unit is out of warranty and repair costs are involved, we will contact you with the exact cost before we begin with the repair.

If you wish to have a new and/or different PMT installed in your photometer head, please contact our factory first, and then return just the HEAD according to the above instructions.

6.6 One Year Limited Product Warranty

All Gencom products are warranteed against defects in material and workmanship for a full year from the date you receive the product. During this period, Gencom will repair or replace, at our option and at no cost to you, any product found to be defective, provided the product is returned to us freight prepaid and properly insured.

This Warranty does not apply in cases of abuse, mishandling, or unauthorized repair, by any other person or company.

Furthermore, the product may be returned for a full refund within 15 days of receipt, providing the product is returned in its original packing, is in new condition, and is returned prepaid and fully insured.

This warranty gives you specific legal rights. You may have other rights which vary from state to state.

7.0 Appendix 1

UNITS SUPPLIED WITH S-20 RESPONSE PMT

If you have specified that your STARLIGHT-1 photometer be supplied with an EMI 9798A or D-160A photomultiplier tube, you should read this section carefully. There is very little difference between the operating of your unit and the operation of the standard unit described in this manual, but the differences are important and you should be aware of them.

Dark Count: It is a physical fact that the more red responsive the photomultiplier tube is, the greater the background count rate will be. An S-20 photocathode will emit 400 electrons $sec^{-1} cm^{-2}$ in complete darkness due to thermoinic emission alone. This is more than 13 times the bialhali photocathode rate. We have selected your tube to be the best available from the hundreds in our stock, but your background count rate could be 3000 c.p.s. or more. Unless you are observing very faint stars under a very dark sky, this will not be a limiting factor for you.

Filters: The S-20 photomultiplier tube which you have choosen will allow you to make measurements in the U, B, V, and R band passes. The filters supplied with your photometer have been carefully selected to provide the best possible match to the U, B, V, R Standard System. It is important that you determine the transformation coefficients for your own telescope/photometer system at the first convenient observing session. The following filters are supplied:

POSITION	FILTER
U	Ultraviolet Channel (1mm Shott UG-1)
B	Blue Channel (1mm Shott GG-400, 1mm Shott BG-25)
V	Visible Channel (1mm Shott OG-515, 1mm Shott BG-18)
R	Red Channel (1mm Shott OG-570)
I	Red Leak Channel (1mm Shott RG-665 + GG-400 + BG-25)
O	Opague Shutter Position

Since you are using a tube with high red sensitivity the red "leak" of the Blue and Ultraviolet Channels becomes a significant factor in your "U" and "B" measurements. This red leak can be measured by using the filters in the "I" position of your filter turret. Therefore the "I" readings should always be subtracted from the "U" and "B" reading to get a proper ultraviolet and blue measurements. This procedure is not necessary for V and R measurements.

NOTE: The "I" position is not to be used for infrared bandpass measurements unless special provisions have been made.