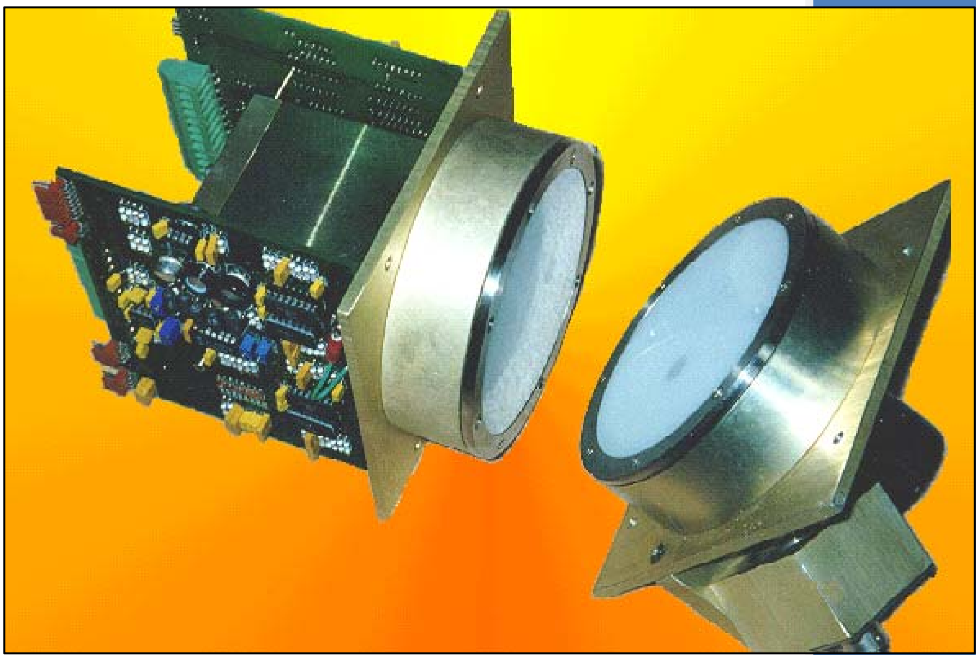
IR MOISTURE SENSOR

SERVICE MANUAL

V4.8 February, 2010



The Leader in Measurement & Control

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CHAPTER 1:

MOISTURE SENSOR OVERVIEW

CHAPTER 1

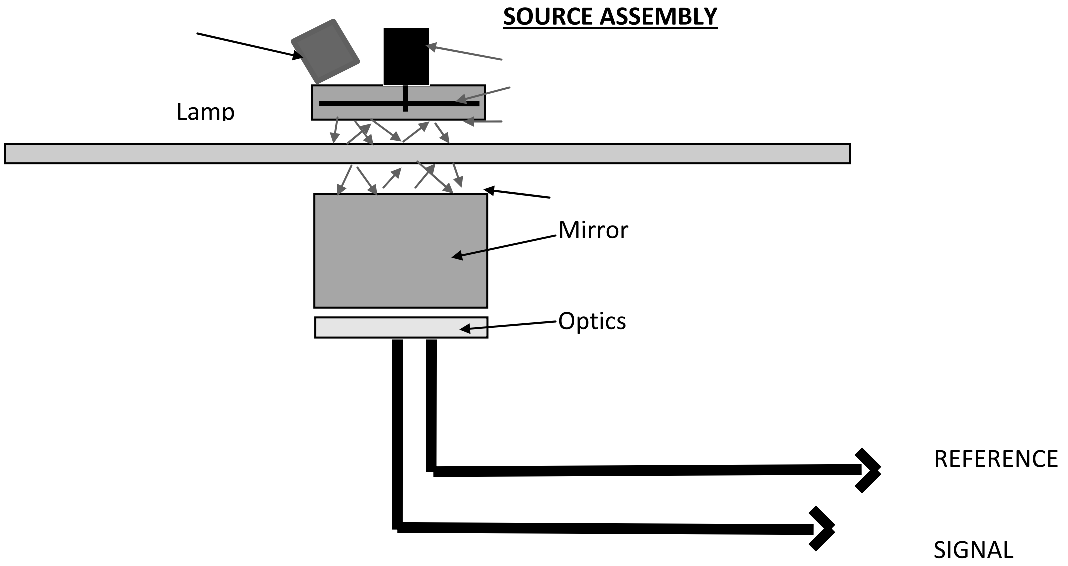
1.0 MOISTURE SENSOR OVERVIEW

1.1 PRINCIPLE OF OPERATION

The Infra-red Transmission Moisture Sensor uses the principle of absorption of certain infra-red wavelengths by water as it passes through paper. The sensor has two parts, a source and a receiver part. The source part is normally located in the low head and includes a light source that is modulated with a chopper wheel. The receiver part is normally in the upper head and detects the light that passes through the paper and analyses the intensity of certain wavelengths.

For fine papers and tissue the sensor typically has two measurement channels - one measures the amount of infra-red light in the 1.85 micron wavelength band - referred to as the REFERENCE measurement, and the other in the 1.93 micron wavelength band - referred to as the MEASURED measurement. From the RATIO of the two measurements and the basis weight of the paper measured by the basis weight sensor, the % moisture content of the sheet can be calculated.

Additional wavelengths can be measured, for example 2.11 micron cellulose measurement. This measurement can make the sensor independent of the Basis Weight Sensor for some grades of paper. An additional reference wavelength can be added, e.g. 1.3 micron, to improve the accuracy slightly for applicable paper types.



CHAPTER 2:

MOISTURE SENSOR SOURCE

CHAPTER 2

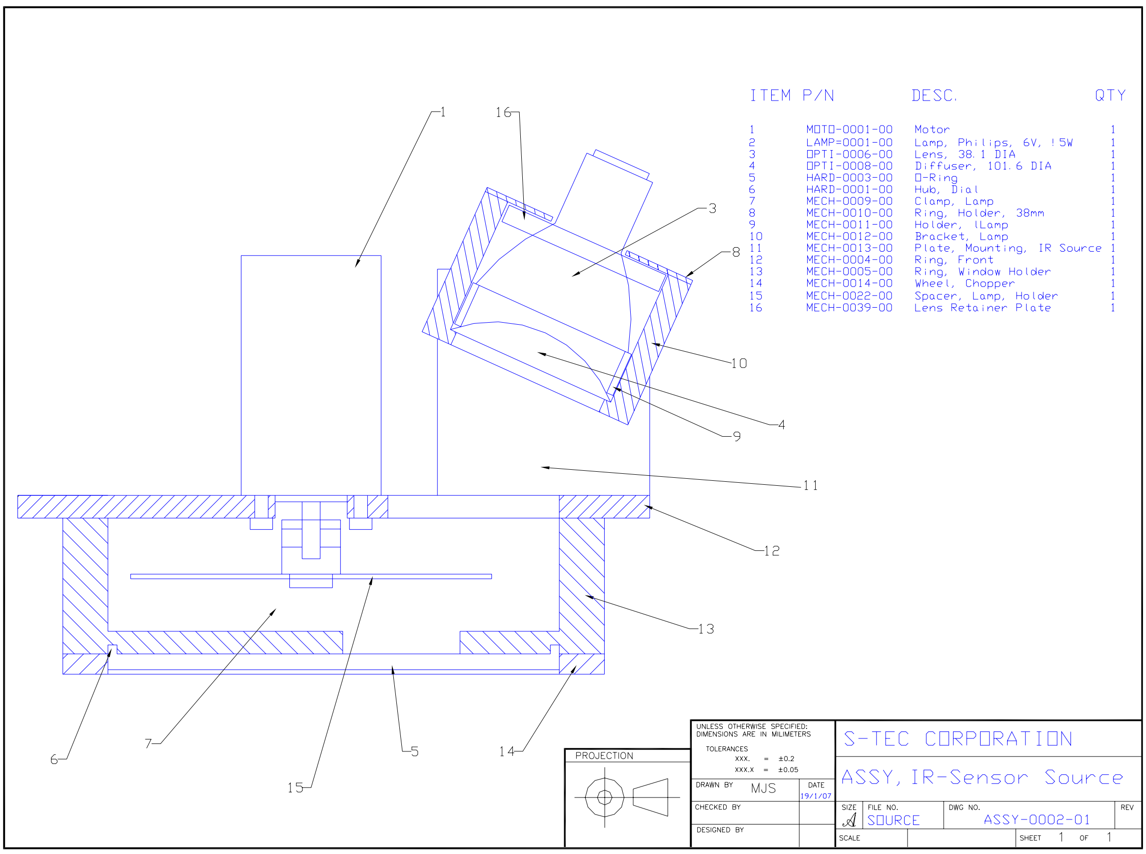
2.0 MOISTURE SENSOR SOURCE

2.1 SOURCE ASSEMBLY

Drawings of the Source Assembly are in the appendix to this section. The Source Assembly basically consists of a 6V Halogen Lamp operated from 5V, thus generating a lot of Infra-Red light as well as visible light. By operating the lamp on 5V, instead of 6V, the life of the lamp is considerably extended. The lamp has its own reflector and the light from the lamp is focused by a plano-convex lens onto the diffuser. The side of the diffuser away from the sheet is mirrored with gold but has a 10mm diameter non-mirrored area for the light to exit the source assembly into the paper. Before reaching the 10mm diameter area, the light must pass through the chopper wheel. The chopper wheel consists of a rotating disk with many holes around the circumference. The light passing through the holes as the disk spins and is "chopped" in a sinusoidal manner. The chopper wheel is rotated by a motor with integral speed control. The motor is supplied by 24Vdc.

Light of all infra-red wavelengths are emitted from the "hole" in the diffuser mirroring and enters the paper in a diffused (random) fashion.

IR SOURCE ASSEMBLY



2.2.1 IR LAMP & OPTICS

The IR Lamp is a 15W, 6V, Halogen Lamp with aluminium reflector which produces a 6° light angle. The Lamp is held in place with a Teflon spacer and stainless steel clamp. The lamp is operated from a 5V dc supply. Wiring to the lamp is soldered directly to the terminals of the lamp. Soldering ensures that the connection is not affected by vibration or oxidation that might otherwise cause variations to the light intensity during head movement.

The 6° light angle is focused inwards and onto the 10mm diameter hole in the diffuser mirroring by a plano-convex lens. The Lamp / Lens assembly is held in place by two M4 stainless screws. A small amount of movement is possible when the screws of the assembly are slackened in order to ensure the light is correctly focussed on the 10mm diameter “hole” in the mirror.

2.2.2 CHOPPER MOTOR

The Chopper Motor is a dc brushless motor with integral speed control electronics. The motor is supplied with 24Vdc. Speed adjustment is fixed at about 667Hz by providing a 5V reference signal. The motor electronics control the speed at 1000 rmp per reference volts, therefore a 5V reference results in 5000 rpm = 667 Hz (8 holes in the chopper wheel). The exact frequency of the chopper is not critical but it must be stead. Frequency in the range 400-800Hz will give the best signal to noise ratio.

2.2.3 DIFFUSER WINDOW

The Diffuser Window consists of a circular diffuser with gold mirroring at the rear of the diffuser. The diffusing side is positioned towards the paper and the mirrored side is towards the sensor. Gold is used as the mirror surface because gold is an excellent reflector at infra-red wavelengths.

A 10mm hole is cut in the mirroring for the light to exit the sensor. Because of the diffuser material the light leaving the source assembly is randomly scattered in Lambertian fashion. Some of the light leaving the diffuser passes through the sheet and is reflected back from the mirroring of the diffuser window on the receiver assembly. Some of the light is reflected from the surface and from within the paper back to the source window. Light therefore is scattered randomly and passes through the paper many times, bouncing between the diffusing mirrors, before entering the 10mm diameter “hole” in the receiver assembly diffuser disk.

The “hole” in the source diffuser window can be offset 15mm from the centre of the disk. The similar “hole” in the receiver diffuser window can be offset 5mm or 15mm. For fine Paper offsets are chosen to provide a total of 20mm offset (15mm + 5mm), and for Tissue 30mm (15mm + 15mm). For heavy papers the light can go straight through (15mm – 15mm). Light from the source to the receiver therefore typically cannot go directly from source to receiver but must pass through the paper several times, bouncing between the diffuser mirrors.

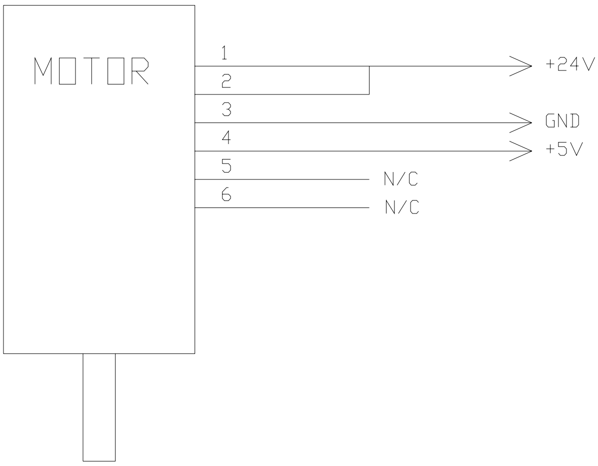
2.2.4 CHOPPER WHEEL

The Chopper Wheel is a 1mm thick stainless steel disk with eight 12mm diameter holes around the outside. As the disk spins it "chops" the light passing through the holes in a sinusoidal pattern.

The disk is held on to the shaft of the motor with a hub which has a grub screw. There is nothing to wear on the chopper wheel and it should never be necessary to change it. If it is removed for any reason, care should be taken to align it to the exact position it was in before removal.

2.3 CHOPPER WHEEL SPEED ADJUSTMENT

The speed of the chopper wheel is controlled by the reference voltage on wire 4 of the ribbon cable connected to the motor. The motor will rotate at 1000 rpm per reference volt. The reference wire is connected to +5V, therefore the motor rotates at about 5000 to produce a chopper frequency of about 667Hz.



Using an Oscilloscope the frequency can be monitored by viewing the sinusoidal signal from one of the channels of the preamplifier output. Refer to the Moisture Sensor Receiver section of this manual for suitable points for testing.

2.4 LAMP REPLACEMENT

Should it be necessary to change the IR Lamp, proceed as follows:

1. Turn off all power to the sensors heads.
2. Unsolder the wires to the old lamp.
3. Remove the four M3 screws to remove the stainless steel Clamp.
4. Remove the old lamp complete with the Teflon spacer.
5. Fit the Teflon spacer to the new lamp and insert into the assembly.
6. Reassemble in the reverse order.
7. Solder the wires onto the new lamp. The lamp is not polarity sensitive so the wires can go on either connection. Standard solder is OK for this purpose because the lamp terminals do not get very hot.

2.5 MOTOR REPLACEMENT

In the event of a motor failure requiring replacement of the motor, proceed as follows:

1. Turn off all power to the sensor heads.

2. Remove the Source Assembly from the heads and take to a clean workbench.

3. Remove the four M4 countersink screws to remove the front ring assembly.

4. Remove the chopper wheel by loosening the grub screw on the motor shaft. *Note the exact position of the wheel on the shaft.*

5. Remove the motor by removing the screws holding the motor.

6. Replace the motor and reassemble in the reverse order. Be very careful to position the wheel in the exact location as before. Also ensure the grub screw is tight and use locktite on the screw to ensure it cannot come loose.

7. Reinstall the source assembly in the head.

2.6 REPLACING THE SENSOR DIFFUSER WINDOW

Should it ever be necessary to change the moisture source window, proceed as follows:

1. Remove the Source Assembly and take to a workbench.

2. Note the orientation of the Diffuser - especially the 10mm diameter "hole".

3. Remove the Ring, Window Holder, complete with the Diffuser Disk, by taking out the eight M4 countersunk screws.

4. Install the new Ring / Diffuser Assembly. MAKE SURE THAT THE ORIENTATION OF THE "HOLE" IS CORRECT.

5. Reinstall the Source Assembly into the heads.

2.7 TROUBLESHOOTING

In case of trouble for which you suspect the source assembly, then there are only a few things to check:

Lamp

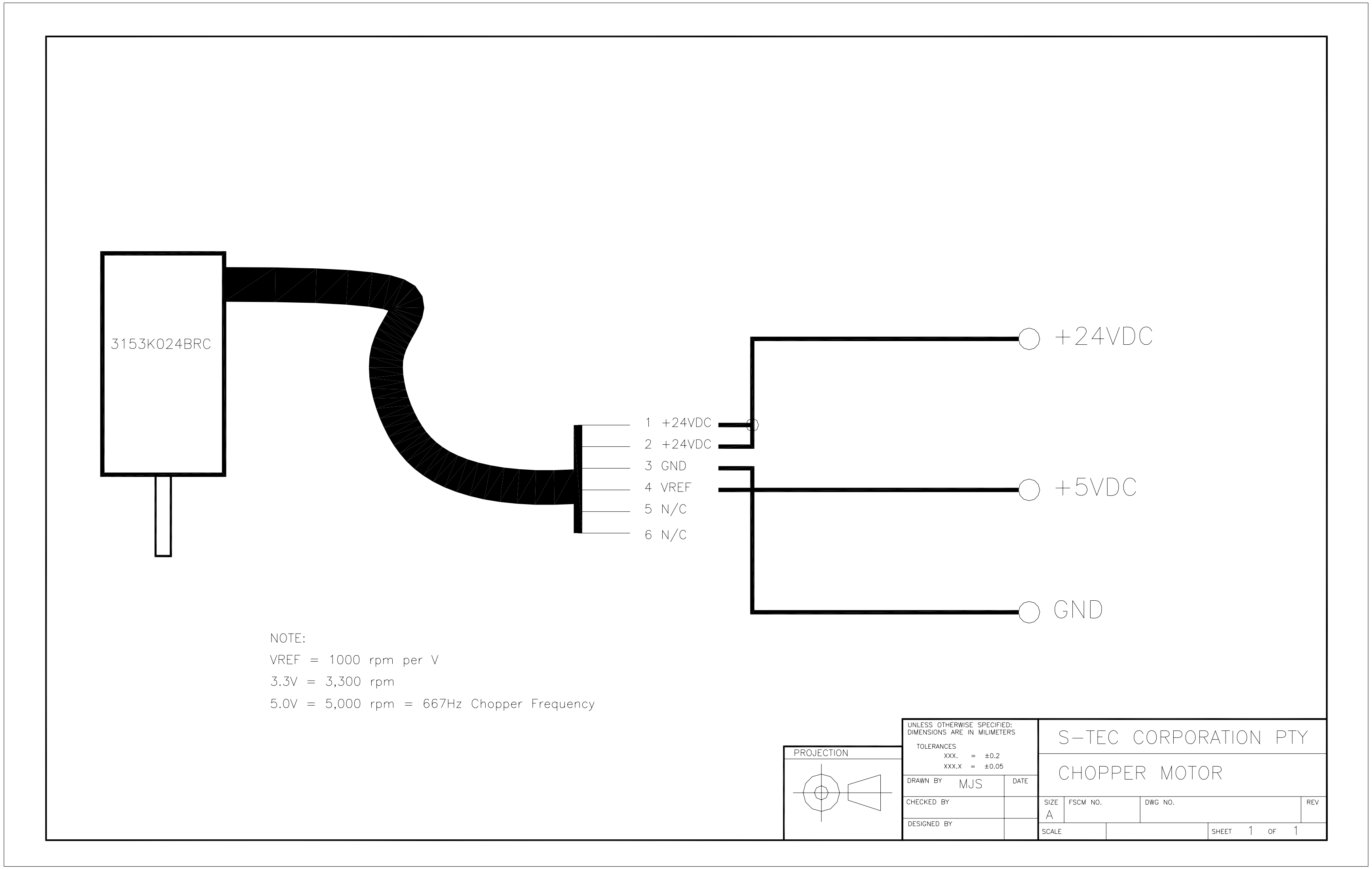
The lamp should always be glowing brightly. If the lamp is not on then check if there is 5V across the terminals of the lamp. If there is 5V then the lamp is faulty and must be replaced. If not then the problem is elsewhere. The procedure for replacing the lamp is described earlier in this section.

Chopper Wheel

The chopper wheel should always be rotating. The chopper wheel can be viewed through the hole where the light enters and is focused on it. If the wheel is not rotating or the speed is uneven, check that there is a *stable* 24V across the motor terminals 1 (+24V), 2 (+24V), 3 (GND), 4 (+5V reference). If +24V and +5V exists and is stable, then the motor may be faulty. Consider replacing it. The procedure for replacing the motor is described earlier in this section.

Optics

The optics - lamp, lamp lens, inside and outside of the diffuser window should be clean. If these are not clean then the signal level will deteriorate. If dirt or dust is observed then these optical components should be cleaned. If the diffuser window is broken or cracked, it should be replaced. Replacement of the window is described earlier in this section.



3153K024BRC
1 +24VDC
2 +24VDC
3 GND
4 VREF
5 N/C
6 N/C
+24VDC
+5VDC
GND
NOTE:
VREF = 1000 rpm per V
3.3V = 3,300 rpm
5.0V = 5,000 rpm = 667Hz Chopper Frequency
PROJECTION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILIMETERS
TOLERANCES
XXX. = ±0.2
XXX.X = ±0.05
DRAWN BY MJS
DATE
CHECKED BY
DESIGNED BY
S-TEC CORPORATION PTY
CHOPPER MOTOR
SIZE A
FSCM NO.
DWG NO.
REV
SCALE
SHEET 1 OF 1

CHAPTER 3:

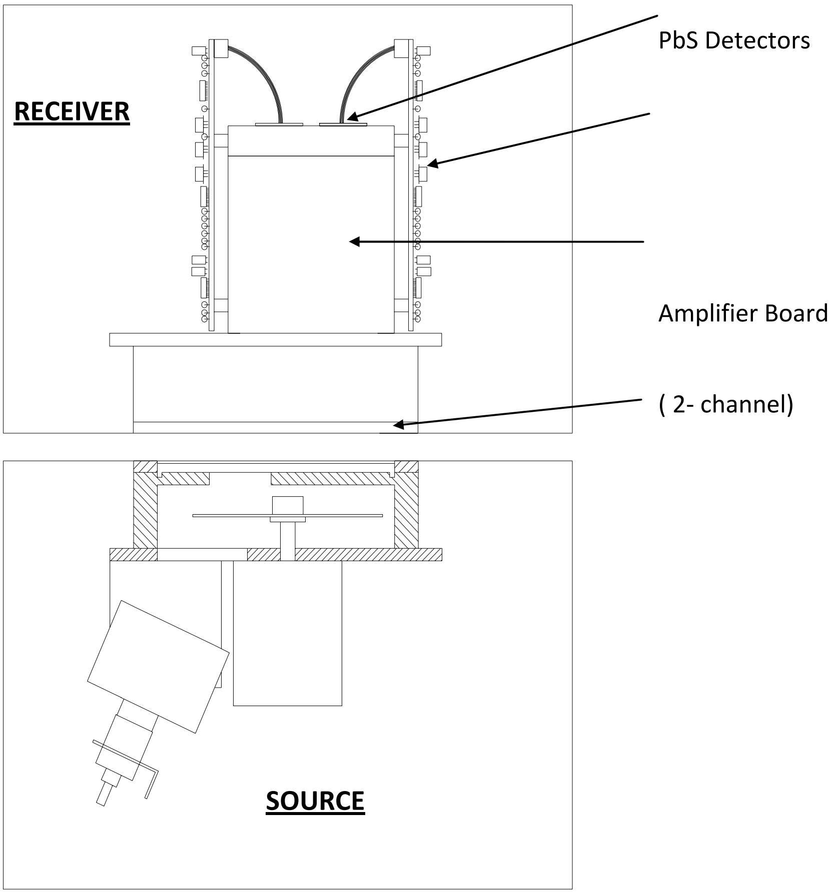
MOISTURE SENSOR RECEIVER

CHAPTER 3

3.0 MOISTURE SENSOR RECEIVER

3.1 PRINCIPLE OF OPERATION

The Moisture Sensor Receiver is the active part of the Moisture Sensor. It measures the amount of infra-red light received at selected wavelengths. The receiver has up to 4 measurement channels. On fine paper just 2 are normally sufficient to accurately measure moisture. The channel chosen in this case are the 1.85 and 1.93 micron bands.



Scattered infra-red light from the source lamp passes through the paper in a random fashion, bouncing between the paper and the diffusing mirrors of the source and receiver assemblies. It enters the receiver through a 10mm (depending on model) “hole” in the diffusing mirror. This beam of light, of all frequencies, is split into 4 equal paths by the S-tec proprietary optics. No details of the optics can be released at this time.

For each of the paths (up to 4), the light is focused into a parallel beam through a narrow-band optical filter. The filter is chosen to match the application. For example for measuring fine paper the bands normally chosen are 1.85 and 1.95 micron wavelengths. The filter is a band pass filter and so stops all light except that close to the chosen frequency. Light of each chosen wavelength is focused onto a Lead Sulphide detector cell (PbS). The cell detects the amount of light that impinges on it. The light from the source is "chopped" sinusoidal by the chopper wheel at ~700Hz. The circuit automatically synchronises to the "chopper" frequency to reject noise from other sources. This sinusoidal variation is amplified by the Moisture Amplifier and converted into a 0 - 2mA signal, one signal for each channel. The current loop signals each drive to an ADC channel with parallel resistor to convert the signal into a voltage proportional to the current.

To reduce the signal to noise ratio of the received signal, and to provide stability when the sensor enclosure temperature changes, the Lead Sulphide Cell (PbS Detector) is cooled internally and the temperature of the cell is closely controlled. The built-in 2-stage cooling mechanism uses the Peltier Cooler principle. The PbS Detector has an integral thermister temperature sensor and the amplifier uses this signal to control the temperature of the PbS Detector to a low and constant temperature.

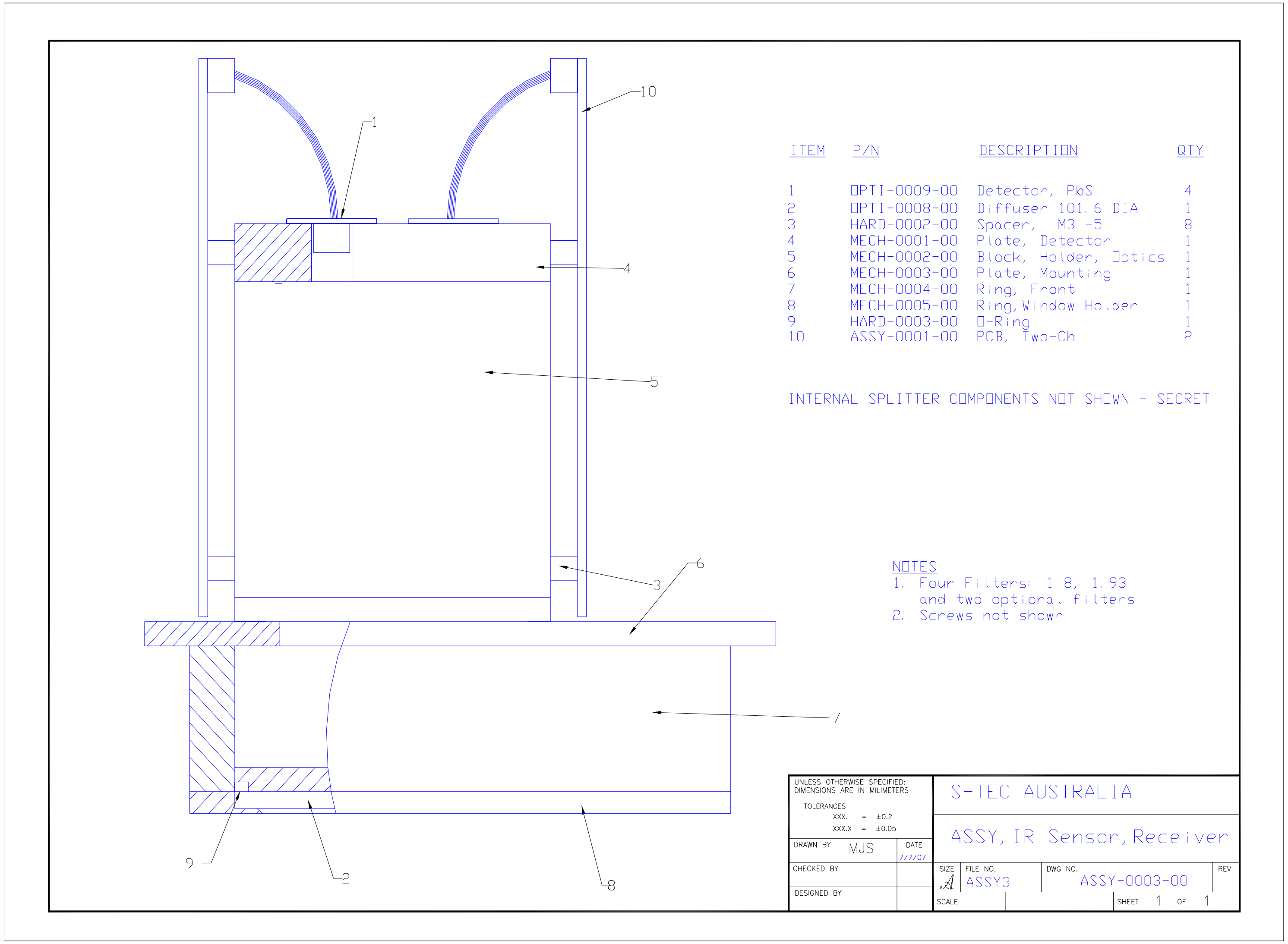
3.2 RECEIVER ASSEMBLY DESIGN DETAIL

The Receiver Assembly can be broken down into a number of component parts:

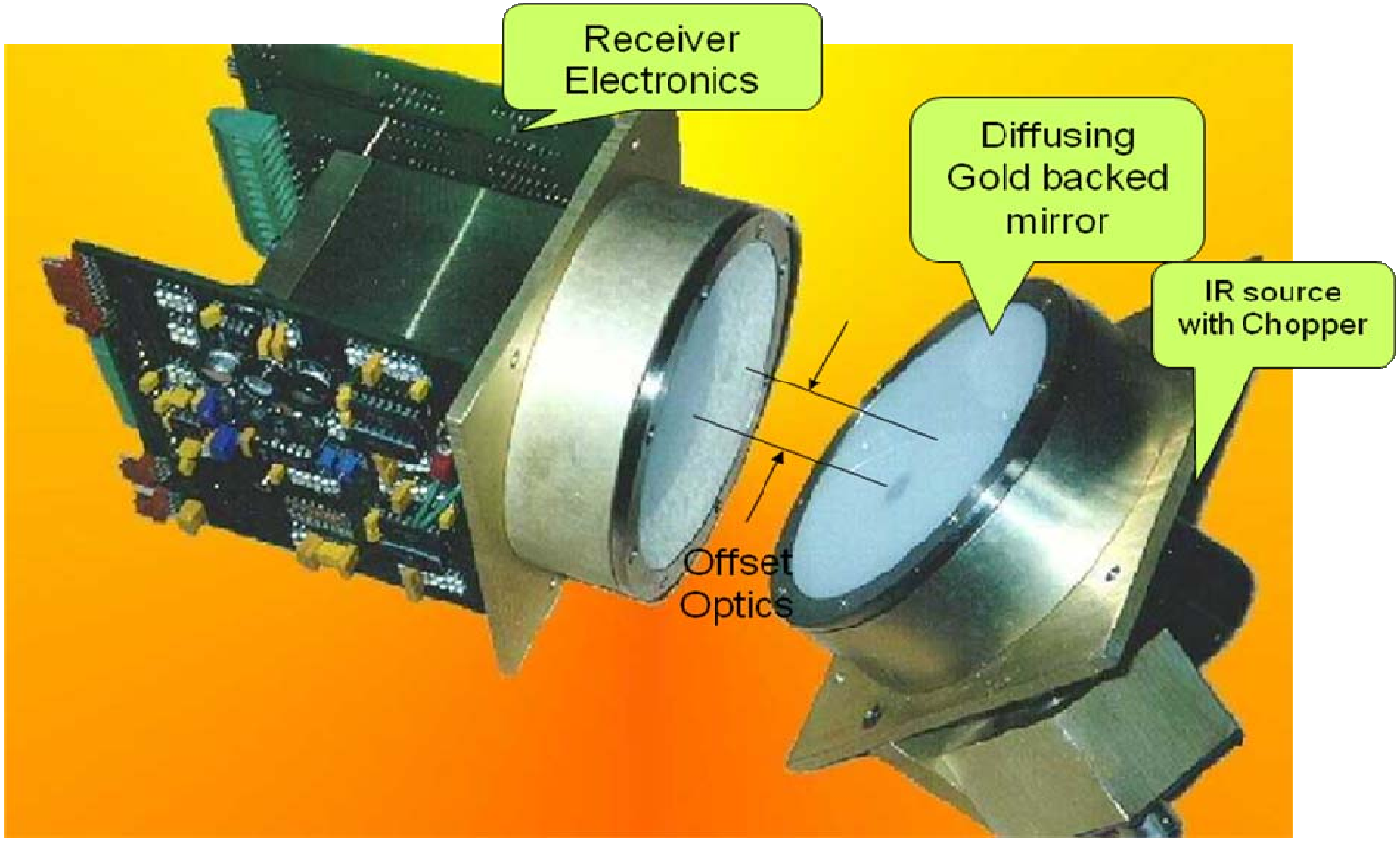
1. Optics
2. PbS Detectors
3. Moisture Amplifier & Gain Control
4. Peltier Cooler Control (part of Amplifier Board)

A detailed design description of each is in the sections below. The Optics are not discussed because there is nothing to go wrong and the design will be the subject of a number of patent application, so prior disclosure of the optic design is not permissible at this time.

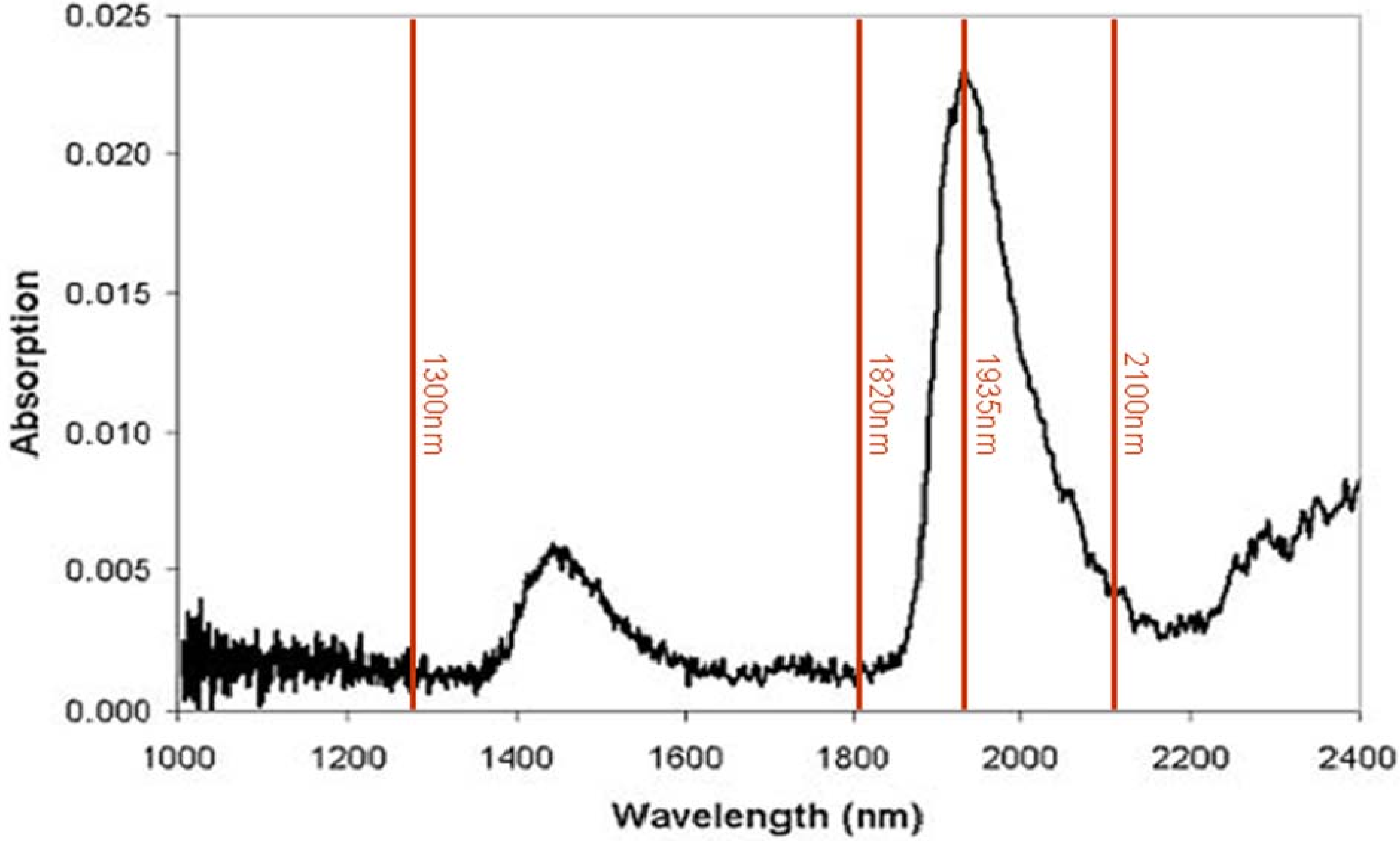
RECEIVER ASSEMBLY



RANDOM SCATTERING OFFSET OPTICS (example model)



USEFUL WAVELENGHTS FOR MOISTURE MEASUREMENT



3.3 PBS DETECTORS

The PbS Detectors (Lead Suphide) are mounted on the top of the optics. Up to 4 PbS Detectors can be mounted to measure a maximum of 4 channels. The PbS Detectors are held in place with two M3 screws and can be removed easily. Typically there are only 2 PbS Detectors and these are connected to a single Amplifier Board. Each cell has 6 wires which terminate into TB1 & TB2 of the Moisture Amplifier Board. The wires terminate as follows:

TB1-1	PbS Channel A	Thermister
TB1-2	PbS Channel A	Thermister
TB1-3	PbS Channel A	Peltier Cooler +
TB1-4	PbS Channel A	Peltier Cooler -
TB1-5	PbS Channel A	Signal
TB1-6	PbS Channel A	Signal

TB2-1	PbS Channel A	Thermister
TB2-2	PbS Channel A	Thermister
TB2-3	PbS Channel A	Peltier Cooler +
TB2-4	PbS Channel A	Peltier Cooler -
TB2-5	PbS Channel A	Signal
TB2-6	PbS Channel A	Signal

The voltage across the PbS Detector Signal wires should be about -150V. The voltage across the Peltier Cooler connections depends on the setting of the control and the temperature of the environment. Typically there is about 0.5V across these wires. The voltage across the Thermister wires is only one or two volts.

To change a Lead Sulphide Cell, do the following:

1. Remove the receiver assembly from the head and take to a clean workbench.

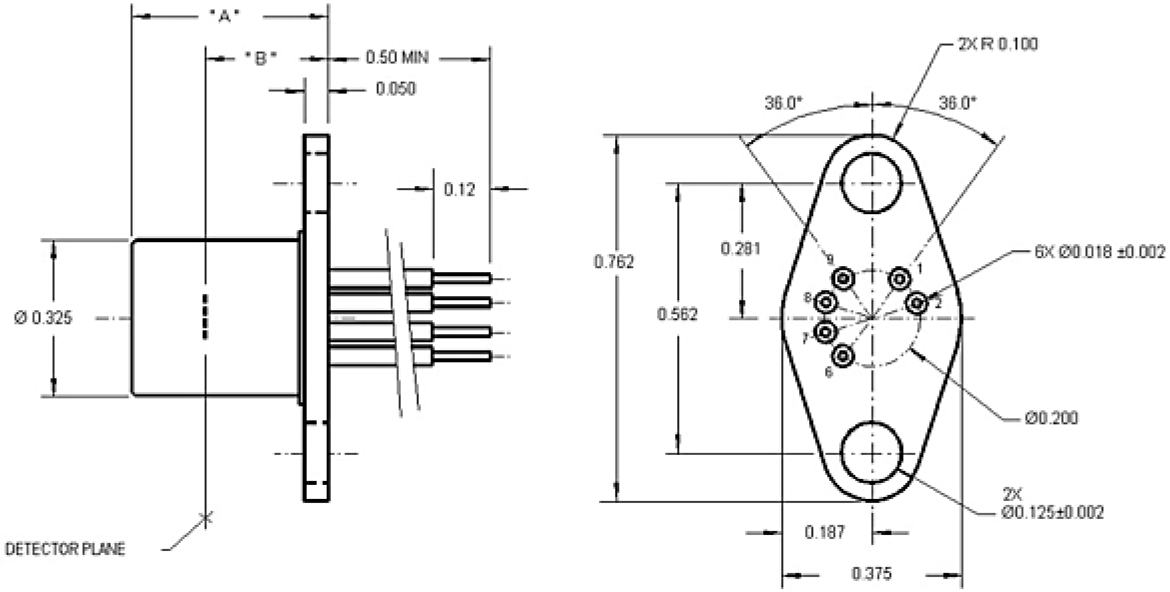
2. Remove the wires from the Amplifier PCB, TB1 or TB2. Note the position of each wire. It is very important to reconnect correctly or the cell can be damaged.

3. Remove the two M3 stainless steel screws holding the cell.

4. Replace with the cell in the same position and reassemble in reverse order to the above.

5. Readjust the gain of the amplifier board. Each cell has a different gain so it is very important that the amplifier board is readjusted after the change. Details about how to adjust the board are later in this section of the manual.

PbS DETECTOR PACKAGE



Dimensions are in inches

PIN FUNCTIONS

PIN NO.	FUNCTION	COLOR
1	THERMISTOR	YELLOW
2	THERMISTOR	YELLOW
6	DETECTOR	WHITE
7	DETECTOR	WHITE
8	COOLER (-)	BLACK
9	COOLER (+)	RED

3.4 MOISTURE AMPLIFIER & GAIN CONTROL

The purpose of the amplifier is to amplify the very small ac signal from the PbS Detector and then to measure it and provide a proportional output current loop signal. Because the signal changes over a very wide range between off-sheet and on-sheet - especially on heavy papers, there can be a need for gain adjustment. Usually absolute channel measurement is not important but ratios between channels are very important. Therefore any gain applied to one channel must be applied to all in order to keep the ratios constant.

The Moisture Amplifier and Gain Control of each Amplifier PC board are described below. The description will be of Channel A. Channel B is identical to Channel A. Numbers and references shown in brackets refer to Channel B:

PREAMPLIFIER

U2-A (U3-A) of the OP-270Z amplifier, amplifies the signal from the PbS Detector with a fixed gain of 10. The signal feeds to U2-B (U3-B) which is an adjustable gain amplifier. The gain of the circuit can be controlled by potentiometer R24 (R28). Adjust the potentiometer so that with no paper in the gap and a properly aligned and clean sensor, the peak to peak signal as seen on an oscilloscope attached to pin 8 of U6 (U7) is not clipping. Adjust the signal so that it just starts to clip then reduce it about 15% as a safety margin. It is very important that the signal never clips in service or the calibration of the sensor will be adversely affected.

GAIN CONTROL

From the amplifier section the signal goes into the gain control amplifier U6-C (U7-C). The nominal gain of the stage is 1.2 with no gain switching selected, but a relative gain of 1.0. The gain is determined by R41 (R54), R64 (R65) and R39 (R52). The computer can select gain 0 and/or gain 1. These can be combined to give 4 levels of gain as follows:

Bit0	Bit1	Gain
0	0	1
1	0	3
0	1	10
1	1	30

When Gain Bit 0 is high (+24V on J2-3), pin 16 of U4 (U5), AD2002A, Analogue Switch IC is high. This closes switch 2 to insert R40 (R53) in parallel with R39 (R52) to increase the gain of the stage by a factor of ~3.0. Similarly when Gain Bit 1 is high (+24V on J2-4), then pin 1 of U4 (U5) is high. This closes switch 1 to insert R38 (R51) in circuit so that it forms a potential divider with R41 (R54), in the feedback circuit of U6 (U7). This increases the gain by a factor of ~10. When both gain bit 0 and gain bit 1 are high, the overall gain of the circuit increases by the product of the two gains to ~30.

FULL WAVE RECTIFIER

The sinusoidal signal from the amplifier circuits is used in U8-B to produce a square wave synchronisation signal. This signal is used to turn on and off switch 3 of the U4 (U5) AD202A Analogue Switch. The Analogue Switch switches only half the cycle of the signal from U6 (U7) via C18 (C24), producing a half wave rectified signal to pin 12 of U6 (U7), OP-11EY. This half wave rectified signal, together with the original signal on pin 13 of U6 (U7) produces a full wave rectified signal on the amplifier output, pin14.

RMS CONVERTER

The full wave rectified signal couples to the RMS Converter U6-A (U7-A), OP-11EY, to produce a voltage proportional to the root mean square of the signal waveform. A voltage in the range 0 to 4V is produced.

CURRENT LOOP DRIVER

The voltage from the RMS Converter circuit feeds into a current loop driver circuit formed by U6-B (U7-B), OP-11EY. The output signal is a current in the range 0 to 1mA. This signal feeds to the ADC input.

3.5 PELTIER COOLER CONTROL

The Peltier Cooler control is intended to keep the PbS detector at a constant, low, temperature. The control circuit is U1-A of the LM124. This Operational Amplifier input is a bridge circuit to compare the temperature of the PbS Detector (determined by the thermister) with the temperature setpoint, determined by the potentiometer R6. The circuit controls the current flowing through the power transistors.

The controlled current passes through the Peltier Cooler 1 (Channel A PbS Detector) and into Peltier Cooler 2 (PbS Detector of Channel B). Because all PbS Detectors are mounted to a common heat sink, one reference temperature can be used for all with the cooling current passing to each in series.

To adjust the cooling of the Peltier Coolers, measure the voltage across the cell. For normal room temperatures adjust R6 so that there is about 0.2V across the Cooler. This will allow the cooling to increase when the internal head temperature increases when on-sheet.

3.6 POWER SUPPLY

The power input to the PCB is via J1. The pin assignments are:

J1-1	+5V (via series resistor in cable)
J1-2	+5V (via series resistor in cable)
J1-3	Gnd
J1-4	+12V
J1-5	-12V
J1-6	Gnd
J1-7	-150V
J1-8	Gnd
J1-9	N/C

The high voltage to the PbS Detector is controlled by the zener diodes CR1, 2, 3 and filtered by R70 and C7. All other inputs have capacitive filtering to ground.

3.7 REPLACING THE SENSOR DIFFUSING WINDOW.

Should it ever be necessary to change the moisture source window, proceed as follows:

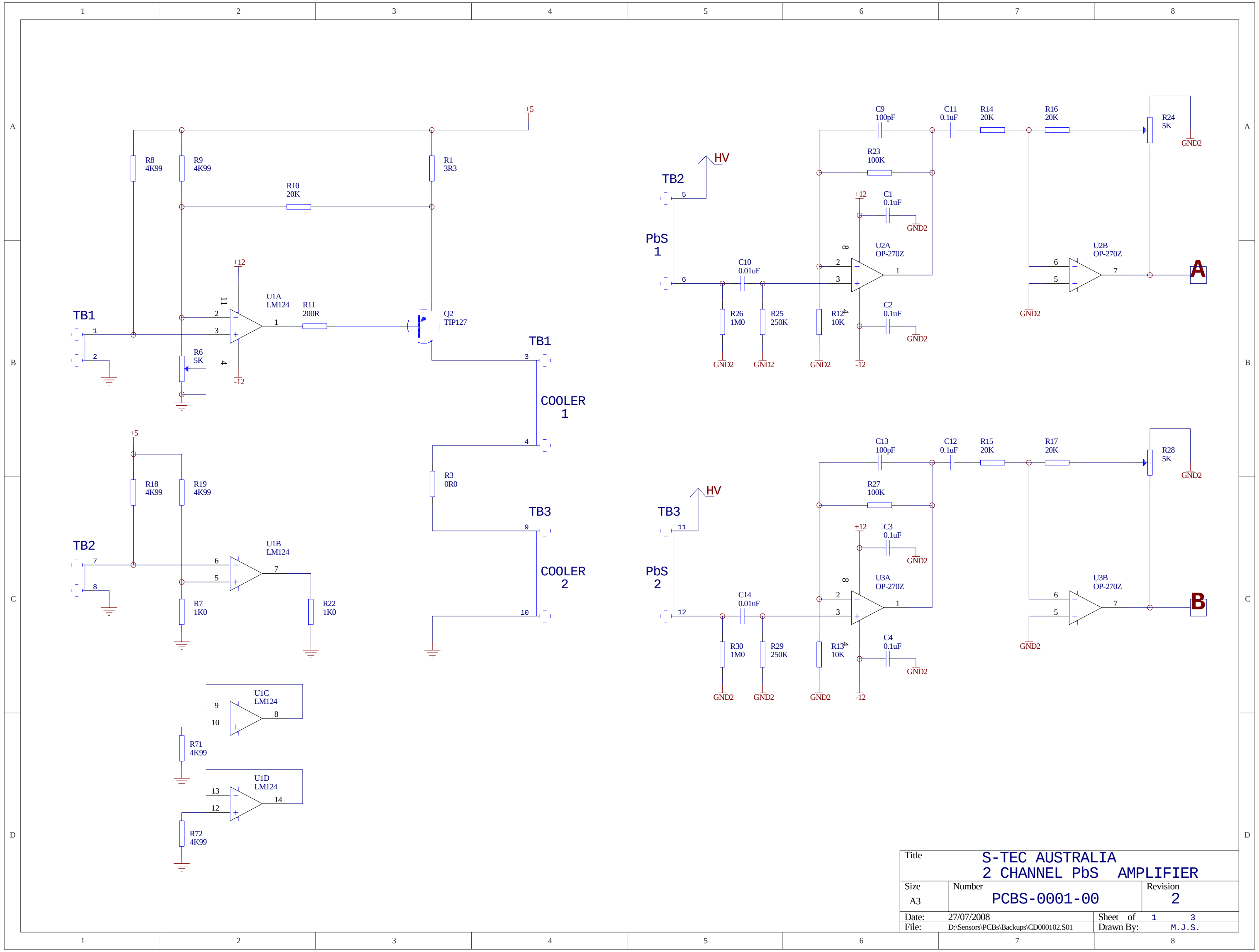
1. Remove the Receiver Assembly and take to a workbench.

2. Note the orientation of the Diffuser - especially the 10mm diameter “hole”.

3. Remove the Ring, Window Holder, complete with the Diffuser Disk, by taking out the eight M4 countersunk screws.

4. Install the new Ring / Diffuser Assembly. MAKE SURE THAT THE ORIENTATION OF THE “HOLE” IS CORRECT.

5. Reinstall the Source Assembly into the heads.



TB1
TB2
TB3
COOLER 1
COOLER 2
PbS 1
PbS 2
HV
A
B
U1A LM124
U1B LM124
U1C LM124
U1D LM124
U2A OP-270Z
U2B OP-270Z
U3A OP-270Z
U3B OP-270Z
Q2 TIP127
Title S-TEC AUSTRALIA
2 CHANNEL PbS AMPLIFIER
Size A3
Number PCBS-0001-00
Revision 2
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Sheet 1 of 3
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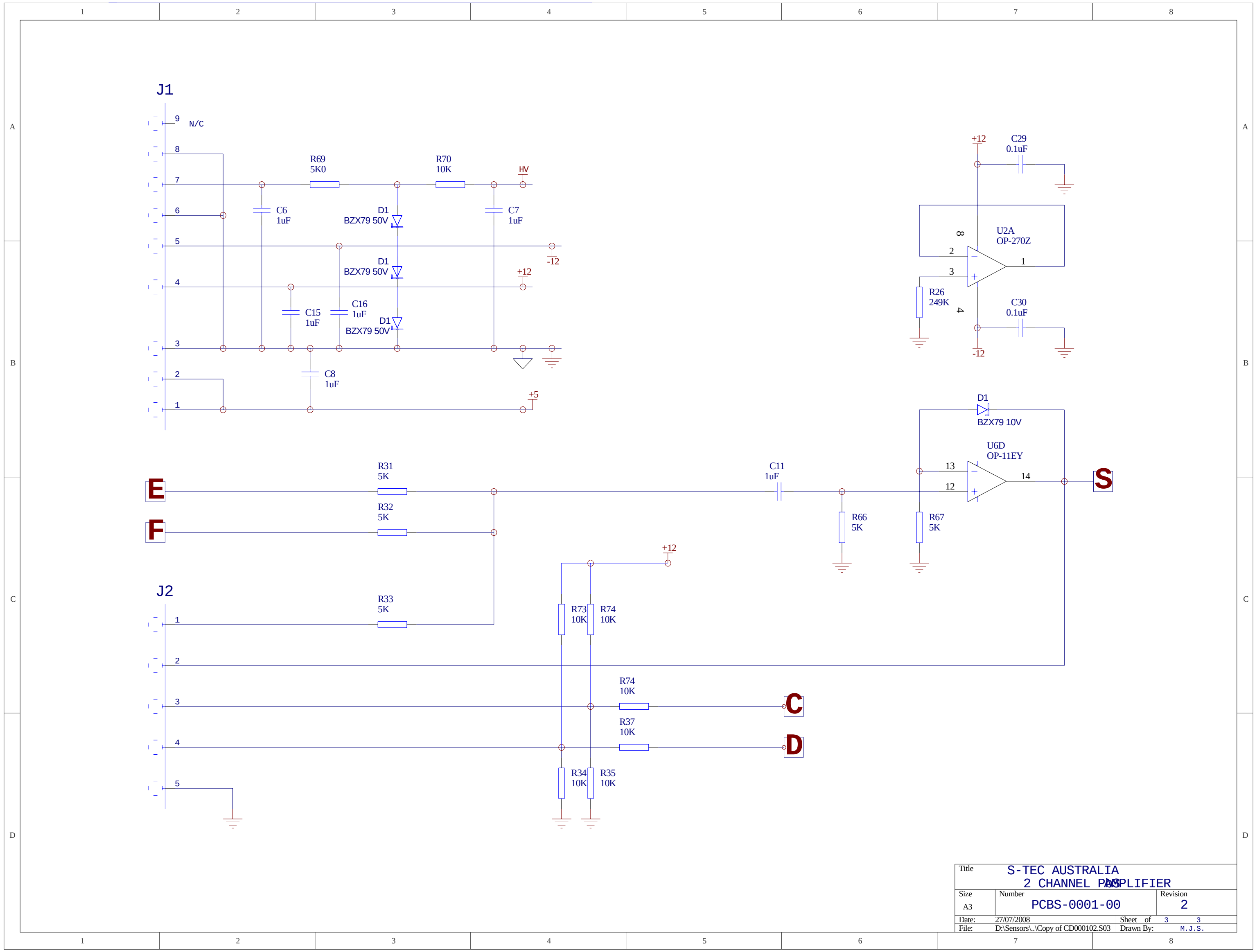
J1
N/C
R69
5K0
R70
10K
HV
C6
1uF
D1
BZX79 50V
C7
1uF
-12
+12
C15
1uF
C16
1uF
C8
1uF
+5
+12
C29
0.1uF
U2A
OP-270Z
R26
249K
C30
0.1uF
-12
D1
BZX79 10V
U6D
OP-11EY
E
R31
5K
F
R32
5K
C11
1uF
R66
5K
R67
5K
S
J2
R33
5K
R73
10K
R74
10K
R74
10K
R37
10K
C
D
R34
10K
R35
10K
Title
S-TEC AUSTRALIA
2 CHANNEL PREAMPLIFIER
Size
A3
Number
PCBS-0001-00
Revision
2
Date: 27/07/2008
Sheet 3 of 3
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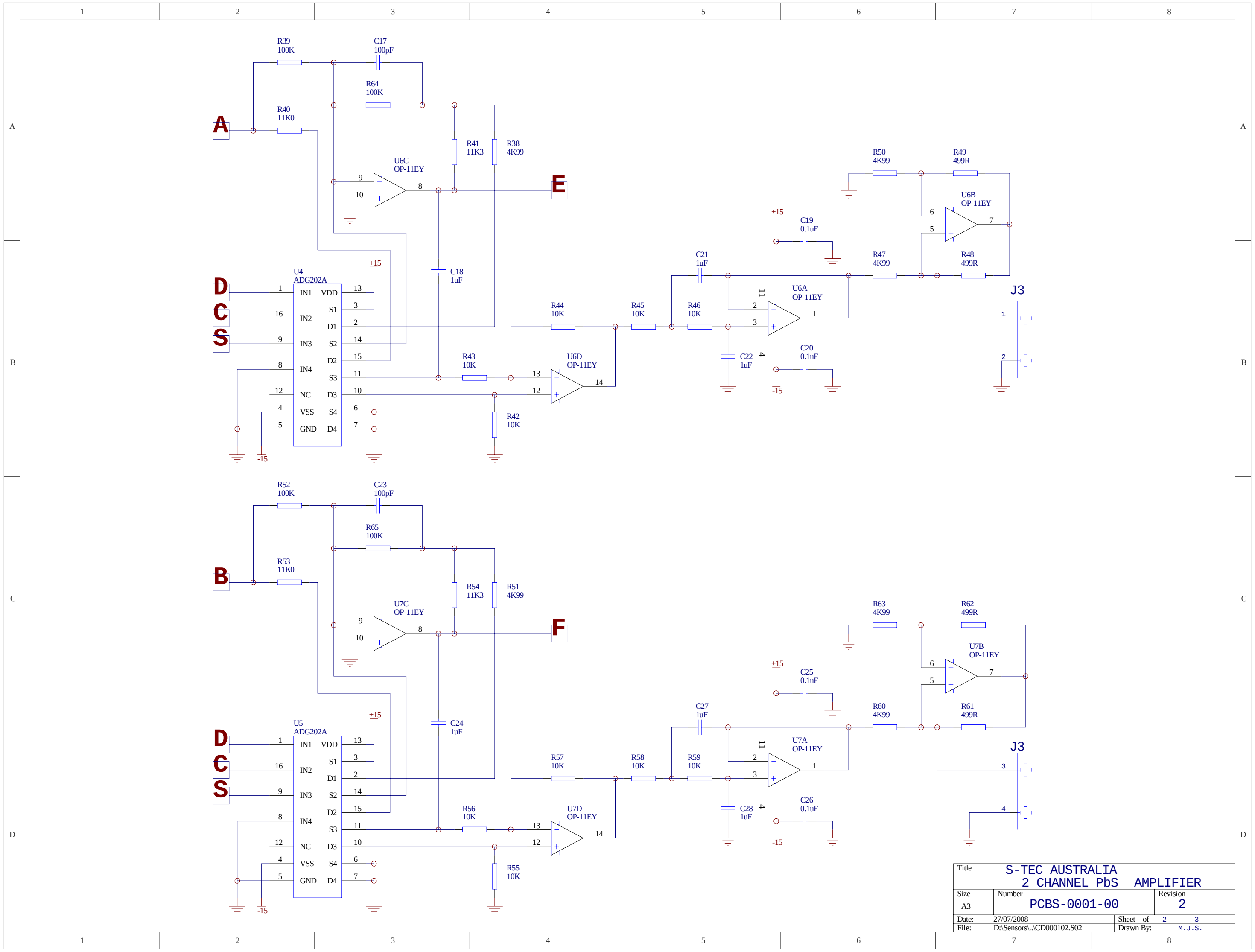
Drawn By: M.J.S.


A
B
C
D
E
F
S
J3
S-TEC AUSTRALIA
2 CHANNEL PbS AMPLIFIER
Size A3
Number PCBS-0001-00
Revision 2
Date: 27/07/2008
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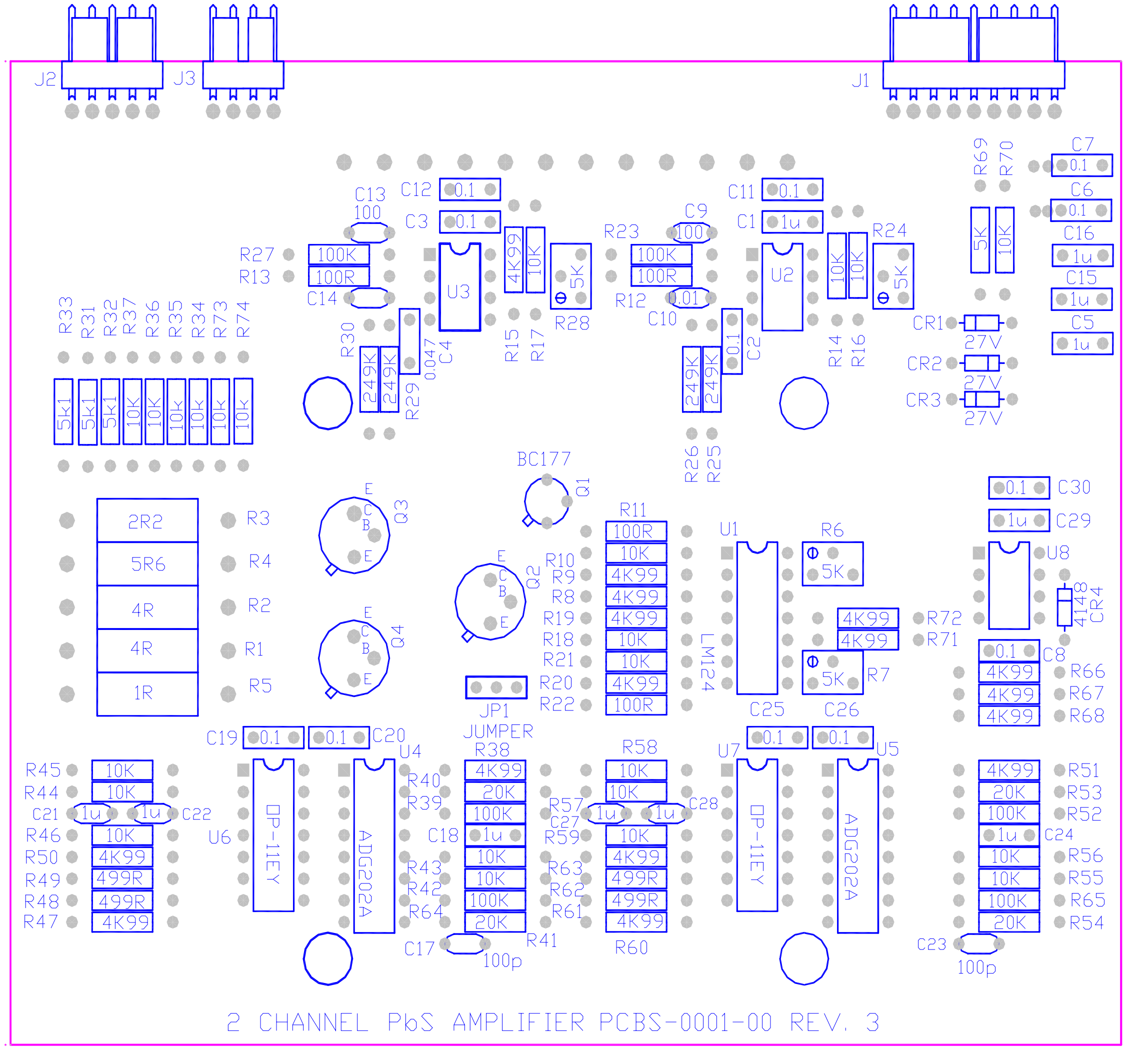
Sheet 2 of 3
Drawn By: M.J.S.


J2
J3
J1
C13 100
C12 0.1
C3 0.1
C11 0.1
C1 1u
C9 100
R27 100K
R13 100R
C14
U3
4K99
10K
5K
R28
R23 100K
100R
R12 0.01
C10
U2
10K
10K
5K
R24
R69
R70
5K
10K
C7 0.1
C6 0.1
C16 1u
C15 1u
C5 1u
CR1 27V
CR2 27V
CR3 27V
R33
R31
R32
R37
R36
R35
R34
R73
R74
5k1
5k1
5k1
10K
10k
10k
10k
10k
10k
R30
249K
249K
R29
0.047
C4
R15
R17
249K
249K
0.1
C2
R14
R16
R26
R25
2R2 R3
5R6 R4
4R R2
4R R1
1R R5
Q3
Q4
BC177
Q1
Q2
E C B E
R11 100R
R10 10K
R9 4K99
R8 4K99
R19 4K99
R18 10K
R21 10K
R20 4K99
R22 100R
U1
LM124
R6 5K
R7 5K
4K99 R72
4K99 R71
C30 0.1
C29 1u
U8
4148 CR4
C8 0.1
4K99 R66
4K99 R67
4K99 R68
JP1 JUMPER
C25
C26
C19 0.1
C20 0.1
U4
R38
C17 100p
R45 10K
R44 10K
C21 1u
1u C22
R46 10K
R50 4K99
R49 499R
R48 499R
R47 4K99
U6
OP-11EY
ADG202A
R40
R39
C18
R43
R42
R64
4K99
20K
100K
1u
10K
10K
100K
20K
R41
R57
C27
R59
R63
R62
R61
R58
10K
10K
1u
1u
C28
10K
4K99
499R
499R
4K99
R60
U7
0.1
0.1
U5
OP-11EY
ADG202A
4K99 R51
20K R53
100K R52
1u C24
10K R56
10K R55
100K R65
20K R54
C23 100p
2 CHANNEL PbS AMPLIFIER PCBS-0001-00 REV. 3

CHAPTER 4:

MOISTURE SENSOR CALIBRATION

CHAPTER 4

4.0 MOISTURE SENSOR CALIBRATION

4.1 CALIBRATION OVERVIEW

The Moisture Sensor is capable of very accurate measurement of the moisture of paper as it is being made on a paper machine. The Sensor itself, together with the ADC, provides signal inputs to the computer. The frequencies are a measure of the amount of Infra-Red signal being received by each channel. Each, of up to 4 channels (2 channels are standard), has a narrow-band optical filter so that only signals in this wavelength band can be detected. From these signals and the Basis Weight of the paper as measured by the Basis Weight Sensor, the computer can calculate the % moisture content of the paper. The computer can also compensate for any dirt build-up or electronic drift by measuring the frequencies during standardisation when there is no paper in the gap. To achieve the above, the computer is programmed with proprietary calibration algorithms.

4.2 CALIBRATION ALGORITHMS

The following algorithms are proprietary and must not be disclosed to others. These Algorithms are programmed into the computer and cover the calibration for the 2-channel moisture sensor.

WW	=	water weight
$I_{1.85}$	=	signal at 1.85µm
$I_{1.93}$	=	signal at 1.93µm
$I_{1.85(stdz)}$	=	1.85µm stdz signal
$I_{1.93(stdz)}$	=	1.93µm stdz signal
WW_o	=	calibration constant
R_o	=	calibration constant
A	=	calibration constant
B	=	calibration constant
BW	=	Basis Weight of the paper from the Basis Weight Sensor

(1) $$\mathbf{R} = \frac{I_{1.85} \times I_{1.93(stdz)}}{I_{1.93} \times I_{1.85(stdz)}}$$

(2) $$\mathbf{K} = \frac{A}{1 + B\left(\frac{BW}{(100g/m2)}\right)}$$

(3) $$\mathbf{WW} = WWo + K(R - R_o)$$

(4) $$\mathbf{\%\ Moisture} = 100 \times \frac{WW}{BW}$$

Standardise (Stdz):

At standardise the channels are measured while there is no paper in the gap. The average signal during time of the standardise is used to compute the standardise values:

$\mathbf{I_{1.85(stdz)}}$ = 1.85µm stdz signal
$\mathbf{I_{1.93(stdz)}}$ = 1.93µm stdz signal

On Sheet:

While scanning on sheet the frequencies are continually measured in order to calculate the moisture at each data box position. The measured values during scanning are:

$\mathbf{I_{1.85}}$ = signal at 1.85µm (each databox)
$\mathbf{I_{1.93}}$ = signal at 1.93µm (each databox)

Dynamic Standardisation:

Dynamic standardisation corrects for any drift due to dirt or other cause between full standardisations. It is not normally necessary to dynamically correct the moisture sensor calibration between standardises.

ALTERNATIVE 3-CHANNEL FORMULA – SPECIAL APPLICATIONS

R1 = Normalised REF/MES
R2 = Normalised REF/FIBRE
K1 = Constant
K2 = Constant
K3 = Constant, tweek
K4 = Constant
K5 = Constant, nominally 1.0
K6 = Constant

%MOI = (K1 LOG R1 + K2 LOG R2 + K3) / (K4 LOG R1 + K5 LOG R2 + K6)

4.3. STATIC CALIBRATION

Static Calibration of the sensor in the S-tec factory is normally carried out using bagged paper samples of known moisture content. A simpler alternative for site use is to use conditioned paper of known basis weight. The moisture content of the conditioned paper can be determined in the laboratory.

The procedure for static calibration should be broken down into the following steps:

1. Sensor stability check.
2. Sampling.
3. Calculation of the calibration constants.
4. Recheck of calibration

A description of each of these steps is below.

4.3.1 SENSOR STABILITY CHECK

Before starting the calibration procedure it is important to ensure that the sensor is stable. Any problems with stability should be resolved before proceeding. Stability of the sensor means that the sensor gives repeatable and consistent ratio readings for the same conditions.

The stability check is performed by doing a total of 30 successive standardise checks. The standardize is commanded from the video screen. The results should be tabulated as follows:

REFERENCE (1.8) VOLTAGE	*MEASURED (1.9) VOLTAGE*	*RATIO REF/MES*
Stz 1 Ref	Stz 1 Mes	Stz 1 Ratio
Stz 2 Ref	Stz 2 Mes	Stz 2 Ratio
Stz 3 Ref	Stz 3 Mes	Stz 3 Ratio
Stz 4 Ref	Stz 4 Mes	Stz 4 Ratio
--	--	--
Stz 30 Ref	Stz 30 Mes	Stz 30 Ratio
Ave Ref	Ave Mes	Ave Ratio 2-signal Ratio

The variation of the counts is not important but any variation of the ratio of the counts is important. The standard deviation (sigma) of the ratio, as tabulated above, should not exceed about 0.005.

4.3.2 SAMPLING

First collect 15 samples of paper of different basis weights and label them 1 to 15. The samples should have a large weight range - at least 3:1. If necessary use more than one sheet of the same paper as a single sample in order to extend the range. Leave the samples near to the paper machine over night so that the moisture of the paper conditions to the environment of the paper machine. Insert each paper sample into the gap while performing a sample check. For each sample do 5 sample checks (A to E) moving the paper a little between each check. Note the values for each sample check. The sample check is commanded from the video screen. For heavier samples it may be necessary to change the sensor.

Record the results of the sampling (voltage) as shown in the table below:

Sample # Voltage	*Sample A*	*Sample B*	*Sample C*	*Sample D*	*Sample E*	*Average*
Sample BW g/m2	xxx.x	xxx.x	xxx.x	xxx.x	xxx.x	
Sample 1 Ref	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
Sample 1 Mes	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
Sample 2 Ref	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
Sample 2 Mes	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
Sample 3 Ref	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
Sample 3 Mes	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
Sample 15 Ref	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
Sample 15 Mes	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx

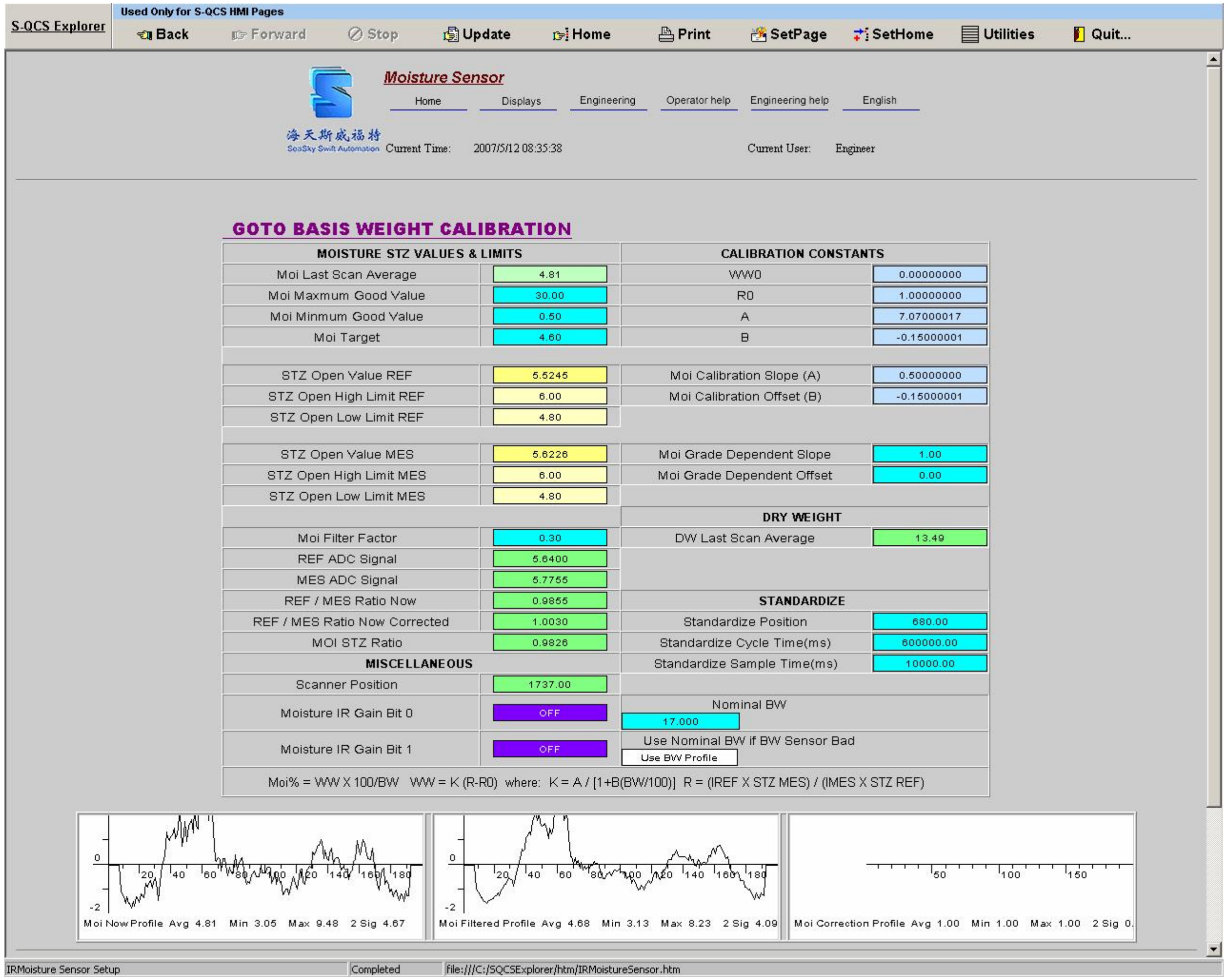
After completing the above sampling, take all of the paper samples into the laboratory to determine the conditioned % moisture content. To do this weigh each sample accurately on a precision balance, then place all samples in an oven at 105°C overnight. After thorough drying (at least 8 hours) remove each sample in turn from the oven and place in a plastic bag and seal. Quickly weigh each sample+ bag then weight the bag empty. The % moisture content of the sample can be determined as follows:

$$\% \text{ Moisture} = \frac{\text{Dry Sample+Bag Weight} - \text{Bag Weight}}{\text{Original Sample Weight}} * 100$$

When all the results of the static sampling have been tabulated, fax these and the stability check results to S-tec. S-tec engineers will use a computer program to fit the best calibration curve through the data and calculate the optimum calibration constants.

S-tec

MOISTURE SENSOR CALIBRATION



4.4 DYNAMIC CALIBRATION

Dynamic calibration is needed to make the sensor read the correct value of moving paper on a paper machine. Although the sensor may be very accurate on static (non-moving) samples, machine conditions can change the calibration depending on such things as moisture gain or loss from the point of measurement to the point of sampling. Whatever the source of any error when measuring moving paper on the machine, a method is needed to check the calibration of the sensor and make any necessary corrections to the calibration.

There are 3 major ways to calibrate the Moisture Sensor on the paper machine. These are:

4.4.1 CALIBRATION TO MILL LABORATORY

This method simply compares the sensor end-of-reel Moisture measurement with that of the Mill laboratory result. To do this well, it is essential that a large number of comparisons are made before adjusting the sensor calibration.

The advantage of this method, which is useful for getting the sensor to the correct “ball park” reading, and that it is simple and the sensor after correction reads similar values to that of the laboratory.

The disadvantage of this method is that the laboratory result is often noisy, can have a systematic error, often changes as the laboratory person changes at each shift, and most importantly, proper precautions are rarely taken by laboratory people to protect the samples from moisture gain or loss. In addition samples measured by the mill laboratory are often not left in the oven for long enough or the oven is not at the correct TAPPI standard temperature of 105°C resulting in either improper drying or the removal of volatiles.

This method, then, is recommended only to get the sensor reading close to the correct value.

4.4.2 SINGLE POINT MEASUREMENT

In this method the scanner heads are put in single point (fixed position on sheet) to continuously measure the Moisture of the paper in that position. Towards the end of the reel, a card is placed in the paper to indicate the start of measurement. At the same time the single point readings are integrated and averaged until reel turn-up occurs.

When the reel is out, many samples are cut from the paper in the position of the sensor during single point measurement. The average Moisture reading calculated from the samples, is compared to the average sensor measurement. If 3 or more such samples (on different reels) show a consistent error, then the sensor calibration is adjusted by this amount.

The advantage of this method is that it is reasonably accurate and not too difficult to do. It does use laboratory sampling methods but precautions should be taken to avoid moisture gain or loss - such as using polythene bags to hold the samples.

The disadvantage of this method is that it can sample only one spot each time and so can give only a required intercept change to the calibration. More sampling in different CD positions is needed to determine if there is a slope error. If the paper is uneven with narrow moisture streaks, then it is difficult to align the measured paper with the sampled paper. This is especially so given the narrow measurement beam of the sensor (10mm diameter light beam at the source diffuser window with an effective width of 15 - 20mm). The paper samples taken will always be larger than 15-20mm measured by the sensor, so sensor measured paper and laboratory sampled paper will not be exactly the same.

4.4.3 CD SAMPLING METHOD

With this method the trend average profile at the reel turn-up is compared to multiple samples of paper taken across the full width of the reel after turn-up. One way to do this is to slab off the top 25mm of paper onto the floor. With a template of know area and sharp knife, samples are taken across the full width of paper. By alternating the position of the sample in the MD direction, all the paper can be sampled. By cutting into the paper layers, many pieces of paper can be averaged in each sample. Proper polythene bagging procedures need to be adhered to in order to avoid the possibility of moisture gain or loss in the long time elapsed from the reel turn-up to the measuring the sample weights in the laboratory.

After weighting each sample and calculating the Moisture from the sample weight (less bag) and the dry paper weight (less bag), the graph of sample basis weight profile can be compared to the graph of sensor profile to show any differences.

The advantage of this method is that the full CD width of the paper is measured at one time and compared with the CD profile. From this result both intercept (offset) and slope (scale) errors can be determined and corrected.
The disadvantage of this method is that it is very time consuming (allow one hour + 8 hours drying time). It can only be performed during stable running of the machine when the end of reel profile can be taken as truly representing the measurement of the slabbed-off paper.

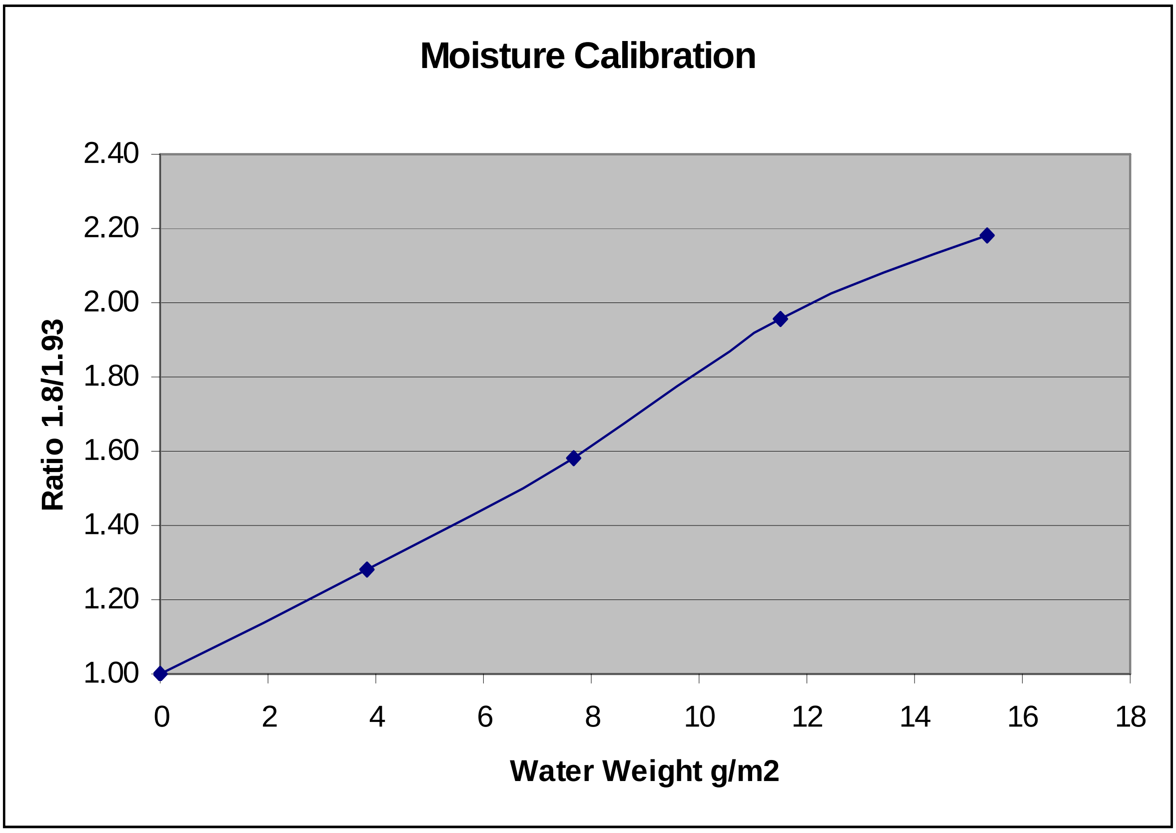
4.5 SENSOR STABILITY WORKSHEET

STZ NUMBER	*REFERENCE (1.85) VOLTAGE*	*MEASURED (1.93) VOLTAGE*	*RATIO REF/MES*
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			
AVERAGE			
SIGMA			

4.6 SENSOR SAMPLING WORKSHEET

Sample # Clean Sensor	*Sample A*	*Sample B*	*Sample C*	*Sample D*	*Sample E*	*Average*
Sample BW g/m2						
Sample 1 Ref						
Sample 1 Mes						
Sample 2 Ref						
Sample 2 Mes						
Sample 3 Ref						
Sample 3 Mes						
Sample 4 Ref						
Sample 4 Mes						
Sample 5 Ref						
Sample 5 Mes						
Sample 6 Ref						
Sample 6 Mes						
Sample 7 Ref						
Sample 7 Mes						
Sample 8 Ref						
Sample 8 Mes						
Sample 9 Ref						
Sample 9 Mes						
Sample 10 Ref						
Sample 10 Mes						
Sample 11 Ref						
Sample 11 Mes						
Sample 12 Ref						
Sample 12 Mes						
Sample 13 Ref						
Sample 13 Mes						
Sample 14 Ref						
Sample 14 Mes						
Sample 15 Ref						
Sample 15 Mes						

Example Calibration Curve for IR Moisture (Newsprint Application)



CHAPTER 5:

KEY SENSOR COMPONENTS

CHAPTER 5

5.0 KEY COMPONENTS

COMPONENT	MODEL	MANUFACTURER	COUNTRY OF ORIGIN
Chopper Motor	3153K024BRC with speed control	Faulhaber	Germany
Lamp	6424 PHILIPS GBA 15W 6V BA15D 6°	Philips	France
Lenses	Various	Meles Griot / Azure Photonics	Germany / China
IR Filters	IR Band Pass	Spectrogon	Sweden
Diffuser Mirrored Windows	Pyrex / Gold / Diffuer	S-tec / Azure	Australia / China
PbS Detectors	Calsensors	AT2-37T	USA
ICs	OP-270 / OP-11 / AD-202 / LM-124	Various	USA
Splitter Optics	S-tec	S-tec	Australia / China
Metal Parts	Anodized/alodyne Aluminium	S-tec	Australia / China