# MODEL SSP-5

## *PHOTOELECTRIC PHOTOMETER*

TECHNICAL MANUAL FOR

THEORY OF OPERATION AND OPERATING PROCEDURES

***** IMPORTANT *****
**PLEASE READ THIS MANUAL THOUROUGHLY BEFORE ATTEMPTING TO OPERATE THE PHOTOMETER**


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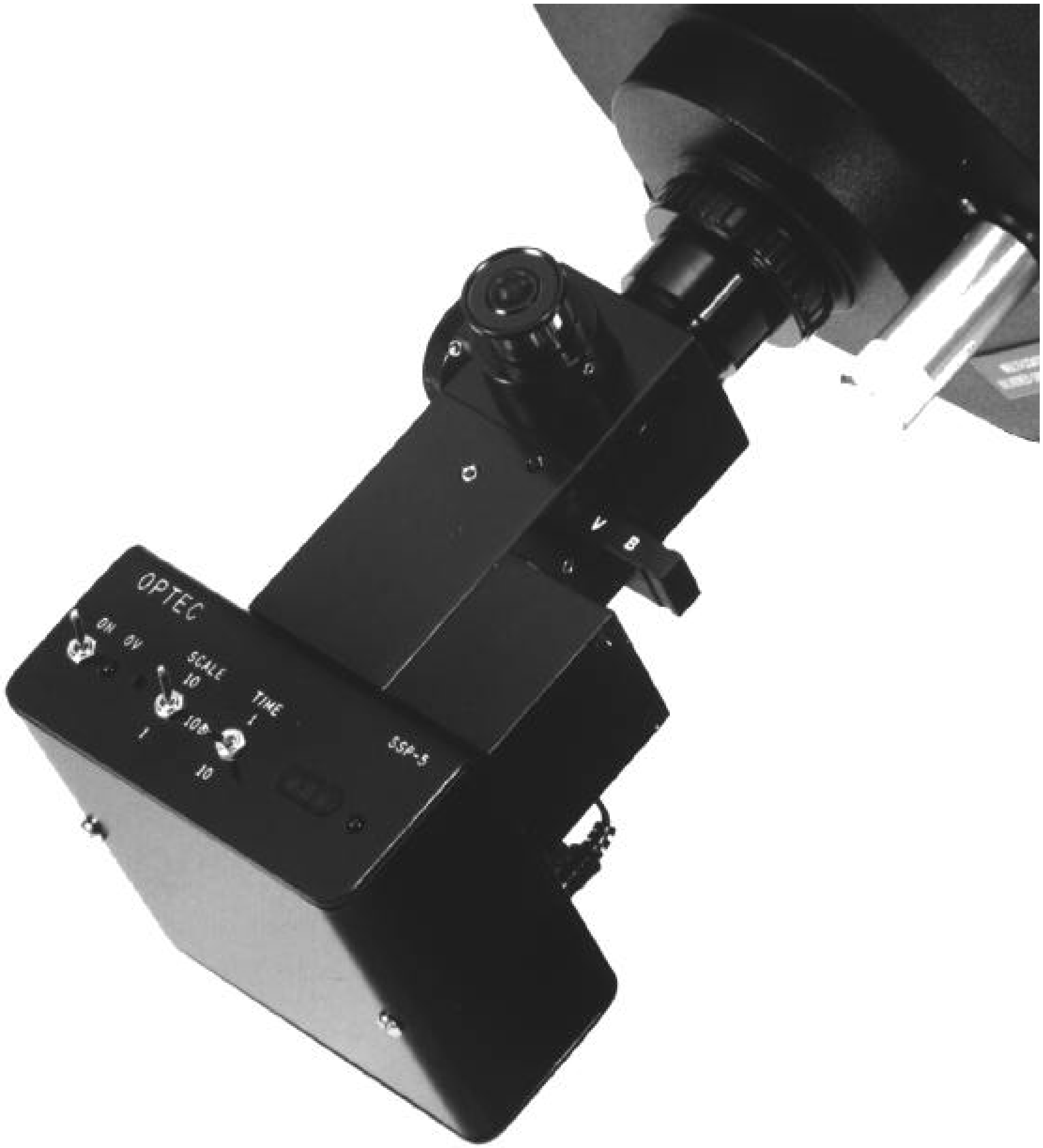


*Figure 1-1. SSP-5 Shown with Meade 8-inch Telescope.*

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# SECTION 1.0

## INTRODUCTION

Optec has developed a high-precision stellar photoelectric photometer which makes use of a miniature photomultiplier tube for sensitivity and faster time response. Using the same design philosophy encompassed in the SSP-3, the SSP-5 looks and operates in very much the same way. The use of a photomultiplier tube (PMT) allows fainter stars to be measured accurately and the enhanced response time, as fast as 1 ms, allows fast events such as lunar occultations to be recorded with greater time resolution.

With the R4040 PMT option, the SSP-5 can exhibit an S-5 response similar to the original 1P21 photomultiplier tube. For researchers interested in greater low light sensitivity and extended red response to 830 nm, the R4457 PMT option is available along with Johnson UBVR filters. Each PMT is a 9-stage, side-on, low-noise photomultiplier housed in a small ½-inch diameter enclosure.

In spite of the fact that a PMT based photometer is more sensitive to damage from bright lights or rough handling, a great deal of effort has been expended to make the SSP-5 nearly as survivable as the SSP-3. The SSP-5 will allow the researcher to measure both bright and faint stars in the UBV spectral region with the degree of precision and reliability associated with the venerable SSP-3.

The SSP-5 Photometer is the central part of a complete stellar magnitude measurement system as shown in Figure 1-2. A comprehensive set of precision filters, data acquisition interfaces, aperture stops, and adapter options are available to fit any observing program.

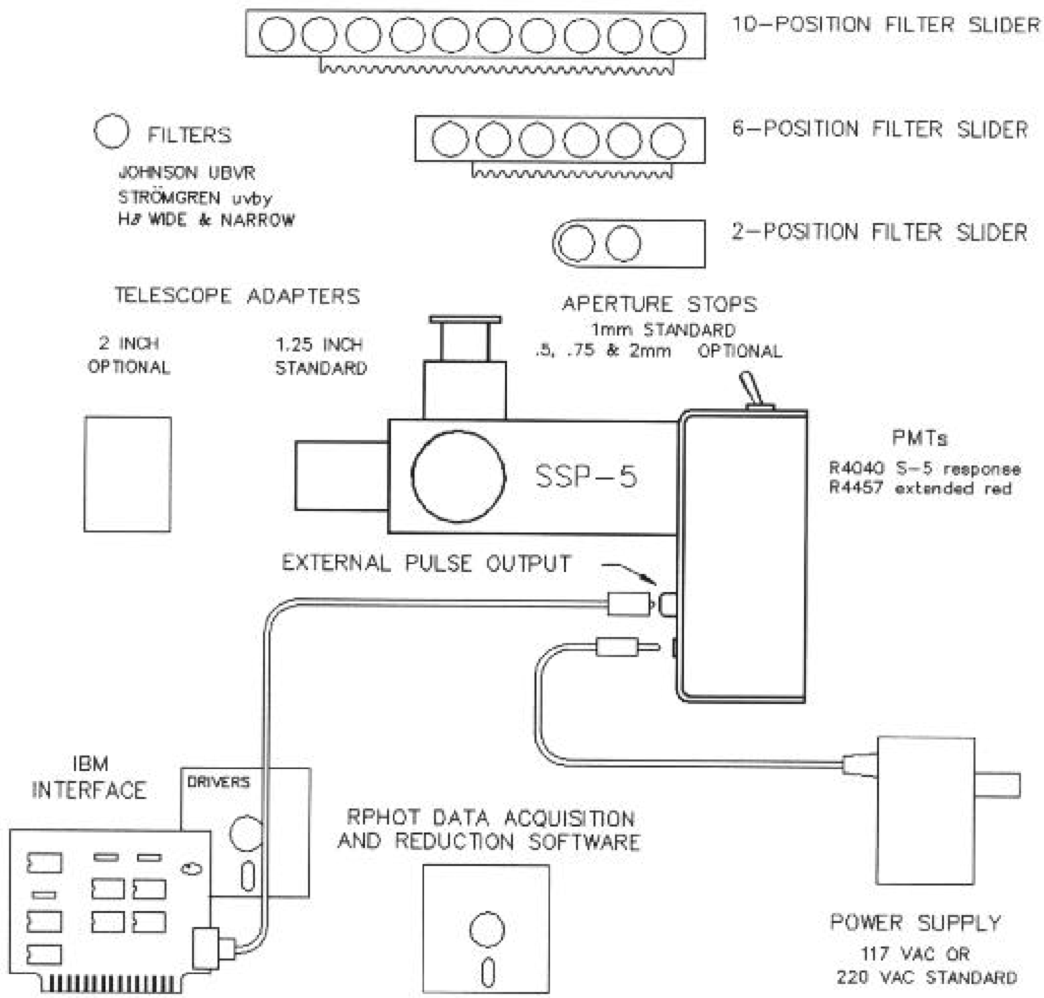


*Figure 1-2. The SSP-5 photometer system and accessories.*

# SECTION 2.0

## THEORY OF OPERATION

### 2.1 PHOTOMETER HEAD

A cross-sectional view of the photometer head is shown in Figure 2-1. Light enters the photometer through the 1¼-inch telescope adapter and is directed either to the focusing eyepiece or the photomultiplier tube (PMT) by means of a flip-mirror. The focusing eyepiece consists of a 1-inch focal length Ramsden and illuminated reticle with a precisely scribed ring that defines the aperture field of view. After a star is centered in the ring, the flip-mirror is rotated to allow light to pass through the aperture stop which separates the star from the background. A Fabry lens then projects an image of the primary mirror/lens onto the photocathode of the PMT.

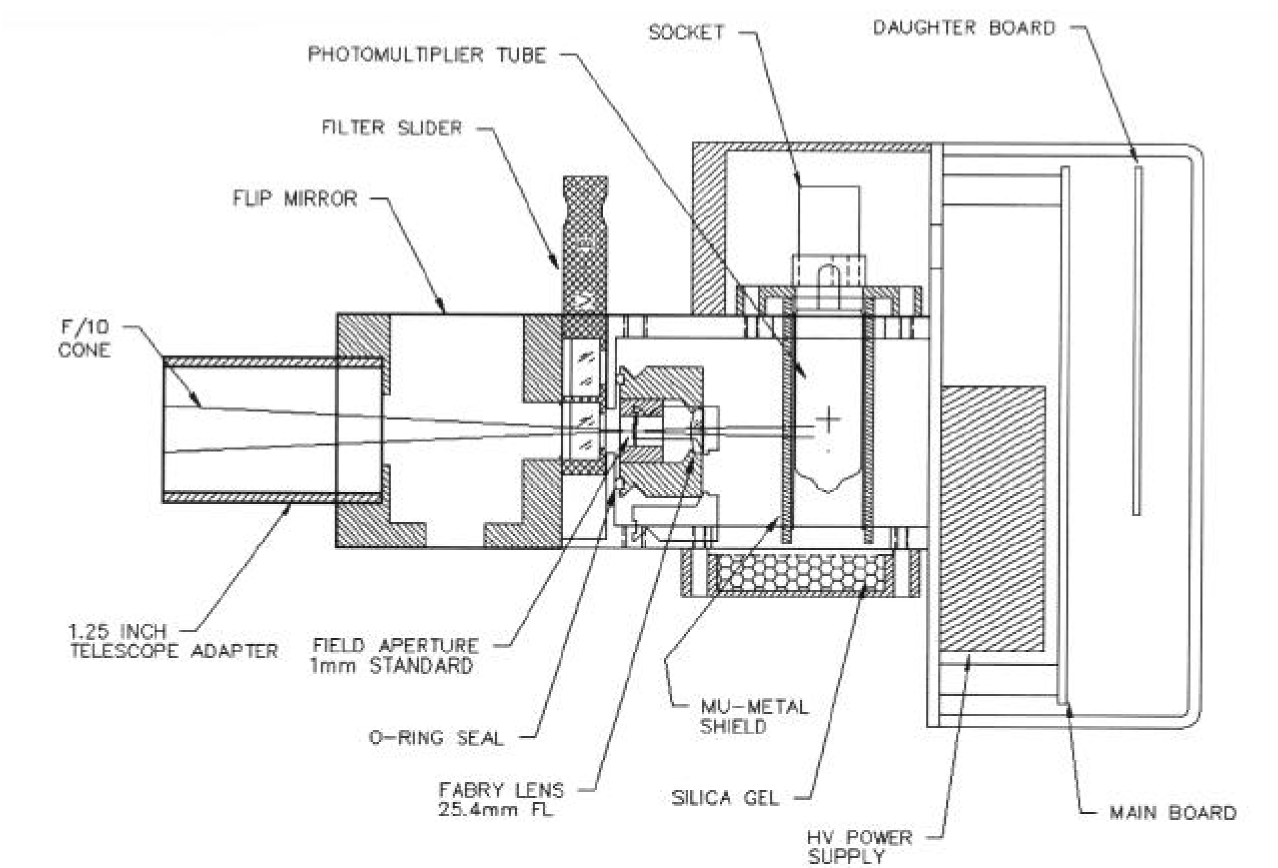


*Figure 2-1. Cross-sectional view of the SSP-5 looking from the top*

## 2.2 DETECTOR - PMT OPTIONS

Optec currently offers two different models of side-on photomultiplier tubes (PMT's) which can be used in the SSP-5. These PMT's are manufactured by Hamamatsu Corporation and measure only 40 mm long by 14 mm in diameter. In this small package is a well designed 9-stage photomultiplier which can operate at -1000 VDC. At the operating voltage of -850 VDC and after several hours of warm-up, the model R4040 PMT has a typical measured dark current of around 8 pA at 70° F ambient temperature.

The model R4457 is an extended red response PMT which can allow measurements into the Johnson R band. The overall gain and quantum efficiency (QE) of the R4457 is much better than the R4040. The QE at the center of the Johnson V band, 540 nm, is approximately 2% for the R4040 and 16% for the R4457. Because of this increased sensitivity, when the R4457 PMT is specified the operating supply voltage is set to -750 VDC rather than -850 VDC. At this voltage, the measured dark current is typically less than 2 pA at 70° ambient temperature.

The spectral response of the R4040 is S-5 which is identical to the S-4 response of the traditional 1P21 tube except for extended response in the UV. This extended response to about 185 nm is due to the special UV transmitting glass used for the tube. The spectral response of the R4457 extends from the same 185 nm at the blue end to 830 nm at the red end. A Fabry lens of B270 glass and 2.9 mm center thickness cuts the transmission to 50% at 315 nm and to 0 at 300 nm. This small loss of UV transmission near 300 nm should not adversely affect the U filter transformation to the standard system.

The R4040 tube is powered by an -850 VDC power supply to give a current amplification of about $1x10^6$. This value was chosen after measuring the signal to dark-noise ratio at several applied voltages and using the voltage giving the highest value. Once set, the operating voltage cannot be changed by the user. When the R4457 PMT is specified, the voltage is turned down to -750 VDC. This lower voltage setting is needed to allow the user to observe brighter stars (brighter than 4th magnitude) without saturating the detector. The current amplification of the R4457 at -750 VDC is about $6x10^5$

A mu-metal shield of high permeability is placed around the PMT to reduce the effect of external magnetic fields (dome motors, the earth's field, conductors inside the SSP-5, etc.) on the path of photoelectrons in the tube. See Figure 2-1. In addition the shield is brought to the same potential as the photocathode, so that photoelectrons are not drawn to the glass tube. To protect against shock hazard, the shield is connected to the high voltage supply through a 22 M ohm current limiting resistor.

As discussed by Miles[1] (1986) the dark current of a PMT is decreased substantially by dehumidifying the tube in a desiccating chamber. This apparently reduces current leakage around the tube pins and socket connectors to a minimum. Before assembly, the tube and socket used in the SSP-5 are placed in a vacuum desiccator for several days before they are installed into the SSP-5. To insure continued dry operating conditions, a rechargeable silica gel canister is used as an access cover on the side of the unit. The silica gel pellets are dark blue when activated and turn pale pink when its drying ability is diminished. At that time, the silica gel canister/cover can be recharged by removing the unit (only 4 screws to take out), and baking it for 4 hours at 250° F. Additional access port covers with desiccant are available (stock #17555) for a small charge. The internal cavity of the photometer head is sealed by using silicon sealant on the non-movable parts and O-ring seals on those parts which are removable, such as the silica gel canister/access port cover.

### 2.3 FIELD APERTURE

As in the SSP-3, a single field aperture of either 0.5, 0.75, 1.0 or 2.0 mm diameter is placed at the focus of the telescope inside the photometer head. This aperture is not removable or changeable after assembly. Experience with the SSP-3 has indicated that the need for adjustable field apertures is not great for the vast majority of applications which usually consist of stellar brightness measurements. The focusing eyepiece contains an illuminated reticle with a scribed ring which precisely coincides with the boundary of the field aperture. Normally, the star is centered within the ring of the focusing eyepiece and then a measurement is started by rotating the flip mirror to the measurement position - a turn of about 180 degrees.

### 2.4 FABRY LENS

Because the photomultipler tube's cathode surface has very poor response uniformity, a Fabry lens is needed to fill a large area of the cathode uniformly without regard to where the star is positioned within the field aperture. Considering an f/10 cone of light as produced by a Celestron or Meade telescope, the Fabry lens used in the SSP-5 will image the telescope's entrance pupil slightly past the wire mesh screen in front of the photocathoe with a spot having a diameter of 2.5 mm. Telescopes with f-ratios in the range of 7 to 20 should work with the 25.4 mm focal length Fabry lens without difficulty. The Fabry lens has a plano-convex shape and a diameter of 9 mm.

### 2.5 FILTERS

In addition to the standard UBVR Johnson filters, the four color (uvby) Strömgren and Hydrogen ß wide and narrow filter sets are available. See Section 6.0 and 7.0 for Johnson and Strömgren filter specifications.

Filters are mounted in two-position sliders which are inserted through a side port. A spring plunger screw keeps a slight amount of pressure on the slider to keep it in place and to locate one position by a detent machined in the slider. The other position is found by pushing the filter slider in until it stops. Filters, or clear windows of identical thickness, have to be used in order to keep the focus in the same position as determined by the focusing eyepiece. Using no filter at all will move the focus up by about 3.5 mm. A black felt light seal is used on the filter slider port to

[1] *Miles, R. 1986, IAPPP Communication 24, 6.*

prevent external lights from being picked up by the PMT. Experience at Optec has shown that even bright office lights do not effect the output when a slider is in place and the flip mirror is in the viewing position. Removing the filter slider does cause stray light to be picked up, but not enough to trip the over voltage protection circuit to be discussed later.

The Model SSP-5A is supplied with a motorized filterslide which allows any of six or ten filters to be selected by computer control. Coupled to the SSPCARD IBM interface, complete automatic control and data acquisition of the photometer is possible. Filter selection cannot be made manually since the filter covers and geared drive to the stepper motor prevent any other selection except by proper activation of the stepper motor. Control of the stepper motor is discussed in Section 8.0.

## 2.6 HIGH VOLTAGE POWER SUPPLY

For stable PMT operation an extremely well regulated and low noise high voltage power supply is needed. The gain of the PMT used in the SSP-5 is proportional to the 7th power of the applied voltage. Thus, for small values a percent change in gain is equal to 7 times the percent change in the applied voltage. For exam ple, a 1 volt change at -850 VDC is equal to a .8% change in PMT gain, or nearly a 0.01 magnitude error. Following a 30 minute warm-up time, the voltage stability for the SSP-5 is ±0.2 V for periods of at least 15 minutes. In the bandwidth of 1 to 0.05 Hz, the voltage noise is less than 0.1 V.

The high voltage supply (see Figure 2-2) uses a 20 kHz oscillator to drive a pot core transformer with a 1 to 55 turn ratio. A voltage doubler and rectifier circuit produces a maximum voltage of about -925 VDC when fully powered. The output is regulated down to the working voltage of -850 VDC or -750 VDC (with the R4457 PMT) by feeding a fraction of the output to a high-gain difference amplifier which compares the output to a very stable voltage reference (10ppm T-C) and amplifies the difference as a correcting voltage to the pot core voltage driver. A failure of the feedback mechanism will not overdrive the PMT causing an expensive tube replacement since the maximum voltage that can be produced is approximately -925 VDC, which is within the maximum ratings of the PMT.

In addition to the base requirement of stability, the high voltage circuitry must fit within the available space of the control box and use a minimum of power. The oscillator, voltage driver and regulator are mounted on the daughter board attached to the main circuit board and occupy about 3 square inches of space. For safety and noise constraints, the pot core transformer, high current TMOS switcher and rectifier circuit are built into a small steel enclosure with approximate dimensions of 1 x 1 x 2 inches which is mounted under the main circuit board. Power consumption of the high voltage supply is about 1.5 watts.

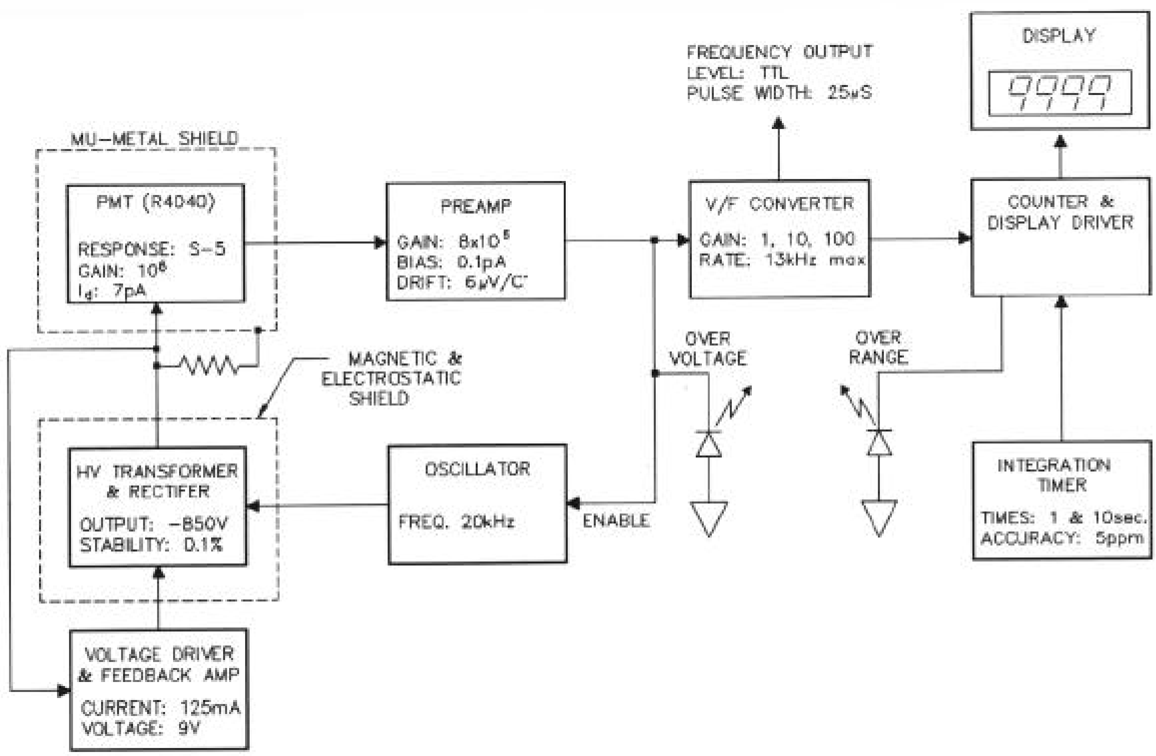


*Figure 2-2. Power supply and signal processing circuit function diagram.*

If the PMT is exposed to bright lights such as the moon or a bright planet, permanent damage could result to the anode stage of the tube. To prevent this, the output of the preamp is connected to a protection circuit which will turn off the high voltage within a few milliseconds when the preamp output nears its saturation point. Thus a 2nd magnitude or brighter star when observed with the V filter and 11 inch aperture telescope will trip the protection circuit and turn on an LED near the power switch. This circuit can only be reset by turning the SSP-5 completely off and then back on after a few seconds wait.

## 2.7 PREAMP & LOW PASS AMPLIFIER

Even with the million fold gain of the PMT, the output current is still very small, on the order of picoamperes for dim stars. This current has to be amplified sufficiently for the V/F converter to work properly without introducing gain instabilities or noise to the output signal.

The preamp used in the SSP-5 is divided into two stages. The first stage is a current-to-voltage amplifier with a gain of $7.9 \times 10^6$. The output voltage is related to the input current from the PMT by the following equation:

$$E_{out} = 7.9 \times 10^6 \cdot I_{in}$$

The amplifier used is an Analog Devices model 549K electrometer which has a bias current of less than 0.1 pA and noise currents much smaller. The second stage is a low pass amplifier of 1.5 gain which also inverts the signal since the V/F converter needs a negative voltage level. The total measured voltage drift is 6µV/°C and output noise is less than 0.1µV in the 0.05 to 350 Hz bandwidth of interest. The response time is defined as the time taken for the output signal to go from 10% to 90% of its final value. The response time of the preamp and low pass amp combination is 1 mS. This rapid response allows for the measurement of stellar angular diameters by observing lunar occultations.

## 2.8 MAIN BOARD

The main circuit board used in the SSP-5 is essentially the same one used in the SSP-3 with some small modifications. Thus the V/F converter, integration timer and counter work in the same way. See Figure 2-2.

The gain or scale of the V/F converter is set by a panel mounted toggle switch to the values of 1, 10, and 100. These values are set by internal pots and have a precision of about 0.5%. The gain linearity of the V/F converter is hard to measure since the input voltage has to be measured to a greater precision but is estimated to be better than 0.03% in the range of 10 Hz to 10 kHz at any one scale setting. The output of the V/F converter is also available as an output to interface with the Optec SSPCARD (IBM computer interface card) or other computer interface.

Since the SSP-5 is operating in a DC mode as compared to other PMT photometers which operate in a photon (pulse) counting mode, it is important to distinguish the difference between the pulses coming from the V/F converterand the photons of light. They are not the same. This becomes very important when considering dark count. With the flip mirror in the viewing position, the 'dark' count of the SSP-5 is the sum total of PMT dark current and V/F amplifier offset voltage, which is many times higher than the dark current. The offset voltage is set high in order that there is some negative voltage going into the V/F converter at all times resulting in a count. The counter will not count backward if input noise voltages change polarity; that is, go from a negative to a positive voltage.

An Epson programmable clock generator IC is used to set the gate times for the counter chip. The unique aspect of this chip is its completeness. No other elements, either passive or active, are needed for it to function. Programming the IC requires setting the levels of 6 pins to either high or low. The precision of the gate time is 0.0005% at 25° C. A front-panel toggle switch sets the integration time to either 1 or 10 seconds.

The output of the V/F converter is fed to a CMOS counter chip that directly drives a 4-digit LED display. Each time the display is updated with a new count, an LED mounted next to the display will flash briefly. If the count exceeds the capacity of the 4-digit display (exceeds a count of 9999), the same LED will turn on until the count is within the range of the display once again. A blank display indicates an over-range condition that is exceeding a count of 12999.

## 2.9 PERFORMANCE

Testing has shown that the SSP-5 is substantially more sensitive in the UBV bands than the SSP-3 which uses a silicon photodiode. Figure 2-3 compares instrument responses in B and V. The display count is expressed in counts per second vs. magnitude for the various filters using an 11 inch aperture telescope. It should be noted that these are approximate display counts, and that accurate determinations of magnitude should be made using the accepted techniques of astronomical photometry. The lower noise limits were measured by taking the standard deviation of 10 consecutive readings at either 1 or 10 seconds of integration with no light incident on the detector. With its lower sensitivity, the SSP-3 low-light-limit shown in Figure 2-3 approximates the operational limit when using the instrument on a star since the contribution of sky and signal noise (shot noise from the star and background sky) is small compared to the instrument noise. However, these terms will effect the low-light-limit of the SSP-5, thus the true low-light-limit will be slightly higher than what is indicated.

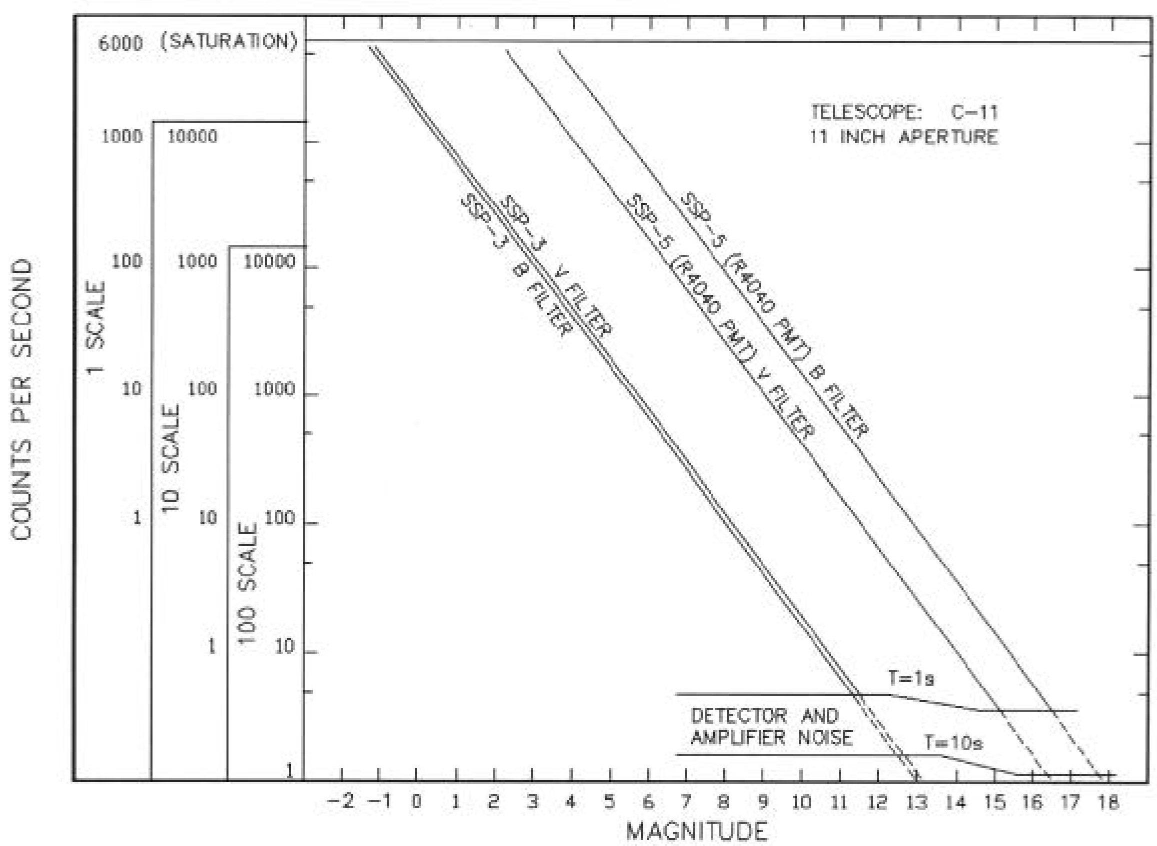


*Figure 2-3. Performance of the SSP-5 compared with the SSP-3 which use a silicon photodiode detector.*

# SECTION 3.0

## OPERATING PROCEDURES

### 3.1 CHECK-OUT LIST

Consult Figure 3-1 for identification of the various controls and features of the SSP-5.

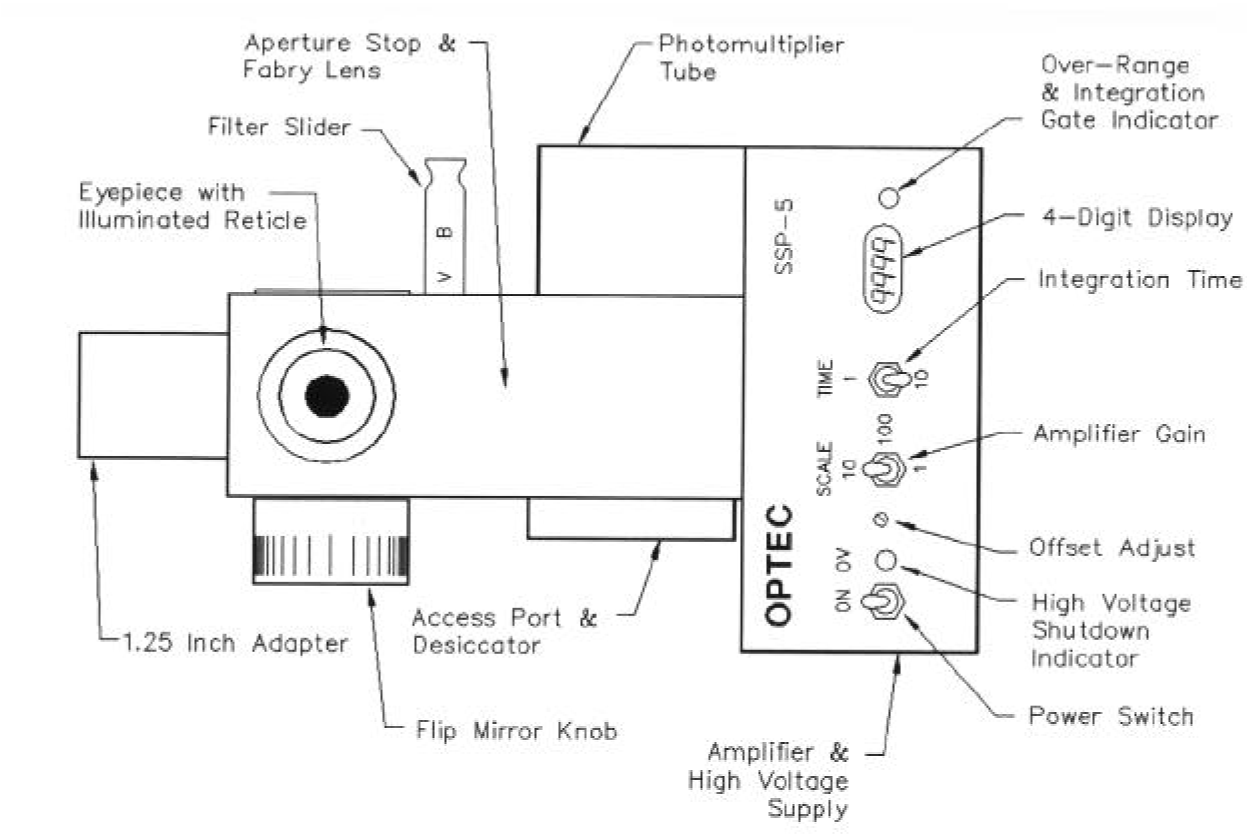


*Figure 3-1. Identification of controls and features of the SSP-5.*

**IMPORTANT:** The use of a photomultiplier tube in this photometer presents a serious shock hazard if the user is careless. If the rear cover is removed for any reason, PLEASE UNPLUG the power supply first. In addition to the possible damage that the PMT can do to the user, be attentive to the fact that serious damage can be brought on the PMT by the same carelessness. The tube should be shielded from bright lights including room lights at all times even when the power is off. NOISY TUBES AND BURNT ANODE STAGES WILL NOT BE COVERED UNDER WARRANTY TERMS. **When not used, the photometer should be stored in a dry place away from heat, vibration, lights and kids.**

Remove the filter slider and clean filters, only if necessary, with a cotton swab dipped in alcohol or lens cleaning fluid. Do NOT rub hard.

Before taking readings, plug the wall mounted power supply into a AC outlet with suitable voltage and connect the 2.5 mm mini-plug into the jack located on the control box near the bottom. Turn the photometer on and allow at least 30 minutes warm-up time at ambient observatory temperature. Make sure the a filter slider is in position and the flip mirror is down so no incident light reaches the photomultiplier tube.

After warm-up, observe that the count on the 4-Digit Display with the mirror down (no light on detector) is within the range of 3 to 7 with SCALE and TIME set at 1. If reading are not within this range, adjust the OFFSET POT with a small screw driver until the correct reading is obtained.

With the U, B and V filters, the common low wattage red lightsfound in most observatories which provide low level illumination will not affect the reading if some precautions are taken to shield the telescope optics from direct illumination. However, when using R4457 PMT, the R filtercan allow more than 100 times more light energy from red light to irradiate the detector. Even interior observatory surfaces which are illuminated by the red light and near the front of the telescope will affect the reading. Before taking important readings with the R filter, it is recommended that the user experiment with the illumination in his observatory to gauge the effect it has on the SSP-5 count.

## 3.2 USING THE PHOTOMETER

With the mirror down, site the star or sky region in the center of the reticle. After confirming that the telescope is tracking properly, carefully flip the mirror up and record the readings.

Because of the extreme low-light sensitivity of the SSP-5, care must be taken to insure that field stars just beyond the visual limit are not within the field aperture during the measurement process as this may cause errors. For example, when using an 11 inch aperture telescope, a 15th magnitude star should be beyond the visual limit. However, if it is within the field aperture, nearly a 0.1 magnitude error could result in the measurement of a 12th magnitude star. A careful check of a photographic star atlas should be made to determine if the aperture field is clear of dim stars.

To take a star or sky brightness measurement, three consecutive readings of 10 seconds integration time (TIME set for 10) each are normally taken. Always ignore the first reading since the mirror can never be flipped up exactly at the beginning of a new 10 second cycle. After seeing the first count displayed, record the next three.
After the reading sequence is completed, return the mirror to the viewing position and confirm that the star is still centered properly in the reticle. Normally, if the star is within a circle of 0.35 radius of the scribed ring center, more than 99% of the star's light has been collected by the detector. This rule of thumb does depend on seeing quality.

At this point, the user has successfully completed making a reading and is referred to other sources of information about stellar photometry. The user is advised to obtain a good working knowledge of the data reduction process. However, a number of computer programs are available to simplify the data acquisition and data reduction process. For instance, Optec offers the *RPHOT Automated Data Acquisition and Reduction Software Package for Aperture Photometry*. *RPHOT* is a complete package for performing Johnson standard photometry using either "all-sky" or differential techniques. Contact Optec for additional information on *RPHOT*. Ask for stock number 17170.

### 3.3 CALIBRATION AND ADJUSTMENTS

For precise determination of stellar magnitude, the filters used in the SSP-5 must be calibrated with standard stars. The procedure for doing this is beyond the scope of this manual and the user is referred to the IAPPP organization and standard texts on photometry. Simple determination of filter correction factors can be made by using a close pair of stars with a wide color temperature difference. This method is used by many members of the IAPPP and is recommended for novice users. Optec also sells a number of data reduction packages for various computers. Contact Optec for descriptive information.

The reticle and detector are critically aligned at the factory no adjustment should be made by the user. If the eyepiece is removed from its mount it may be necessary to realign the detector which will probably have to be done at Optec. If dust on the reticle is troublesome, remove it by blowing air (canned air for camera cleaning is suggested) through the 1¼ inch telescope adapter.

If the reticle ring needs to be adjusted in brightness, the circuit board mounted potentiometer located on the bottom right corner of the main circuit board can be adjusted. Use a small screwdriver to turn the control counterclockwise to brighten the reticle or clockwise to dim it.

If the photometer is exposed to a bright star, moon or other source of illumination which exceeds the safe threshold level of the tube's anode current, the high voltage will be turned off and the red LED near the power switch will be switched on. After appropriate measures are taken to reduce the illumination levels to the photomultiplier tube, turn the power off and then back on to reset the high voltage power and continue use.

# SECTION 4.0

## TROUBLE-SHOOTING GUIDE

The following common problems and solutions have been collected over the years from our customers and our attempts to solve their instrument problems. Before calling us, read through these and relevant sections of this manual to see if an easy solution exists for your errant photometer.

**1) Unit has been turned on and left to warm up for the proper time but no display is seen unless light is incident on the detector.**

With a small screw driver adjust the offset control pot on the front panel. With no light incident on the detector, rotate the control pot CCW for at least 20 turns to make sure a display value is seen and then rotate CW until a count of 5 is obtained with the GAIN and TIME set for 1

**2) The dark count (no light on the detector) appears to drift with time and temperature beyond what you have been accustomed to.**

This could be a moisture problem especially for observatories located in humid locations. Moisture contamination of the PMT socket pins and around the first preamp stage could cause erratic changes in the count. The photometer should always be stored in a warm dry place when not used. The desiccant contained in the side access port of the photometer head may have to be reactivated. Remove the four mounting screws holding the cover on and check to see if the small pellets still have a deep blue color. If they are a pale transparent blue or pink, bake the cover containing the pellets at a temperature of 250° F for about 4 hours. Make sure you do the work on the photometer head in a dimly lit room so as not to expose the photomultiplier tube to bright lights. Exposure to bright lights even with the power off can cause the noise counts from the tube to increase for several days. Allow the unit to stabilize for several hours at ambient temperature before measuring the drift. If the problem does not disappear or reduce to acceptable levels, it will have to be returned to Optec for repair.

**3) When you first turn the unit on, a display count is seen momentarily and then disappears. Adjustments to the offset do not work. The integration LED flashes in the usual manner and the battery is good.**

The most common chip to fail on the main circuit board is the ICL7217 counter chip from Intersil. Experience has shown the above symptom occurs when this chip fails in the usual way. Since the chip is socketed, the part can be easily replaced. Contact Optec for a replacement.

**4) The unit appears to give much higher than expected counts every once in a while.**

Any surge in the power line may cause an increase in the number of counts for the integration interval. Refrigerator compressors, dome motors, and telescope position servos could easily be the cause of this problem. Vibration and strong radio signals from nearby stations may also cause similar symptoms. Use a surge protector with RF filtering to solve the power surge problem. There is no solution for nearby radio stations.

**5) The night appears clear but the star count is diminishing with time faster than expected due to changing extinction conditions.**

A common problem, especially with Celestron and Meade telescopes, is that a nearly invisible film of condensed water will develop on the corrector plate or main mirror during the night if the dew point is high enough. Usually this fog film can only be seen when a strong light is projected down the front of the telescope and the optics carefully inspected. A hair dryer is the only cure.

**6) As the star approaches the edge of the detector the count begins to fall but it looks as if the star is still completely within the ring as seen in the eyepiece.**

The stellar light profile (energy vs. radius from the center of the star) is much larger than what is seen. On a good night a seeing disk could appear to be about 2 arc second in diameter. However, to capture over 99% of the energy a detector diameter (field aperture) of over 20 arc seconds is needed. A hazy night or a night with much greater turbulence could increase the stellar profile many more times. Thus, care must be taken to keep the star from drifting near the edge of the detector since some of the incident energy will be lost.

**7) An external counter or computer (not the SSPCARD) is connected to the SSP-5 and the count displayed on the photometer is significantly different when compared to the count recorded on the external device.**

It is possible for extra noise counts to be picked up on long signal cables if proper techniques are not followed. The SSPCARD (Optec's IBM interface card) uses a Schmidt trigger input gate on the interface card to prevent small amounts of noise on the cable from affecting the count. Make sure that your external device has similar input noise protection. A shorter or shielded cable may also have to be used.

# SECTION 5.0

## SPECIFICATIONS

### DETECTOR (R4040 option)

| | |
|---|---|
| Type | 9-stage side-on photomultiplier tube |
| Model | R4040 from Hamamatsu |
| Photocathode | Sb-Cs |
| Spectral Range | 185 - 650 nm (S-5) |
| Cathode Sensitivity | 35 mA/W at 360 nm (Johnson U band) |
| | 10 mA/W at 550 nm (Johnson V band) |
| Quantum Efficiency | QE=14% at 360 nm |
| | QE=2% at 540 nm |
| Operating Voltage | -850 V |
| Gain | ≈ $1 \times 10^6$ at -850 V |
| Rise Time | 1.4 ns (PMT only) |
| Dark Current | ≈ 8 pA at -850 V and 25° C |

### DETECTOR (R4457 option)

| | |
|---|---|
| Type | 9-stage side-on photomultiplier tube |
| Model | R4457 from Hamamatsu |
| Photocathode | Multialkali |
| Spectral Range | 185 - 830 nm |
| Cathode Sensitivity | 60 mA/W at 360 nm (Johnson U band) |
| | 70 mA/W at 550 nm (Johnson V band) |
| | 20 mA/W at 700 nm (Johnson R band) |
| Quantum Efficiency | QE=20% at 360 nm |
| | QE=16% at 540 nm |
| | QE=3.5% at 700 nm |
| Operating Voltage | -750 V |
| Gain | ≈ $2 \times 10^5$ at -750 V |
| Rise Time | 1.4 ns (PMT only) |
| Dark Current | ≈ 2 pA at -750 V and 25 C |

### PREAMP/LOW PASS AMPLIFIER

| | |
|---|---|
| Type | Current-to-Voltage for 1st Stage |
| Bias Current | .15 pA Max. |
| Offset Voltage | <.25 mV |
| 1st Stage Gain | $7.9 \times 10^6$ |
| 2nd Stage Gain | 1.5 |
| Input Voltage Noise | 4 µV(p-p) (.1 to 10Hz) |
| Input Current Noise | .003 pA (.1 to 10Hz) |
| Maximum Output Voltage | -4.0 V |
| Operating Frequency Range | 0.05 to 350 Hz |
| Response Time | 1 msec |

## A/D CONVERTER

| | |
|---|---|
| Type | Voltage-to-Frequency |
| Full Scale Frequency | 10 KHz (13 KHz maximum) |
| Full Scale Input Voltages | -66 mV (100 SCALE) |
| | -660 mV (10 SCALE) |
| | -6.6 V (1 SCALE) |
| Linearity | <0.3% |
| Offset | <.5 mV (adjustable to 0) |

## COUNTER/DISPLAY

| | |
|---|---|
| Integration Times (Gate) | 1 and 10 seconds |
| Timer | Quartz crystal programmable timer |
| Timer Accuracy | +/-5ppm at 25° C |
| Display | 4-digit (9999) |
| Character Height/Color | .11 inch - Red |

## POWER SUPPLY

| | |
|---|---|
| Type | AC to DC wall mount |
| Input Voltage | 110-120 VAC U.S. Model |
| | 110-240 VAC International Model |
| Output Current | 200 mA rated maximum |

## EYEPIECE

| | |
|---|---|
| Focal Length | 25 mm |
| Optical Design | Ramsden |
| Reticle Illumination | Green LED |
| Field of View | 0.4 degrees at 2000 mm focal length |

## MECHANICAL

| | |
|---|---|
| Body Material | Aluminum 6061-T6 alloy |
| Finish | Bright Dip Black Anodized |
| Overall Length | 9 inches (tip to tip) |
| Weight | 3 lbs. 6 oz. |
| Telescope Coupler | 1.25 inch (standard) |

# SECTION 6.0

## JOHNSON FILTERS

The UBV filter system established by Johnson is generally followed today for photoelectric systems using a 1P21 or equivalent photomultiplier tube. This system defines wide color bands in the spectrum interval from 300 to 720 nm. Using the red-sensitive R4457 PMT, SSP-5 owners can now perform photometry into the Johnson R band as well (out to 960 nm). The S-5 response of the R4040 is nearly identical to the S-4 response of the original 1P21 photomultiplier tube, so the recommended filters for the R4040 most closely match Johnson's original filter specifications. However, by specifying some of the SSP-3 filters for use with the R4457 PMT, the response of this filter-detector combination can more closely match Johnson's standard UBVRI response functions.

Filter-detector response is defined as the normalized product of filter transmission times detector response for each wavelength interval. Table 6-2 lists the filter-detector responses (also referred to as the response function) of the Johnson UBVRI system. The filter-detector responses shown in Tables 6-3 (R4040 PMT) and 6-4 (R4457 PMT) are provided for comparison. Table 6-5 lists the filter transmission values for both SSP-5 (UBV and SSP-3 (UBVR filters. These values were used to calculate the filter-detector responses shown in Tables 6-2 and 6-3.

The SSP-5 UBV filters are all made from combinations of Schott colored glass. The glass types and thickness for each filter has been computer optimized for the best fit with the Johnson standards. Table 6-1 list the physical specifications for the SSP-5 UBV and SSP-3 UBVR filters.

| PHYSICAL SPECIFICATIONS | |
|---|---|
| Diameter | 12.7±0.15 mm |
| Thickness | 7.0±0.3 mm |
| Surface Quality | 80 - 50 |
| Flatness | 2 Waves within center 6 mm |
| Wedge | Not to exceed 5 ARC minutes |

*Table 6-1. Physical characteristics of the Optec filters.*

| Wavelength nm | Johnson U | Johnson B | Johnson V | Johnson R | Johnson I |
|---|---|---|---|---|---|
| 300 | 0.00 | ---- | ---- | ---- | ---- |
| 310 | 0.10 | ---- | ---- | ---- | ---- |
| 320 | 0.61 | ---- | ---- | ---- | ---- |
| 330 | 0.84 | ---- | ---- | ---- | ---- |
| 340 | 0.93 | ---- | ---- | ---- | ---- |
| 350 | 0.97 | ---- | ---- | ---- | ---- |
| 360 | 1.00 | 0.00 | ---- | ---- | ---- |
| 370 | 0.97 | ---- | ---- | ---- | ---- |
| 380 | 0.73 | 0.11 | ---- | ---- | ---- |
| 390 | 0.36 | ---- | ---- | ---- | ---- |
| 400 | 0.05 | 0.92 | ---- | ---- | ---- |
| 410 | 0.01 | ---- | ---- | ---- | ---- |
| 420 | 0.00 | 1.00 | ---- | ---- | ---- |
| 440 | ---- | 0.94 | ---- | ---- | ---- |
| 460 | ---- | 0.79 | 0.00 | ---- | ---- |
| 480 | ---- | 0.58 | 0.02 | ---- | ---- |
| 500 | ---- | 0.36 | 0.38 | ---- | ---- |
| 520 | ---- | 0.15 | 0.91 | 0.00 | ---- |
| 540 | ---- | 0.04 | 0.98 | 0.06 | ---- |
| 560 | ---- | 0.00 | 0.72 | 0.28 | ---- |
| 580 | ---- | ---- | 0.62 | 0.50 | ---- |
| 600 | ---- | ---- | 0.40 | 0.69 | ---- |
| 620 | ---- | ---- | 0.20 | 0.79 | ---- |
| 640 | ---- | ---- | 0.08 | 0.88 | ---- |
| 660 | ---- | ---- | 0.02 | 0.94 | ---- |
| 680 | ---- | ---- | 0.01 | 0.98 | 0.00 |
| 700 | ---- | ---- | 0.01 | 1.00 | 0.01 |
| 720 | ---- | ---- | 0.01 | 0.94 | 0.17 |
| 740 | ---- | ---- | 0.00 | 0.85 | 0.36 |
| 760 | ---- | ---- | ---- | 0.73 | 0.56 |
| 780 | ---- | ---- | ---- | 0.57 | 0.76 |
| 800 | ---- | ---- | ---- | 0.42 | 0.96 |
| 820 | ---- | ---- | ---- | 0.31 | 0.98 |
| 840 | ---- | ---- | ---- | 0.17 | 0.99 |
| 860 | ---- | ---- | ---- | 0.11 | 1.00 |
| 880 | ---- | ---- | ---- | 0.06 | 0.98 |
| 900 | ---- | ---- | ---- | 0.04 | 0.93 |
| 920 | ---- | ---- | ---- | 0.02 | 0.84 |
| 940 | ---- | ---- | ---- | 0.01 | 0.71 |
| 960 | ---- | ---- | ---- | 0.00 | 0.58 |
| 980 | ---- | ---- | ---- | ---- | 0.47 |
| 1000 | ---- | ---- | ---- | ---- | 0.36 |
| 1020 | ---- | ---- | ---- | ---- | 0.28 |
| 1040 | ---- | ---- | ---- | ---- | 0.20 |
| 1060 | ---- | ---- | ---- | ---- | 0.15 |
| 1080 | ---- | ---- | ---- | ---- | 0.10 |
| 1100 | ---- | ---- | ---- | ---- | 0.08 |
| 1120 | ---- | ---- | ---- | ---- | 0.05 |
| 1140 | ---- | ---- | ---- | ---- | 0.03 |

*Table 6-2. Standard UBVRI Response Functions According to Johnson.*

| wavelength nm | SSP-5 U | SSP-5 B | SSP-5 V | R4040 PMT |
|---|---|---|---|---|
| 300 | 0.00 | ---- | ---- | 0.98 |
| 310 | 0.33 | ---- | ---- | 0.98 |
| 320 | 0.58 | ---- | ---- | 1.00 |
| 330 | 0.79 | ---- | ---- | 1.00 |
| 340 | 0.94 | ---- | ---- | 1.00 |
| 350 | 1.00 | ---- | ---- | 0.98 |
| 360 | 0.98 | 0.00 | ---- | 0.96 |
| 370 | 0.93 | 0.04 | ---- | 0.94 |
| 380 | 0.73 | 0.21 | ---- | 0.91 |
| 390 | 0.36 | 0.47 | ---- | 0.88 |
| 400 | 0.07 | 0.73 | ---- | 0.86 |
| 410 | 0.03 | 0.89 | ---- | 0.84 |
| 420 | 0.00 | 0.99 | ---- | 0.80 |
| 440 | ---- | 0.99 | ---- | 0.72 |
| 460 | ---- | 0.82 | 0.00 | 0.63 |
| 480 | ---- | 0.48 | 0.00 | 0.55 |
| 500 | ---- | 0.17 | 0.04 | 0.46 |
| 520 | ---- | 0.03 | 0.99 | 0.39 |
| 540 | ---- | 0.01 | 0.98 | 0.32 |
| 560 | ---- | 0.00 | 0.78 | 0.25 |
| 580 | ---- | 0.00 | 0.53 | 0.17 |
| 600 | ---- | ---- | 0.38 | 0.12 |
| 620 | ---- | ---- | 0.22 | 0.07 |
| 640 | ---- | ---- | 0.12 | 0.04 |
| 660 | ---- | ---- | 0.07 | 0.02 |
| 680 | ---- | ---- | 0.03 | 0.01 |
| 700 | ---- | ---- | 0.01 | 0.002 |
| 720 | ---- | ---- | 0.00 | 0.0005 |
| 740 | ---- | ---- | 0.00 | 0.0000 |
| 760 | ---- | ---- | ---- | 0.0000 |
| 780 | ---- | ---- | ---- | 0.0000 |
| 800 | ---- | ---- | ---- | 0.0000 |
| 820 | ---- | ---- | ---- | 0.0000 |
| 840 | ---- | ---- | ---- | 0.0000 |
| 860 | ---- | ---- | ---- | 0.0000 |
| 880 | ---- | ---- | ---- | 0.0000 |
| 900 | ---- | ---- | ---- | 0.0000 |
| 920 | ---- | ---- | ---- | 0.0000 |
| 940 | ---- | ---- | ---- | 0.0000 |
| 960 | ---- | ---- | ---- | 0.0000 |
| 980 | ---- | ---- | ---- | 0.0000 |
| 1000 | ---- | ---- | ---- | 0.0000 |
| 1020 | ---- | ---- | ---- | 0.0000 |
| 1040 | ---- | ---- | ---- | 0.0000 |
| 1060 | ---- | ---- | ---- | 0.0000 |
| 1080 | ---- | ---- | ---- | 0.0000 |
| 1100 | ---- | ---- | ---- | 0.0000 |
| 1120 | ---- | ---- | ---- | 0.0000 |
| 1140 | ---- | ---- | ---- | 0.0000 |

*Table 6-3. R4040 Normalized Response with Response Functions of Optec UBV Filters.*

| Wavelength nm | SSP-3 U | SSP-3 B | SSP-3 V | SSP-3 R | R4457 PMT |
|---|---|---|---|---|---|
| 300 | 0.00 | ---- | ---- | ---- | 0.77 |
| 310 | 0.00 | ---- | ---- | ---- | 0.76 |
| 320 | 0.00 | ---- | ---- | ---- | 0.79 |
| 330 | 0.15 | ---- | ---- | ---- | 0.81 |
| 340 | 0.40 | ---- | ---- | ---- | 0.84 |
| 350 | 0.61 | ---- | ---- | ---- | 0.83 |
| 360 | 0.92 | 0.05 | ---- | ---- | 0.86 |
| 370 | 1.00 | 0.17 | ---- | ---- | 0.86 |
| 380 | 0.82 | 0.36 | ---- | ---- | 0.86 |
| 390 | 0.37 | 0.56 | ---- | ---- | 0.86 |
| 400 | 0.00 | 0.71 | ---- | ---- | 0.86 |
| 410 | 0.00 | 0.82 | ---- | ---- | 0.87 |
| 420 | 0.00 | 0.94 | ---- | ---- | 0.89 |
| 440 | ---- | 1.00 | ---- | ---- | 0.91 |
| 460 | ---- | 0.76 | 0.00 | ---- | 0.93 |
| 480 | ---- | 0.44 | 0.00 | ---- | 0.95 |
| 500 | ---- | 0.26 | 0.59 | ---- | 0.97 |
| 520 | ---- | 0.11 | 0.96 | 0.00 | 1.00 |
| 540 | ---- | 0.04 | 1.00 | 0.07 | 0.99 |
| 560 | ---- | 0.01 | 0.85 | 0.09 | 0.96 |
| 580 | ---- | 0.00 | 0.57 | 0.36 | 0.91 |
| 600 | ---- | ---- | 0.29 | 0.71 | 0.86 |
| 620 | ---- | ---- | 0.11 | 0.92 | 0.79 |
| 640 | ---- | ---- | 0.03 | 1.00 | 0.71 |
| 660 | ---- | ---- | 0.01 | 0.96 | 0.64 |
| 680 | ---- | ---- | 0.00 | 0.86 | 0.57 |
| 700 | ---- | ---- | 0.00 | 0.40 | 0.29 |
| 720 | ---- | ---- | ---- | 0.27 | 0.21 |
| 740 | ---- | ---- | ---- | 0.17 | 0.16 |
| 760 | ---- | ---- | ---- | 0.09 | 0.10 |
| 780 | ---- | ---- | ---- | 0.04 | 0.06 |
| 800 | ---- | ---- | ---- | 0.00 | 0.007 |
| 820 | ---- | ---- | ---- | 0.00 | 0.006 |
| 840 | ---- | ---- | ---- | 0.00 | 0.004 |
| 860 | ---- | ---- | ---- | 0.00 | 0.003 |
| 880 | ---- | ---- | ---- | 0.00 | 0.0014 |
| 900 | ---- | ---- | ---- | 0.00 | 0.0000 |
| 920 | ---- | ---- | ---- | 0.00 | 0.0000 |
| 940 | ---- | ---- | ---- | 0.00 | 0.0000 |
| 960 | ---- | ---- | ---- | 0.00 | 0.0000 |
| 980 | ---- | ---- | ---- | 0.00 | 0.0000 |
| 1000 | ---- | ---- | ---- | 0.00 | 0.0000 |
| 1020 | ---- | ---- | ---- | ---- | 0.0000 |
| 1040 | ---- | ---- | ---- | ---- | 0.0000 |
| 1060 | ---- | ---- | ---- | ---- | 0.0000 |
| 1080 | ---- | ---- | ---- | ---- | 0.0000 |
| 1100 | ---- | ---- | ---- | ---- | 0.0000 |
| 1120 | ---- | ---- | ---- | ---- | 0.0000 |
| 1140 | ---- | ---- | ---- | ---- | 0.0000 |

*Table 6-4. R4457 Normalized Response with Response Functions of Optec UBVR Filters.*

| Wavelength nm | SSP-5 U | SSP-5 B | SSP-5 V | SSP-3 U | SSP-3 B | SSP-3 V | SSP-3 R |
|---|---|---|---|---|---|---|---|
| 300 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 310 | 0.23 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 320 | 0.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 330 | 0.53 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 |
| 340 | 0.64 | 0.00 | 0.00 | 0.28 | 0.00 | 0.00 | 0.00 |
| 350 | 0.70 | 0.00 | 0.00 | 0.37 | 0.00 | 0.00 | 0.00 |
| 360 | 0.71 | 0.00 | 0.00 | 0.48 | 0.04 | 0.00 | 0.00 |
| 370 | 0.68 | 0.02 | 0.00 | 0.49 | 0.14 | 0.00 | 0.00 |
| 380 | 0.54 | 0.10 | 0.00 | 0.39 | 0.28 | 0.00 | 0.00 |
| 390 | 0.28 | 0.24 | 0.00 | 0.17 | 0.41 | 0.00 | 0.00 |
| 400 | 0.04 | 0.39 | 0.00 | 0.00 | 0.50 | 0.00 | 0.00 |
| 410 | 0.00 | 0.48 | 0.00 | 0.00 | 0.55 | 0.00 | 0.00 |
| 420 | 0.00 | 0.56 | 0.00 | 0.00 | 0.60 | 0.00 | 0.00 |
| 440 | 0.00 | 0.63 | 0.00 | 0.00 | 0.57 | 0.00 | 0.00 |
| 460 | 0.00 | 0.60 | 0.00 | 0.00 | 0.39 | 0.00 | 0.00 |
| 480 | 0.00 | 0.40 | 0.00 | 0.00 | 0.21 | 0.00 | 0.00 |
| 500 | 0.00 | 0.17 | 0.03 | 0.00 | 0.11 | 0.49 | 0.00 |
| 520 | 0.00 | 0.04 | 0.73 | 0.00 | 0.05 | 0.74 | 0.00 |
| 540 | 0.00 | 0.01 | 0.88 | 0.00 | 0.02 | 0.72 | 0.00 |
| 560 | 0.00 | 0.00 | 0.92 | 0.00 | 0.01 | 0.60 | 0.04 |
| 580 | 0.00 | 0.00 | 0.92 | 0.00 | 0.01 | 0.40 | 0.16 |
| 600 | 0.00 | 0.00 | 0.92 | 0.00 | 0.00 | 0.21 | 0.33 |
| 620 | 0.00 | 0.00 | 0.92 | 0.00 | 0.00 | 0.08 | 0.44 |
| 640 | 0.00 | 0.00 | 0.92 | 0.00 | 0.00 | 0.02 | 0.50 |
| 660 | 0.00 | 0.00 | 0.92 | 0.00 | 0.00 | 0.00 | 0.53 |
| 680 | 0.00 | 0.00 | 0.92 | 0.00 | 0.00 | 0.00 | 0.51 |
| 700 | 0.01 | 0.00 | 0.92 | 0.00 | 0.00 | 0.00 | 0.46 |
| 720 | 0.15 | 0.00 | 0.92 | 0.00 | 0.00 | 0.00 | 0.41 |
| 740 | 0.30 | 0.00 | 0.92 | 0.00 | 0.00 | 0.00 | 0.34 |
| 760 | ---- | ---- | ---- | 0.00 | 0.00 | 0.00 | 0.27 |
| 780 | ---- | ---- | ---- | 0.00 | 0.00 | 0.00 | 0.21 |
| 800 | ---- | ---- | ---- | 0.00 | 0.00 | 0.00 | 0.16 |
| 820 | ---- | ---- | ---- | 0.00 | 0.00 | 0.00 | 0.11 |
| 840 | ---- | ---- | ---- | 0.00 | 0.00 | 0.00 | 0.08 |
| 860 | ---- | ---- | ---- | 0.00 | 0.00 | 0.00 | 0.06 |
| 880 | ---- | ---- | ---- | 0.00 | 0.00 | 0.00 | 0.04 |
| 900 | ---- | ---- | ---- | 0.00 | 0.00 | 0.00 | 0.03 |
| 920 | ---- | ---- | ---- | 0.00 | 0.00 | 0.00 | 0.02 |
| 940 | ---- | ---- | ---- | 0.00 | 0.00 | 0.00 | 0.01 |
| 960 | ---- | ---- | ---- | 0.00 | 0.00 | 0.00 | 0.01 |
| 980 | ---- | ---- | ---- | 0.00 | 0.00 | 0.00 | 0.01 |
| 1000 | ---- | ---- | ---- | 0.00 | 0.00 | 0.00 | 0.01 |
| 1020 | ---- | ---- | ---- | 0.00 | 0.00 | 0.00 | 0.00 |
| 1040 | ---- | ---- | ---- | 0.00 | 0.00 | 0.00 | 0.00 |
| 1060 | ---- | ---- | ---- | 0.00 | 0.00 | 0.00 | 0.00 |
| 1080 | ---- | ---- | ---- | 0.00 | 0.00 | 0.00 | 0.00 |
| 1100 | ---- | ---- | ---- | 0.00 | 0.00 | 0.00 | 0.00 |
| 1120 | ---- | ---- | ---- | 0.00 | 0.00 | 0.00 | 0.00 |
| 1140 | ---- | ---- | ---- | 0.00 | 0.00 | 0.00 | 0.00 |

*Table 6-5. Transmission of the Optec SSP-5 UBV and SSP-3 UBVR filters.*

# SECTION 7.0

## STRÖMGREN FILTERS

The Strömgren uvby is the most widely used intermediate-band photometric system. The letters u, v, b, y refer to the colors ultraviolet, violet, blue and yellow respectively. Because these filters have a narrow passband, the system is totally filter defined, and variations in detector spectral response, telescope transmission, and the second order terms used for the extinction corrections and the transformation equations can be safely ignored. In addition, the use of these filters provide more useful astrophysical information than the Johnson UBV system.

The Strömgren filters offered by Optec are manufactured by Spectro-Film of Woburn, Massachusetts to our specifications. Spectro-Film has been making the Strömgren filters for professional observatories worldwide for the last 10 years and is considered the primary source for these filters. As a result, these filters used with the SSP-5 should match the results from most photometry programs throughout the world. Table 7-1 lists the filter specifications.

The vby filters are multiple cavity interference type using dielectric quarter wave stacks with spacers of metal film. They have excellent transmission characteristic and long life when properly stored. However, all interference filters can be damaged when exposed to high humidity for long periods of time. When not used, these filters should be stored in a glass jar with a small amount of desiccant added to keep the air dry. In such an environment, these filters will last virtually forever.

| **OPTICAL SPECIFICATIONS** | | | |
|---|---|---|---|
| **Filter** | **Center Wavelength** | **Bandpass** | **Type** |
| u | 342 nm | 25 nm | 6mm UG11 + 1mm WG345 |
| v | 410±2 nm | 16±1.6 nm | interference |
| b | 470±2 nm | 19±1.9 nm | interference |
| y | 550±2 nm | 24±2.4 nm | interference |

*Table 7-1. Optical specifications of Strömgren filters.*

The u filter is made from 2 pieces of Schott colored glass. The first glass of UG11 defines the red side of the pass band and the WG345 defines the blue side. The red leak of the UG11 glass beyond 700 nm should not be a source of error with the R4040 PMT since the spectral response is extremely small at that wavelength and redder. The surface of the UG11 glass has poor resistance to weathering (humidity) and must be protected in a manner similar to the vby filters. Unlike the interference filters which cannot be restored, the weathered surface of this filter can be repolished. If a small amount of weathering is observed, a white haze on the surface, a Q-tip with jewelers rouge and water can normally repolish the surface. Use light pressure and blow dry the filter immediately afterwards.

| **PHYSICAL SPECIFICATIONS** | |
|---:|---|
| Diameter | 12.7±0.15 mm |
| Thickness | 7.0±0.3 mm |
| Surface Quality | 80-50 |
| Wedge | Not to exceed 5 ARC minutes |

*Table 7-2. Physical specifications of Strömgren filters.*

# SECTION 8.0

## SSP-5A OPTION

### 8.1 PHYSICAL CHARACTERISTICS

The SSP-5A photometer is nearly identical in appearance andoperation to the SSP-5 except for the addition of a motorized 6- or 10-position slider and 9-pin connector. The stepper motor is located under the control circuit board and connects to the filter slide rack by a pinion and shaft going through the photometer main body. See Figure 2-1.

The small 4-phase stepper motor is run on 12V DC power which is supplied through the 9-pin connector - it does not use power from the battery or charger. The important physical and electrical specifications for the motor used in the SSP-5A are listed in Table 8-1.

| | |
|---|---|
| Number of Phases | 4 |
| Step Angle (full step) | 7.5 degrees |
| Steps per Rev. | 48 |
| Holding Torque | 2.8 oz.-in. |
| Operating Temp. Range | -15 to +50°C |
| DC Operating Voltage | 12 volts |
| Resistance per Winding | 70 Ω |

*Table 8-1. Specifications for Model PF35-48C Stepper Motor from Nippon.*

### 8.2 PROCEDURE FOR DETERMINING FILTER POSITION

Each filter position is separated by 33 full steps of the stepper motor. In order to determine position, 165 or more full steps in either direction are delivered by the stepper motor to home the slider against one side of its mounting.After this homing procedure, the computer or controller determines position by keeping track of the number of 33 step intervals from the home position. Stalling the motor against its mounting will not harm the motor or mounting covers in any way.

The pulse rate to the stepper can be varied under computercontrol and the optimum rate (fastest position change without losing steps due to slider inertia), with or without acceleration, must be determined experimentally. For a first approximation, try a steady pulse rate of 100 steps per second and observe whether the positions are kept accurately when changed repeatedly.
After the proper position is obtained, it is important to wait approximately 1/2 second before starting an integration. The microphonics from moving the slider and the electrical noise

generated by the high current pulse sent to the motor affect the detector/electrometer circuit by causing a momentary increase in the number of output pulses from the photometer. A short period of time is needed for the sensitive electronics to settle.

## 8.3 CONNECTING AND OPERATING THE STEPPER MOTOR

If the SSPCARD and associated cable are purchased with the SSP-5A, you can skip this section.

A 9-pin AMP connector is supplied with the SSP-5A for those wishing to design and build their own stepper controller or computer interface. Table 8-2 lists the pin numbers of the 9-pin connector which are connected to the motor and the proper step sequence that these lines must follow.

| FUNCTION | | T1 | T2 | T3 | T4 | COMMON |
|---|---|---|---|---|---|---|
| MOTOR WIRE COLOR | | black | orange | brown | yellow | connect red & red |
| PIN NO. FOR SSP-3A CONN. | | 7 | 4 | 3 | 2 | 1 |
| STEP | 1 | On | On | Off | Off | |
| SEQUENCE | 2 | Off | On | On | Off | |
| C.W. ROT. | 3 | Off | Off | On | On | |
| | 4 | On | Off | Off | On | |
| | 1 | On | On | Off | Off | |

*Table 8-2. Function and Color Code of Motor Wires.*

Table 8-3 on the next page lists the pin numbers of the 9-pin AMP connector and their associated function. Either a shielded or unshielded 9-wire cable can be used. Since the amount of current used by the stepper motor is just a few hundred milliamps, small gauge wire can be used in the cable. Cables of lengths up to 100 feet have worked successfully.

**IMPORTANT**: Power is supplied to the SSP-5A by the SSPCARD through the 9-conductor cable (stock no. 17152). Remove the internal 9-volt battery and do not use the battery charger when using the SSP-5A in this mode. This is also applicable for custom installations when using pins 6 and 8 (Table 8.3) to supply power to the SSP-5A.

| PIN# | COLOR | FUNCTION |
|---|---|---|
| 1 | Connect Red & Red | +12 To Stepper |

| | | |
|---|---|---|
| 2 | Yellow | T4 To Stepper |
| 3 | Brown | T3 To Stepper |
| 4 | Orange | T2 To Stepper |
| 5 | Green | Signal Common |
| 6 | Orange | +12 Volts DC |
| 7 | Black | T1 To Stepper |
| 8 | Brown | Power Ground |
| 9 | Gray | Pulse Output |

*Table 8-3. Pin Number and Function for the Motor Control Cable Connector.*

## 8.4 USING THE SIGNETICS SAA1027 STEPPER DRIVER

The Signetics SAA1027 stepper motor drive IC is available from Optec for a small charge. This 16-pin IC allows easy control of the stepper motor and requires only a few external resistors, a 12 V DC power source and a two control lines from the computer or controller. A typical circuit is shown in Figure 8-1.

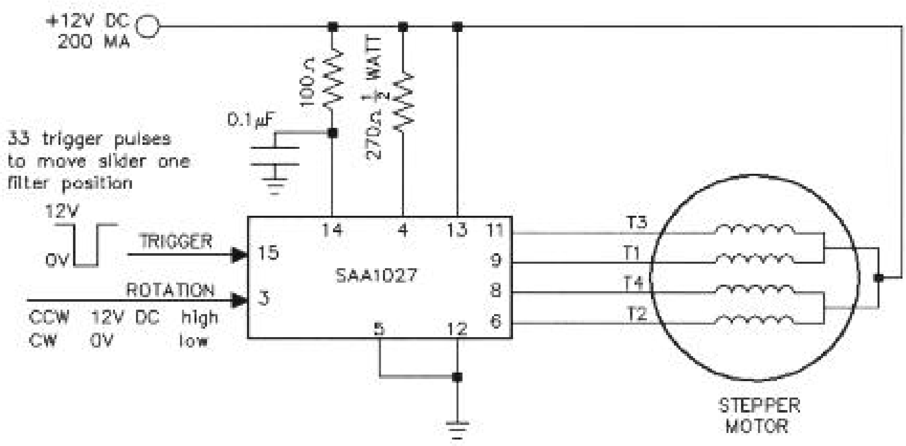


*Figure 8-1. Typical Stepper Control Circuit Using the SAA1027.*

# APPENDIX A

# ANALOG OUTPUT OPTION

The analog output connector modification (stock no. 17022) adds a direct connection to the electrometer output. This modification includes a chasis-mounted 4-pin jack near the frequency output RCA jack. The 4-pin plug is included but may also be obtained from Radio Shack (part no. 274-001) and should be wired by the user to the chart recorder. The pin outs are given in Table A-1 below. The electrometer output is a 0 to -4.6 V DC signal with 1 msec rise time for the SSP-5. An inverting buffer amp is recommended since the connector is directly wired to the electrometer.

| PIN NUMBER | FUNCTION |
|---|---|
| 1 | Signal Ground |
| 2 | Signal: 0 to -4.6 Volts DC |
| 3 | Not Connected |
| 4 | Not Connected |
| CASE | Chasis Ground: Shield |

*Table A-1. Pin Number and Function of Analog Output Connector.*

# APPENDIX B

## DETERMINATION OF FIELD APERTURE ANGULAR SIZE

The SSP-5 and SSP-3 photometers offer a fixed aperture which must be selected at initial purchase. In most instances the standard field aperture of 1mm diameter is best suited. However, 0.5mm, 0.75mm and 2mm field apertures are also offered optionally.

To determine the angular size of each field aperture with a particular telescope, refer to Table B-1 below. Remember that even though the seeing disk of a star may appear as small as 2arc seconds, the stellar profile may be many times larger. A good rule of thumb is to ensure the star's image remains within the central 70% of the field aperture to ensure that 99% of the stellar energy falls upon the detector. The reader is referred to section 9.4 of *Astronomical Photometry* by Henden & Kaitchuck (Optec stock no. 17330) for a full discussion of diaphragm selection and stellar profiles.

Another important consideration in selecting an aperture size is the accuracy of the telescope mounting system. Periodic errors (as well as erratic errors) can cause the star to drift within the field. Your aperture must be large enough to ensure that the star remains within the center of the detector field of view for the duration of the photometer integration period, typically 10 to 60 seconds.

| **TELESCOPE FOCAL** | **DETECTOR APERTURE SIZE** | | | |
|---|---|---|---|---|
| **(Common Configurations)** | **0.5mm** | **0.75mm** | **1.0mm** | **2.0mm** |
| 1280 mm (8 inch f/6.3) | 81" | 121" | 161" | 322" |
| 1600 mm (10 inch f/6.3) | 64" | 97" | 129" | 258" |
| 2000 mm (17½ inch f/4.5) | 52" | 77" | 103" | 206" |
| 2032 mm (8 inch f/10) | 51" | 76" | 101" | 203" |
| 2540 mm (10 inch f/10) | 41" | 61" | 81" | 162" |
| 2794 mm (11 inch f/10) | 37" | 55" | 74" | 148" |
| 3912 mm (14 inch f/11) | 26" | 40" | 53" | 105" |

*Table B-1. Angular Size of Common Telescope/Aperture Combinations in Arc Seconds.*

# APPENDIX C

## SAMPLE DATA ENTRY FORM

The sample report form printed on the back cover is useful for recording data when using the differential photometry technique. Basically, this method is to compare the brightness of the variable star to that of a nearby comparison star which is known to have no variability. No attempt is made here to educate the user in all aspects of proper observing procedure and the associated data reduction. A number of texts about astronomical photometry are available which describe the proper methodology.

Figure C-1 shows an observing report for the night of September 18-19, 1984, of Nova Vulpecula and the comparison star HD182618. Observations were made with the V filter using an 11 inch aperture telescope.

VAR.. NOVA    DOUBLE DATE Sept. 18-19, 1984

COMP. HD 182618    PAGE ______ OF ______

OBSERVER J.P.    NOTES ______

TELESCOPE C-11

CONDITIONS GOOD

| UT | STAR | FILTER | SCALE | TIME | COUNT | SKY | COMMENTS |
|---|---|---|---|---|---|---|---|
| 1::21 | COMP | V | 10 | 10 | 894 | 402 | |
| | | | | | 891 | 402 | |
| | | | | | 594 | 401 | |
| 1:24 | NOVA | V | 10 | 10 | 509 | | |
| | | | | | 507 | | |
| | | | | | 510 | | |
| 1.:29 | COMP | V | 10 | 10 | 881 | | |
| | | | | | 880 | | |
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*Figure C-1. Sample Data Entry Using the Report Form.*

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