ThetaScan® TL Series Specifications

Maximum working distance*:		
	TL40 optical head	100 mm
	TL160 optical head	5 meters
Maximum measuring range*:		
	TL40 optical head	± 1degree (± 3600 arc-seconds)
	TL160 optical head	± 0.16 degree (± 600 arc-seconds)
Bandwidth, analog:		standard 10 Hz, maximum 1000 Hz
Bandwidth, LCD display:		dynamic
Maximum resolution:		0.1 arc-second (0.485 μradian)
Linearity:		99.0% over entire range
Cross-coupling over entire measuring range:		0.5% over entire range
Power requirement:		100V, 120V, or 220V

*Maximum working distance and maximum angular measuring range cannot be simultaneously achieved. Specifications subject to change without notice.

WARRANTY

Micro-Radian Instruments warrants the ThetaScan® to be free from defects in materials and workmanship for a period of one (1) year from the date of shipment. If the product proves defective during this warranty period, Micro-Radian Instruments, at its option, will either repair the defective product without charge for parts and labor, provide a replacement in exchange for the defective product, or issue credit for a new product.

In order to obtain service under this warranty, Customer must provide Micro-Radian Instruments with notice of the defect before the expiration of the warranty period and make suitable arrangements for the performance of service.

This warranty shall not apply to any defect, failure, or damage caused by improper use or improper or inadequate maintenance and care. In no case shall Micro-Radian Instruments' liability on a claim exceed the selling price of the product.

Title and ownership of items shipped FOB origin passes to Customer when the carrier picks up the shipment at our Bellingham, Washington facility. If there is any damage in transit, Customer should notify the carrier immediately.

Title and ownership of items shipped FOB destination passes to Customer upon delivery to the Customer's receiving door. Such shipments are fully insured by Micro-Radian Instruments. If there is any damage in transit, Customer should notify Micro-Radian Instruments immediately.

Claims for incorrect or defective products must be filed within 30 days of delivery. If no such claim is filed, Customer will consider all items acceptable under the terms in which they were ordered.

Customer must pay all transportation charges associated with return of items. Items returned, whether in or out of warranty, with any transportation, collect, or COD charges due will not be accepted.

Conditions of this warranty follow.

Conditions of Warranty

The E2 electronic unit and optical head listed below are warranted to be free from defective parts and manufacture for a period of one (1) year provided that:

1/. The E2 unit is not dropped, abused, or physically damaged.

2/. The optical head is not dropped, abused, or damaged. Scratched or broken objective lenses are not covered by this warranty.

3/. The optical head is not disassembled.

4/. The optical head cable is not pulled, abused, or damaged.

5/. The E2 unit is always connected to power of the proper voltage and frequency.

6/. The E2 unit is not probed with an ohmmeter.

7/. The optical head and optical head cable are not probed with an ohmmeter.

8/. The E2 unit listed below is connected only to the corresponding optical head.

9/. The E2 unit and optical head do not become wet or frozen.

10/. The E2 unit and optical head combination listed below are returned together with all transportation charges paid by the purchaser.

11/. Examination of the instrument demonstrates that the defect is covered by this warranty.

E2 electronic unit serial number:

Optical head type and serial number

Warranty effective date:

This warranty is non-transferable.

micro-radian INSTRUMENTS

Micro-Radian Instruments

1.0 Introduction

1.1 The ThetaScan® autocollimator is a dual-axis angle measurement system that uses its own collimated light to accurately measure small angular displacements of an external reflector. It will simultaneously measure angular changes about two orthogonal axes. The axes of measurement are commonly referred to as pitch and yaw or azimuth and elevation.

1.2 Although a reflector is essential to the operation, it is not supplied by Micro-Radian except as an accessory. Often the reflector is an integral part of the equipment that is subject to angular movement. The autocollimator does not constrain or interact with the equipment bearing the reflector. The ability of the autocollimator to make accurate measurements is dependent on the quality of the reflector.

2.0 Light Source

2.1 The ThetaScan TL series optical heads use a visible red (670nm) emitting laser diode module as a light source. The laser is modulated at 4 kHz with a 50% duty cycle. Laser light is only accessible by the user through the emitting aperture (objective lens). The beam emitted from the aperture is between 2 mm and 10 mm in diameter. The total energy of this beam has been carefully measured at the factory to be well within the limits of Class II laser products.

2.2 Do not stare into the laser beam or look at the reflections of the beam from shiny surfaces. The laser emits visible red light and the beam can be easily seen on most surfaces or by holding a piece of paper in front of the objective lens.

2.3 Labels. There are 2 important labels attached to the ThetaScan TL series optical head. Removal of these labels will void the warranty. The labels are shown below.

Figure 1.

Figure 2.

2.4 A laser radiation emission indicator light (green LED) is located at the rear of the optical head. This indicator may be readily viewed without exposure to laser radiation.

2.5 Please call Micro-Radian at 360-752-9900 with any questions on the laser or laser radiation.

3.0 Detector

3.1 The TL series autocollimators utilize the most advanced ultra-linear detectors available. These detectors are position sensing and take the centroid of all the light incident upon then. Unlike ccd-based detectors, the position sensing detector (PSD) is not frequency-limited by the line scan rate.

3.2 Unlike the human eye, the detector cannot distinguish between multiple images. Therefore, the autocollimator must “see” only one reflector at any given time.

4.0 Performance

4.1 The performance of digital autocollimators can be compromised by the conditions imposed by the intended applications. Reduced performance can be caused by (but not limited to) the following and combinations thereof:

a) Very small reflecting surface or reduction of aperture.
b) Poor quality of reflective surface.
c) Reflecting surface that is not optically flat.
d) Reflection of ambient light into the objective lens.
e) Vibrations in fixtures, tables, equipment, building, etc.
f) Electrical noise
g) Air movement near the line of sight, including human movement and air current from fans or air conditioners
h) Temperature fluctuations

4.2 Micro-Radian endeavors to optimize the performance of every autocollimator to the particular application for which it was purchased. This may include optimizing the calibration for a particular working distance or range of distances. Also, the measurement frequency (bandwidth) will be optimized for the application. Where the autocollimator in use has previously been used in other dissimilar applications, it is advisable to return the autocollimator to the factory for re-optimization for the new application.

4.3 The performance of the autocollimator is dependent on whether the reflector is moving and the corresponding measurement frequency of the autocollimator. All frequencies are set at the factory during the calibration procedure and are not adjustable in the field unless the autocollimator has been equipped with the optional bandwidth switch.

4.3.1 The bandwidth of the analog outputs is selected by the customer at the time of order. Any bandwidth from 10 Hz to 1000 Hz can be chosen. This bandwidth cannot be changed in the field unless the autocollimator is equipped with the optional analog bandwidth switch. A low analog bandwidth should be selected for applications that require low noise measurements of a static reflector. A high analog bandwidth should be selected for applications that require maximum angular information of a moving reflector. Because noise is proportional to bandwidth, a high bandwidth will limit the resolving ability of the autocollimator.

4.3.2 The bandwidth of the LCD display is dynamic. The LCD will initially display measurement data at a bandwidth of 250 Hz. If the reflector is moving, the LCD will continue to display data at this bandwidth. If the reflector is static, the LCD will incrementally transition to 0.2 Hz. The transition will occur over a period of 30 seconds from when the reflector stops moving.

4.3.3 The bandwidth of the RS-232 output is tied to the bandwidth of the LCD display. There are two data transfer modes available over the RS-232: (1) the direct display mode will send what appears on the LCD and (2) the averaging mode will send the 1-second average of what appears on the LCD.

4.3.4 Servo applications

4.3.4.1 The ThetaScan® series instruments have a measurement delay of 25 ms due to the DSP processing. For servo feed-forward and feed-back loops which require high measurement bandwidth with minimal delay in measurements, the optical heads can be supplied in a “servo” form. The servo-autocollimator has minimum delay and a measurement bandwidth of 5000 Hz.

4.4 Performance limitations

4.4.1 Operating temperature:

Maximum: 52° C/125° F

Minimum: -18° C/0° F, or the dew point, whichever is higher.

4.4.2 Storage temperature:

Maximum: 65° C/150° F

Minimum: -30° C/-20° F, or the dew point, whichever is higher.

4.4.3 Humidity

4.4.3.1 The relative humidity is not important provided condensation does not occur. The optical elements cannot function properly if coated with moisture droplets, frost, or ice. If condensation collects on one or more of the optical elements and subsequently freezes, the force exerted could cause a displacement irreparably damaging the instrument. Damage caused by condensation is not covered by the warranty.

4.4.4 Autocollimator performance will be dependent on the quality of the target reflector.

4.4.4.1 A mirror should be used for making measurements to 0.1 arc-second and should be optical grade, front surface, and flat to 1/10th wave or better. The best material is fused quartz, but pyrex is adequate for a lab environment. The mirror should be large enough to provide a full aperture reflection without distortion caused by rounding at the edges. Best results are obtained from mirrors with diameters at least 50% larger than the optical head aperture. Mirror thickness should be at least 15% of the diameter so that mounting clamps will not cause appreciable bending.

4.4.4.2 Prisms and corner reflectors must be free of strains and striae, and have deviation errors of no more than a few arc-seconds.

4.4.4.3 Other reflectors (bare glass, zerodur, etc.) may be used but might significantly degrade the instrument performance. At times, such reflectors may not provide an adequate return beam for any measurement.

4.5 Vacuum compatibility

4.5.1 All TL series optical heads will operate in vacuum. Often special materials are required to minimize outgassing and Micro-Radian can build these into the optical heads at the customer's request.

4.6 The performance of all optical heads is reduced as working distance increases and as working distance varies from the distance at which the instrument was calibrated.

4.7 Performance specifications given are maximums. These maximums cannot be simultaneously achieved. For instance, at a given maximum working distance the given maximum angular measuring range will not be achievable and the actual angular measuring range will be much less than the maximum.

5.0 Performance terminology

5.1 Resolution

5.1.1 Autocollimator resolution, or sensitivity, is defined as the smallest angle that can be detected by the instrument.

5.1.2 Autocollimators measure the position and/or the movement of an image of their own light source on the surface of a detector. Ultimate resolution is more dependent on the focal length of the objective lens and the detector sensitivity than on the diameter of the objective lens.

5.1.3 Autocollimators with objective lenses of less than 100 mm focal length are intended for use at short working distances only. The reduced optical leverage of short focal length objective lenses results in reduced resolution.

5.1.4 Resolution is inversely correlated to reflector distance. As the distance between the autocollimator and the reflector increases, the resolution will decrease.

5.1.5 Resolution is inversely correlated to analog bandwidth. As the analog bandwidth increases, the autocollimator resolution will decrease. This is due to increased RMS noise with increasing bandwidth.

5.2 Precision

5.2.1 Autocollimator precision is defined as the repeatability of measurements.

5.2.2 Precision is dependent on measurement drift and the two are inversely correlated.

5.2.3 Autocollimator drift will vary as a function of the environment. Small changes in air current and temperature will cause measurement drift over time. Such environmental considerations typically outweigh the electronic and light source drift inherent in the autocollimator itself.

5.3 Accuracy

5.3.1 Autocollimator accuracy is defined as the correlation of the autocollimator readings to a known standard.

5.3.2 Autocollimator accuracy is affected by the same factors that affect resolution.

5.3.3 Autocollimator accuracy is described in terms of linearity. Linearity will tend to be highest near null and will tend to decrease toward the edges of the measuring range. The linearity given for the TL series reflects the "worst case" linearity at the edges of the measuring range.

5.3.4 The known standards used to define the accuracy of the TL series are a collection of custom designed tungsten carbide angle blocks calibrated by the National Institute of Standards and Technology.

5.4 Drift

5.4.1 Measurement drift is caused by external factors including ambient temperature changes, vibrations, air currents, convection in the light path, and expansion/contraction of external and internal components. The measurement drift inherent in the autocollimator itself is minimal.

5.4.2 Measurement drift in the axis which is orthogonal to the ground will be higher than drift in the other axis due to convection in the light path.

5.4.3 Some manufacturer's autocollimators periodically re-zero themselves to give the appearance of no drift. Micro-Radian does not employ this feature. All measurements from Micro-Radian autocollimators are true measurements.

6.0 Optical heads

6.1 Each TL optical head is machined from 6061 aluminum and is black anodized inside and out. The optical head contains the optical elements, laser light source, detector, and pre-amp circuit board. DC power to the head is ±15V or less.

6.2 The TL autocollimator uses an ultra-linear position sensing photo-detector. This type of detector finds the centroid of all the light hitting it and outputs a corresponding voltage. These voltages are converted into angle by the autocollimator.

7.0 E2 Electronic unit

7.1 The E2 unit contains a switching power supply, printed circuit board, LCD display, RS-232 interface, and BNC analog outputs. The unit can be supported by the feet that extend from the bottom of the unit. It can also be supported by the adjustable bail/handle. The bail has the added benefit of allowing the user to position the instrument at the most comfortable operating angle.

7.2 Digital Signal Processing

7.2.1 With the DSP, the autocollimator linearity is enhanced by correction of the inherent non-linearities of the detector and the lens. This is achieved by a piecewise linearization approach. Each axis is divided into 32 measurement ranges. Each range has an associated correction factor that was determined during the calibration procedure for that instrument. Each time the instrument takes a reading, the DSP combines the raw reading with the correction factor to yield a linearized reading. Linearity is further improved by the total elimination of analog dividers.

7.2.2 The DSP allows the E2 to digitize data immediately and at much higher sampling rate (oversampling) than could be achieved with conventional analog processing. Processing is accomplished in a purely digital world and output is fully digital. The added error normally contributed by a final A/D conversion is eliminated.

7.2.3 The DSP eliminates the drift associated with analog electronics.

7.3 Dynamic Bandwidth LCD

7.3.1 The display is a backlit 16x2 character Liquid Crystal Display, providing simultaneous arc-second readouts of azimuth and elevation.

7.3.2 The LCD will initially display measurements at 250 Hz. If the reflector is moving, the LCD will continue to display measurements at 250 Hz. If the reflector is static, the LCD bandwidth will incrementally decrease to 0.2 Hz. The incremental bandwidth decrease will occur over a period of 30 seconds from when the reflector stops moving.

7.3.3 The dynamic bandwidth of the LCD is independent of the analog bandwidth of the instrument.

7.3.4 The LCD has a factory-set threshold value of 5%. When the intensity of the reflected beam hitting the detector becomes less than 5% of the emitted beam, the display will go blank. This feature is used to aid in the initial gross alignment of the autocollimator to the reflector. This feature can also be used to determine whether the target reflector is of sufficient size and quality to achieve accurate measurements.

7.3.5 The LCD viewing surface is delicate. Do not poke or otherwise damage the vinyl window protecting the display.

7.4 Zero Mode

7.4.1 The E2 unit will display the absolute reflector angle when initially activated. To enter the zero mode, depress the zero button on the front panel. This will zero the display, irrespective of the reflector angle. Subsequent readings will be made with respect to this zero. A small Z will appear in the lower right corner of the display while the zero mode is active. To return the unit to the absolute measure mode, press the zero button again. The Z indicator will disappear. The unit will now read the absolute mirror angle.

7.4.2 Do not engage the zero mode while performing the initial alignment of the autocollimator as this may result in limiting the field of view.

7.4.3 The zero mode affects the LCD display only and has no effect on the RS-232 output or the analog output.

7.5 RS-232 output

7.5.1 The E2 has a built in male RS-232 connection in the rear of the unit.

7.5.2 The RS-232 has two modes: display and average.

Mode	Data	Size	Command to activate
Display	LCD display data	24-bit each number	hex FF
Average	1-second average of LCD display data	32-bit each number	hex FE

7.5.3 Output is in binary format with Elevation data first followed by Azimuth data. The Least Significant Byte (LSB) is first with 2's complement.

7.5.4 To convert the binary data into angle (in units of arc-second):

Mode	Multiplier
Display	(24-bit data x 256)/-65536 = Measurement in arc-seconds
Average	(32-bit data)/-65536 = Measurement in arc-seconds

7.5.5 The maximum data bandwidth over the RS-232 is 30 Hz. To realize data bandwidths in excess of 30 Hz, the analog outputs should be utilized.

7.5.6 Pin callouts for the connector.

Pin	Signal
2	receives to the E2
3	transmits from the E2
5	ground

7.5.7 The data rate over the RS-232 is 9600 baud, composed of 8 data bits plus even parity and 1 stop bit.

7.5.8 MicroSoft® quickbasic is not compatible with the RS-232 due to parity incompatibility.

7.5.9 For sample RS-232 code, see appendix A. Any software used to access the RS-232 should be fault recoverable.

7.5.10 A null modem cable must be used when interfacing the autocollimator with a computer.

7.6 Analog outputs

7.6.1 The analog outputs are found on the front panel as BNC-type connectors. The outputs can source or sink up to 5 mA. Short circuiting the outputs to ground will not harm the electronics. A high impedance load is recommended when using the analog outputs.

7.6.2 The analog outputs are DC, or slowly varying AC voltages. As DC voltages, their level will decrease to zero at null, changing polarity when crossing through this origin point.

7.6.3 Analog output scale factors

Optical head	Scale factor (mV/arc-second)
TL40	1.0
TL160	10.0

7.6.4 The analog bandwidth is factory set at the customer-selected value. Any value from 10 Hz to 1000 Hz can be chosen. This bandwidth setting cannot be changed in the field unless the autocollimator is equipped with the optional bandwidth switch.

7.6.5 The analog outputs should be used whenever data capture rates exceeding 30 Hz are desired.

7.7 Switching power supply

7.7.1 The power supply in the E2 will automatically switch to permit use of the E2 with input power between 100 volts and 220 volts. No modifications are necessary.

8.0 Operation

8.1 Set up

8.1.1 Mount the optical head and aim it at the reflector. For best results, position the optical head as close as possible to the reflector. Connect the interconnecting cable on the optical head to the E2 electronic unit. Plug the power cord into an outlet of the appropriate voltage. Depress the power switch on the front panel. Adjust the optical head until numbers appear on the LCD. Further adjust the optical head to read approximately null. Verify that the zero mode is not engaged.

8.2 Warm up

8.2.1 Allow the autocollimator temperature to equilibrate for at least 10 minutes. The autocollimator will exhibit measurement drift during this period. Only after the measurement drift has stabilized should readings be attempted.

8.3 Readings

8.3.1 The azimuth (yaw) display and output will move in a positive direction for angular displacement of a mirror in a relative clockwise direction when viewed from above. Counter-clockwise mirror rotation will produce a negative display and output. The elevation (pitch) display and output will move in a positive direction for angular displacement of a mirror upwards (positive mirror pitch). Depressed elevation mirror movement (negative mirror pitch) will produce a negative display and output.

8.3.2 The reversed images reflected by porro prisms and the inverted images reflected by trihedrals or corner reflectors will result in output shifts opposite in polarity to those received when using a conventional mirror. Penta-prisms are used as an optical square, primarily to shift the optical axis 90 degrees; in this case, the object reflector determines output polarity.

8.4 Shut down

8.4.1 To shut down the autocollimator, depress the power switch.

9.0 Calibration

9.1 Introduction

9.1.1 The ThetaScan® autocollimator is calibrated to angle standards established by the United States National Institute of Standards and Technology (NIST). The calibrations are fully traceable to the NIST and a calibration certificate is provided in the front of this manual. The factory does not recognize non-NIST angle standards for calibration verifications or comparisons.

9.2 Calibration approach

9.2.1 The ThetaScan® has several internally set numbers which are optimized to achieve a calibrated response. These numbers are divided into two sets, one set for each axis. Each set contains one number for offset correction, one number for gain correction, and 33 numbers for a linearized correction look-up table. These numbers are resident in the instrument and are accessible only by the factory.

9.2.1.1 The offset number is set so that when the ThetaScan® beam is reflected in a corner cube, the instrument will display a nominal angle reading of zero.

9.2.1.2 The gain correction number is set so that when the ThetaScan® beam is reflected off of a NIST-calibrated angle block which is rotated 180 degrees in a fixed plane, the change in angle read by the instrument will be twice that of the angle block.

9.2.1.3 The 33-point look-up table is adjusted so that at any point in the calibrated range the angle change read by rotating a small value angle block by 180 degrees in a fixed plane will be the same. An angle which is less than 1/20 of the calibrated range is considered small.

9.2.2 Micro-Radian uses a computer controlled two-axis mirror to help automate the calibration procedure. At least 6 passes are made in each axis in a recursive averaging manner to obtain a calibration more precise than a single pass could obtain.

9.2.3 The ThetaScan® does not require regular re-calibrations. However, Micro-Radian can provide such services upon request.

9.3 Calibration verification

9.3.1 Customer verifications of our calibrations are welcomed. However, the high measurement sensitivity of the ThetaScan® instruments must be considered. Temperature changes, air movement, vibration, poor reflector quality, and obstructions in the light path will adversely affect your measurement accuracy and drift.

10.0 Instrument care

10.1 To insure optimum performance from the ThetaScan®, observe the following:

10.1.1 Do not drop or mishandle the optical head or electronic unit. Damaged optical components render the instrument inoperable.

10.1.2 The window protecting the LCD is easily scratched. Use care when cleaning.

10.1.3 Do not attempt to open the optical head or the electronic unit without consulting the manufacturer. Do not probe the instrument with an ohmmeter.

10.1.4 Do not touch the optical head lens. While fingerprints on the lens will not affect the operation, excessive cleaning of the lens may damage its coating.

10.1.5 Regular calibrations are not necessary. However, Micro-Radian Instruments offers calibration services upon request.

10.1.6 Use only the optical head/electronic unit pair that is indicated in the front of this manual. Use of optical heads to which the electronics have not been calibrated will give incorrect data.

11.0 Troubleshooting

11.1 For personal assistance with questions, contact Micro-Radian Instruments directly.

☎ 360-752-9900   🖹 360-752-9902   🖃 info@micro-radian.com

11.2 Display is erratic or blank**.**

11.2.1 The display is equipped with a threshold value of 5%. When the light entering the autocollimator is less than 5% of the full beam intensity, the numbers on the display will go blank. This feature is used to assist in the initial gross alignment of the autocollimator to the target reflector. It is also used to verify that the reflector is of sufficient quality for minimum measurement capability. Possible causes for the threshold value to be reached include:

- Target reflector is too far away or at too large an angle.
- Target reflector is not flat or not sufficiently reflective.
- There is an obstruction in the light path.

11.2.2 To verify that the instrument is functioning, place a flat, full aperture mirror directly against the front of the barrel.

11.3 Measurement drift.

11.3.1 The primary cause of drift are the refractive effects of air turbulence in the light path between the optical head and the mirror. This can cause fluctuations of a second or more over a few centimeters and several seconds over longer paths. Culprits include air currents from heating and air-conditioning ducts, open windows, or fans. Drift is also caused by convection in the light path. The drift effects caused by the air in the light path will be most evident in the measurement axis which is orthogonal to the ground (typically elevation or pitch)

11.3.2 Drift is caused by vibrations. Even with the optical head and mirror securely mounted to a heavy base, the whole structure will seldom vibrate as a unit without flexure. Vibration may come from machinery in an adjacent room, or from traffic, including foot traffic indoors as well as vehicle traffic outside. To identify vibration, place a dish of water on the base and look at the reflection of a ceiling light on the surface. Ripples signify a problem.

11.4 Excessive crosstalk

11.4.1 Crosstalk occurs when a mirror rotation in one plane causes a readout in the orthogonal display (in addition to the primary plane readout). Detector orientation is set at the factory such that measured crosstalk during checkout is less than 0.2%. Observed crosstalk in excess of this indicates that the axis of mirror movement is not parallel to the axis of measurement in the optical head.

11.5 RS-232 interface not functional

11.5.1 The RS-232 interface observes standard pin out assignments (see section 7.5.4). Verify that the pin outs are compatible.

11.5.2 The RS-232 uses even parity. This is not compatible with MicroSoft® quickbasic.

11.5.3 Verify that the E2 controller is sending and receiving data through the correct pins using a scope.

11.5.4 Review the sample code in appendix A of this manual. This code is intended to illustrate a procedure to acquire data over the RS-232.

12.0 Angular conversions

1 radian	=	360/2π
	=	57.29578 degrees
1 milliradian	=	0.05729578 degrees
	=	3.4377468 minutes
	=	206.2648 seconds
1 microradian	=	0.2062648 seconds
1 degree	=	0.01745329 radians
	=	17.45329 milliradians
1 minute	=	0.00029088 radians
	=	0.29088 milliradians
	=	290.88 microradians
1 second	=	0.0000048481 radians
	=	0.0048481 milliradians
	=	4.8481 microradians

13.0 Sample RS-232 code, BASIC

```
'******************* Test the RS232 ******************************
LOCAL FN work
  DEFINT I
  '************** First open the Comport ******************
  OPEN "C",-1,9600,2,0,1,64
  '***************** Now clear the buffer ****************
  I2&=0
  PRINT "Clearing buffer"
  WHILE LOF(-1,1)<>0
    READ #-1,a$;0
    I2&=I2&+1
    LONG IF I2&>100
      PRINT "Buffer can not be cleared"
      PRINT ASC(a$)
      CLOSE #-1
      EXIT FN
    END IF
  WEND
  PRINT "buffer cleared"
  DO
    CLS
    '****************** send out request for data ***************
    PRINT #-1,CHR$(255);
    '****************** Now wait for the data *******************
    I2&=0
    WHILE LOF(-1,1)<6
      'PRINT I2&,LOF(-1,1)
      I2&=I2&+1
      LONG IF I2&>100
        PRINT "No Data"
        CLOSE #-1
        EXIT FN
      END IF
    WEND
    '*************** Now read and Translate the data *************
    PRINT "Display data"
    FOR I1= 1 TO 2
      READ #-1,b$;0
      I2&=ASC(b$) : I3&=I2&<<8
      READ #-1,b$;0
      I2&=ASC(b$) : I3&=I3& OR (I2&<<16)
      READ #-1,b$;0
      I2&=ASC(b$) : I3&=I3& OR (I2&<<24)
      PRINT -1*I3&/65536.0,
    NEXT I1
    PRINT:PRINT
    '****************** Now get the 1sec Az/El average *************
    '****************** send out request for data ***************
    PRINT #-1,CHR$(254);
    '****************** Now wait for the data *******************
    I2&=0
    WHILE LOF(-1,1)<8
      'PRINT I2&,LOF(-1,1)
```

```
  I2&=I2&+1
  LONG IF I2&>10000
    PRINT "No Data"
    CLOSE #-1
    EXIT FN
  END IF
WEND
'*************** Now read and Translate the data *************
PRINT "Az & El 1 sec average data"
FOR I1= 1 TO 2
  READ #-1,b$;0
  I2&=ASC(b$) : I3&=I2&
  READ #-1,b$;0
  I2&=ASC(b$) : I3&=I3& OR (I2&<<8)
  READ #-1,b$;0
  I2&=ASC(b$) : I3&=I3& OR (I2&<<16)
  READ #-1,b$;0
  I2&=ASC(b$) : I3&=I3& OR (I2&<<24)
  PRINT -1*I3&/65536.0,
NEXT I1
```