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Resistance Array Tool

RESISTANCE ARRAY TOOL

12 Sensor Springbow, 1¹¹/₁₆" , Ultrawire™

Operational & Maintenance Manual



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0 ABOUT THIS MANUAL

0.1 MANUAL HISTORY

Date	Issue	Description	Auth	Chk	App
27/03/08	A	Initial Release.	FV/RS	PS	PS
08/04/08	B	See ECR5449 (WD-85798 from Iss PT3 to PT4)	RS	PS	PS
15/05/09	C	Section 4.1.3 (4) correction of tool current. Also see ECRs 4814, 5370, 5390, 5415, 5429, 5437, 5525, 5570, 5661, 5706, 5735, 5771, 5835 & 5981.	RS	PS	PS

0.2 UPDATES TO BE USED WITH THIS MANUAL

Consult the CD Directory for the appropriate Manual Updates to be used with this Manual.

0.3 TECHNICAL HELP

For further technical help contact Sondex as follows:

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0.4 FEEDBACK

Please help us improve future issues of this manual by sending your comments or corrections to www.ge-energy.com/oilfield, referencing the document number.

Thank you.

Photographs and sketches are for illustration purposes only. Depending on the tool model that you have, certain features or dimensions may differ from those shown.

Documents from external sources (i.e. MSDS), supplied with/referenced in this manual, are considered the latest version at time of manual issue. However, the document can be altered by the external source without prior notice to Sondex.

1 EQUIPMENT

The Resistance Array Tool (RAT) is designed to solve the problem of accurate fluid phase identification in horizontal or highly deviated wells. It is run centralised within the wellbore, ideally combined with an Inclinator tool to aid interpretation.

The tool has an array of 12 specially developed miniature sensors, mounted on the inside of a set of springbows. Each sensor senses the apparent resistance of the fluid at a specific point across the area of the pipe so that the time variation of the characteristics can be monitored.

The monitored resistances, as they vary with position and time, can be interpreted to improve the understanding of what is flowing through the pipe. This insight can then aid decisions about maintenance or further development of the well or pipeline.

Because the measurements are taken in a single plane across the diameter of the wellbore, rather than spaced along it, an accurate cross-sectional plot can be generated. Optional software can be used to provide a 3D image of the phases along the well.

The use of springbows allows the tool to be used when running in or out of the well and minimises power requirements, particularly when deployed using Memory recording.

1.1 OPERATING PRINCIPLE

Water and hydrocarbons (oil or gas) often do not form a solution. Instead the smaller constituent appears as bubbles within the majority fluid. The bubbles may be very small, as in an emulsion, or become very large, resulting in total separation into layers.

To optimise the operation of a well, it is useful to understand the relative proportions of water and hydrocarbons in a pipeline. Water generally contains sufficient salt to make it significantly lower in resistivity than hydrocarbons, which have very low conductivity. By measuring the resistance at different points across the pipe, a clearer view of the proportion of water/hydrocarbons and the presence of bubbles can be gained.

1.2 APPLICATIONS

- Phase identification in horizontal & highly deviated wells.
- Calculation of the percentage of each phase present.
- Plotting of phase composition along the wellbore.
- Identification of water entry areas.
- Changes of wellbore fluids with time or different production rates.



Figure 1.1 RAT

1.3 INTERFACING & TOOL COMBINATIONS

- Simultaneous operation with other Sondex Ultrawire™ tools.
- Memory or SRO operations.
- Combines with PIA to give well inclination.
- Standard 1³/₁₆" UN 12tpi Sondex or GO end connectors.

1.4 SPECIFICATION

Parameter	Specification	Remarks
Tool Address	31	
Max. Pressure	15,000psi	
Max. Temperature	177°C	
Nominal Diameter	1 ¹¹ / ₁₆ " (43mm)	Springbow fully closed.
Make-up Length	51.4" (1305mm)	
Overall Length	55.3" (1405mm)	Including thread protectors.
Depth Offset	15.4" (391mm)	From bottom of tool. Fully open.
Weight	16.2lbs (7.35kg)	
Number of sensors	12	1 sensor per springbow.
Width of springbow	0.25" (6.35mm)	
Telemetry	Ultrawire™	
Operating Current		
• Logging mode	<100mA	
Recommended Casing sizes	3.5" - 7"	
Max. Frame Rate	6 Hz	Maximum polling rate for new data. Faster polling will result in some 'Not Ready' responses.
Scan time per sensor	4.8ms	Time interval between measurements at each sensor.
Orientation - rotation	±4.5°	5° from vertical to 100°
Orientation - deviation	±2.5°	Full range (0° to 100°)
End threads (top/bottom)	1 ³ / ₁₆ " 12 UN2A GO (female/male)	
End connectors (top/bottom)	4mm single conductor (male pin/female socket)	Sondex Ends

2 SAFETY

In normal use, there are few specific safety instructions for the safe handling of the RAT. The following are guidelines only and should be followed in addition to any specific company and regional regulations.



Warning!

HOT WORK! Sondex equipment may, under certain circumstances or failure modes, become a potential source of ignition. Using it must therefore be considered "**HOT WORK**" and appropriate precautionary procedures should be followed when testing at surface in areas where there is a risk of gas leaks or other potentially explosive atmospheres.

There are no springs inside the tool that could pose a hazard through high compression/tension. However, one spring is visible from the outside. This spring is under low compression and therefore poses very little hazard to the operator.



Warning!

Heavy Equipment

The tool is heavy and appropriate safe handling procedures should be followed when moving it.



Caution!

The sensors may be damaged when the tool is dropped. To protect the sensors, the closing ring must be fitted around the springbows to avoid damaging the sensors. The tool must be transported in its carry tube and/or flight case.



Caution!

Electro Static Discharge (ESD)

All tools with electronic boards that contain solid state circuits (transistors, diodes, semiconductors) may become damaged when contacted with an electrostatic charge.

When handling tools, which contain electronic parts that are ESD sensitive, the following guidelines should be followed to reduce any possible electrostatic charge build-up on the user's body and the electronic parts:

- Always ensure proper ESD precautions are taken when handling electronic parts that are ESD sensitive during maintenance.
- Avoid touching the tool electronics, unless stated otherwise in this manual.

Note that ESD is less likely to affect tools when the housing is fitted.

The tool contains very sensitive electronic circuitry. Consequently the tool should be handled with care.



Liquid O-ring

LOR101 is used for lubricating the tool during maintenance. Contact with skin or eyes can be harmful. For more details, refer to the Material Safety Data Sheet for Liquid O-ring.

2.1 RECOMMENDATIONS



The product should be installed, adjusted and serviced by qualified electrical maintenance personnel. Improper installation or operation of the equipment may cause injury to personnel or equipment. Before beginning any installation or commissioning work ensure that electrical power is disconnected and locked out.

NOTE: Installation must meet National Wiring Regulations in accordance with IEC/UL 61010 latest revision.

WARNING 1: The outer casing of the product should be connected to a known good system ground before making any other electrical power connection. This system ground to be maintained until all electrical power connections are disconnected and locked out.

WARNING 2: Units with exposed Electrical Connectors are supplied with protective insulating end caps bearing a warning of High Voltage. These end caps should only be removed when Electrical Power is disconnected and locked out for the purposes of interconnection to other Units. Under no circumstances should equipment be operated with the Electrical Connectors exposed.

WARNING 3: Units with moving parts such as callipers can be activated immediately on application of Electrical Power. A safe area should be established around any such Units before the application of Electrical Power.

WARNING 4: Units with moving parts such as springs can retain significant Potential Energy. Great care should be exercised when removing Closing Rings or handling over tightened assemblies.

WARNING 5: Units containing seals may entrap pressure. Disassembly should only be carried out in accordance with recommended procedures ensuring the release of pressure prior to the disengagement of cap threads.

WARNING 6: If the equipment is not installed, commissioned and used in accordance with the manufacturer's specifications, protection provided may be impaired.



Standard Personal Safety Gear must be worn at all times including but not limited to: Safety glasses, gloves and steel-toed boots.

Equipment exceeding 18Kg in weight should be handled with extreme care. Heavy items should be mechanically lifted. Any installation of equipment over 10Kg to be lifted over 1 metre should be at least a two man lift. Good lifting practice should be exercised at all times including but not limited to:

- Use of correct personal safety gear.
- Lift using legs not back
- Not proceeding with a lift in the presence of any doubt of completing the lift safely
- Use of mechanical lifting aids wherever possible
- Ensuring work area is free of clutter and tripping hazards

3 THEORY OF OPERATION

3.1 BLOCK DIAGRAM

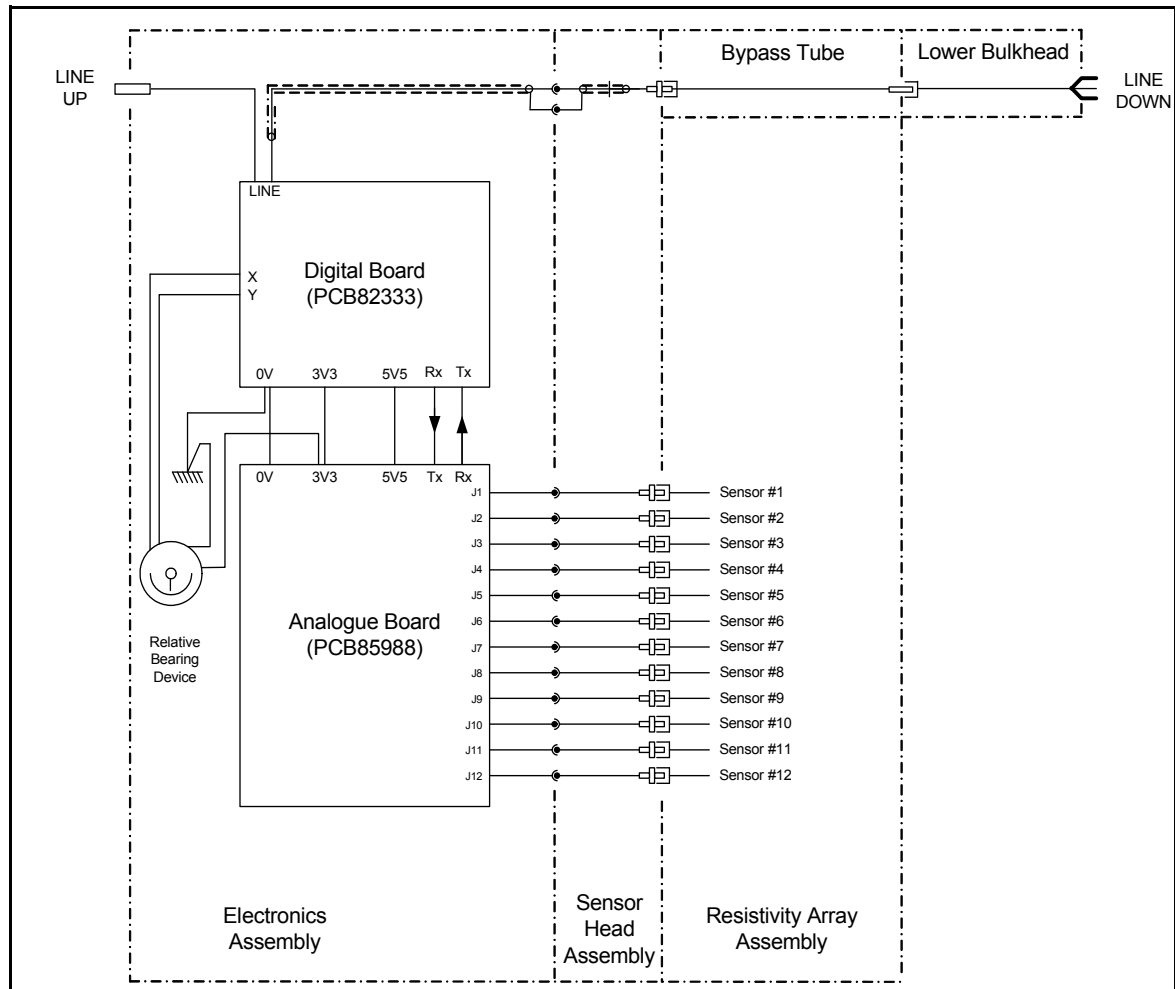


Figure 3.1 Block Diagram

3.2 DESCRIPTION

3.2.1 TOOL DESIGN PRINCIPLE

Water and hydrocarbons (oil or gas) often do not form a solution. Instead the smaller constituent appears as bubbles within the majority fluid. The bubbles may be very small, as in an emulsion, or become very large, resulting in total separation into layers.

Typically, when drilling for, and ultimately extracting, oil and gas, water also enters the pipeline. In a pipeline which is non-vertical, the lighter fluids tend to be more concentrated along the upper side of the pipe. Lighter fluids will also tend to flow faster in an upward direction than the heavier ones, even to the extent that particular fluids can end up going in the opposite direction to the general flow. This is illustrated in [Figure 3.2](#).

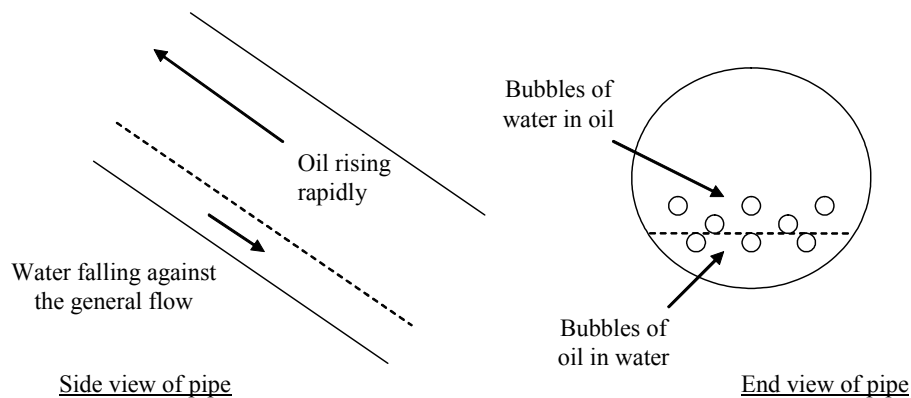


Figure 3.2 Water/Oil mix in elevated pipe

To optimise the operation of a well, it is useful to understand the relative proportions of water and hydrocarbons in a pipeline. The water generally contains sufficient salt to make it significantly lower in resistivity than hydrocarbons which have very low conductivity. By measuring the resistance at different points across the pipe, a clearer view of the proportion of water/hydrocarbons and the presence of bubbles can be gained.

3.2.2 MECHANICS

The Resistance Array Tool incorporates 12 sensors arranged around the periphery of the tool, which are deployed toward the inner surface of the pipe via springbows. By placing sensors in different parts of the pipe's cross section, the variation in fluid content can be monitored. The tool is closed while running in hole and opens automatically when it leaves the tubing and enters the larger diameter of the casing. If the tool passes any restriction, either up or down, the bow springs will collapse to prevent damage to the sensors.

The sensor bodies are clipped onto the bowspring.

The key sensor mechanics comprise:

- a probe tip that ultimately connects to the sensor electronics input.
- a reference contact, typically at earth potential.

The electrodes in the sensor are positioned within a protective shroud.

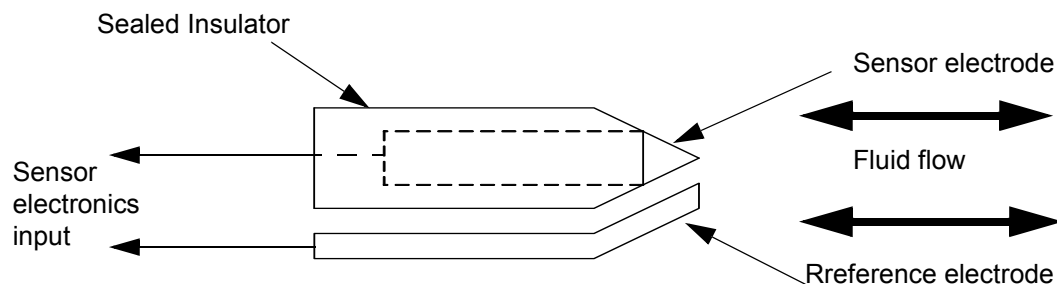


Figure 3.3 Sensor overview

A further sensor provides information about the orientation of the tool and therefore the array.

3.2.3 ELECTRONICS

The tool operates on Ultrawire™ telemetry and accumulates data for delivery at up to 6 times per second. The tool may be polled in excess of 100 frames per second, but this results in 'Not Ready' messages. However, other parts of the system, e.g. wireline telemetry speed, will usually limit the maximum frame rate significantly. For example, the default configuration of the Warrior logging software is set at 6 samples/second.

Further details can be found in [Section 6 Electrical Description](#).

3.2.4 RELATIVE BEARING DEVICE

The relative bearing device is a pendulum based device, which is used to measure tool rotation. It is not intended to be a survey instrument, but merely to indicate which sensor is uppermost.

3.3 MEASUREMENT OVERVIEW

3.3.1 SIGNAL PROCESSING

Resistance measurements can be made between the probe tips, or electrodes, at a rate of up to 10,000 samples per second. Each measurement results in a number that is proportional to the logarithm of the resistance detected between the sensor electrodes, and therefore the fluid resistivity, with a range of 5 decades of resistance.

Each sensor is sampled twice every 4.8mS. The resulting information is presented through the Ultrawire™ telemetry in two ways.

The first way is to provide a mean and standard deviation. This pair of numbers is provided for each of the sensors typically six times per second, depending on the configuration of the logging software. At a 30 feet per minute, this provides a measurement resolution of 1".

The second way is to provide histograms of measurements for each of the sensors. Data for these are collected over periods 12 times as long as for the mean and standard deviation and this provides a more detailed view of the distribution of measurements being made. Each histogram is divided into 16 bins of values.

The distribution of values is illustrated in [Figure 3.4](#).

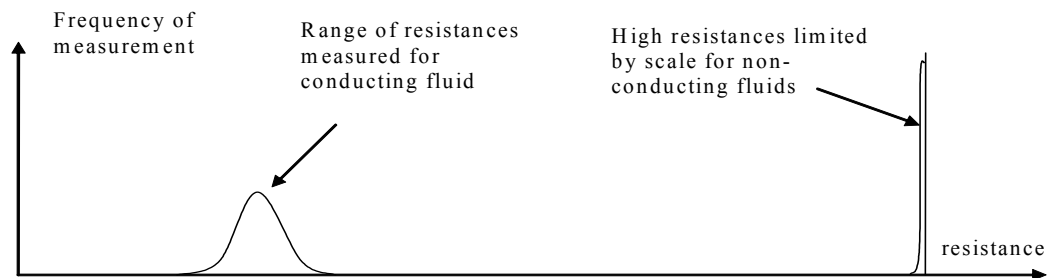


Figure 3.4 Distribution of measured values

3.3.2 MEAN & STANDARD DEVIATION**Generation of the values**

For each of the sensors, resistance values are measured many times over the period being summarised.

The mean value can be calculated as follows:

$$m = \frac{\sum(R)}{n} \quad \text{Equation 3.1}$$

where:

- m = Mean value.
- R = Measured values.
- n = Number of samples taken.

To calculate the standard deviation, the following function can be used:

$$S = \sqrt{\frac{\sum(R - m)^2}{n}} \quad \text{Equation 3.2}$$

or

$$S = \sqrt{\frac{\sum(R^2)}{n} - m^2}$$

where:

- S = Standard deviation.
- m = Mean value.
- R = Measured values.
- n = Number of samples taken.

Mix of fluid types

The conducting fluids (water) will have an apparent resistance as measured with the sensor probe of R_c . This value may be determined by a variety of means including making measurements in zones of the well containing water, by taking a sample and dipping the probe into it, or by assuming the lowest value measured by the probe over the complete well is water.

The insulating fluids (hydrocarbons) similarly have an apparent resistance as measured by the sensor probe of R_i . Because the resistivity of a typical hydrocarbon is practically infinite, it should be noted that for practical purposes the circuit will either:-

- Hit the end of its scale range and in which case the mean will be fixed at the limit and the standard deviation will be zero.
- Report a slightly lower value which reflects the presence of contaminants on the probe tip. Providing these contaminants are still a very high resistance compared to the water in the well then the accuracy of the method will not be jeopardised.

Calculation of Hold-up

The proportion of water in the fluid mix, in the well, is commonly known as hold-up. To determine the hold up, the following calculation should be made:

$$h = \frac{A_w}{A_t} \quad \text{Equation 3.3}$$

where:

- h = Hold-up.
- A_w = Cross sectional area of the well that is occupied by water (at any one position along the axis of the well).
- A_t = Cross sectional area of the well that is available to flowing fluids (typically pipe internal diameter).

Where the readings are polarised between a resistance R_i for the insulating fluid or R_c for the conducting part, the mean reading will be:

$$m = (h \times R_c) + (1 - h) \times R_i \quad \text{Equation 3.4}$$

where:

- m = Mean value.
- h = Hold up.
- R_c = Conducting fluid resistance.
- R_i = Insulating fluid resistance.

Similarly the standard deviation will be

$$S = \sqrt{(h \times S_c^2) + ((1 - h) \times S_i^2) + h \times (1 - h) \times (R_i - R_c)^2} \quad \text{Equation 3.5}$$

where:

- S = Standard deviation.
- h = Hold up.
- S_c = Standard Deviation of conducting fluid resistance.
- S_i = Standard Deviation of insulating fluid resistance.
- R_c = Conducting fluid resistance.
- R_i = Insulating fluid resistance.

The sampling period over which the mean average is taken must be long compared to the natural variations in the fluid flow regime and any prior sampling electronics. Typically 1 second would be sufficient.

Manipulation of the above equations leads to a formula for holdup that is based on the measured mean, standard deviation and the resistance R_i :

$$h = \frac{x}{x + S^2} \quad \text{Equation 3.6}$$

where: $x = (R_i - m)^2$

where:

- h = Holdup.
- S = Standard deviation.
- R_i = Insulating fluid resistance.
- m = Mean value.

This only holds for the distribution being polarised between 2 tight distributions for water and hydrocarbon.

3.3.3 HISTOGRAMS

A more detailed view of the sensor data can be conveyed by histogram. A quantity of value ranges, or bins, are defined and counts accumulated for these when a sample has a value within their range. The situation shown in [Figure 3.4](#) might result in a set of histogram bins as in [Figure 3.5](#).

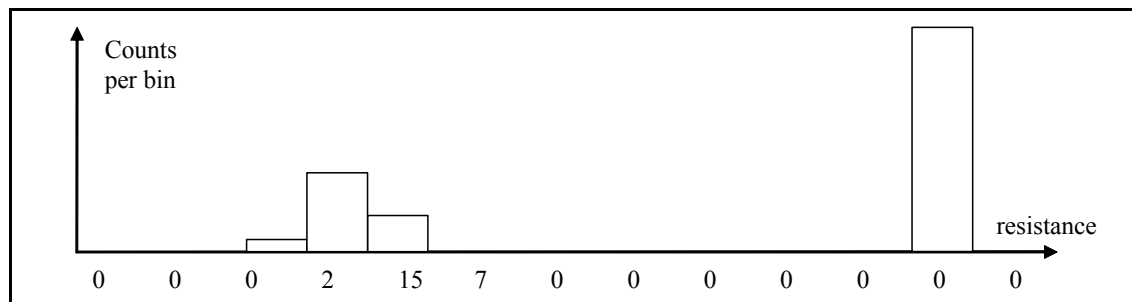


Figure 3.5 Histogram representation of measured data

The histogram data can be used to generate either the mark-space information, with the threshold retrospectively set, or produce the overall mean and standard deviation (with an accuracy limitation through the pre-rounding of values). However, the view of hold-up in the proximity of a given sensor is more easily obtained from the histogram itself, as is the distribution of the conductive part of the fluid.

The transfer of histogram information requires more data to be passed than either of the two other approaches considered above.

3.3.4 DATA COMBINATION

Within a limited bandwidth, the Binary States and Mean and Standard Deviation methods allow more frequent reports to be made on the fluid status than can be done with histogram bins. The approach actually adopted for the RAT is to use a combination of Histograms and Means and Standard Deviations.

Each report consists of a mean and standard deviation for each of its 12 sensors and the histogram data for one of the sensors. A sequence of 12 reports results in a full set of histograms for the sensors, covering the whole period, and 12 snapshots within that period showing the variation for each individual sensor.

3.3.5 SALINITY INDICATION

The RAT is a tool for determining the mix of water and hydrocarbons. It is not intended to provide a definitive indication of the resistivity of the water and thereby its salinity. As the sensors are susceptible to changes in sensitivity through build up of deposits on the electrodes, component wear and replacement or maintenance, they are not calibrated for direct reading of fluid conductivity. However, it is recognised that users may wish to gain some insight into the salinity of the water being encountered.

The values at the lower end of the range being returned, associated with a low standard deviation or showing at the lower end of the histogram, relate to the water content. The lower these values, the lower the resistance in the water portion.

The resistance of saline is affected by both the salinity and its temperature. Lower values will be caused either by an increase in the concentration or temperature, or a combination of both. A change in temperature from 30°C to 120°C will have a similar effect on the measured resistance as an increase in salinity concentration by a factor of 3.2.

4 OPERATING PROCEDURE

Note: Also refer to [7.2 Extraordinary Maintenance](#)

4.1 PRE-LOGGING CHECKS

4.1.1 MECHANICAL

- 1 Check that O-rings and sealing surfaces are undamaged, clean and greased.
- 2 Remove the closing rings.
- 3 Check that all springbows are in good condition.
 - Check that all sensors are located securely within the appropriate springbow.
- 4 Check that the locking ring is hand tight, so that the sensors are held in the sensor head. Also check that the locking ring is locked down to the central shaft by ensuring that the appropriate grub screws are tight.
- 5 Check that the bow clamp locking rings are tight.
- 6 Check that the inner split ring on the sensor head is tight and also that the grub screws are tightened to prevent it from unscrewing.

4.1.2 ELECTRICAL

- 1 Ensure that upper and lower electrical connectors are clean, dry and undamaged.
- 2 Using a Multimeter, check the through-resistance between the top and bottom LINE connections. It should be a short-circuit and the resistance should be $< 0.5\Omega$.

Note: The resistance of the connecting leads should be taken into account when taking this measurement.

- 3 Using a Multimeter, check the resistance between the LINE connections and the chassis (effectively the d.c. resistance of the internal electronics). The resistance should exceed $100k\Omega$.

4.1.3 OPERATIONAL

- 1 Connect the RAT to a suitable telemetry controller, and to a logging system via a wireline cable or suitable dummy cable.
- 2 Attach a Bullnose Ultrawire™ Terminator (BUL006) to the bottom of the toolstring. Although the tool may appear to work without the Bullnose, it will be more susceptible to telemetry errors if the Bullnose is not used.
- 3 Switch on the logging system.
- 4 The RAT tool current should be approximately **80mA**.
- 5 Slide the closing ring off the tool, so that the springbows open.
- 6 Check that all springbows are opened correctly and that the sensors are held correctly within them.

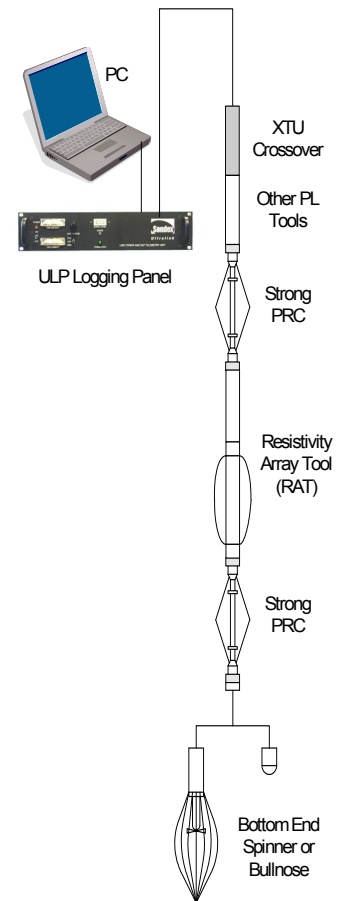


Figure 4.1 Recommended Toolstring configuration

4.2 CONNECTING TO TOOLSTRING

4.2.1 GENERAL

In terms of measurement, the position of the RAT within the toolstring is not particularly critical. However, other tools can affect where the RAT can be placed. This is mainly where other PL tools, any XSH and/or a tractor are used. The main criteria is to ensure that the RAT is centralised.

4.2.2 CENTRALISATION

Centralisation is very important, and becomes a critical issue in horizontal wells. If the RAT is below centre, all the sensors will be below their desired positions, resulting in an overestimate of the water fraction. If the tool is very significantly de-centralised, the uppermost sensor may not reach the casing (in 7" casing); in such cases, any oil flowing along the top side of the well may go undetected.

A common mistake is to believe that just because a toolstring supports itself on the ground, it will centralise in a horizontal well. This is not necessarily the case, for the following reasons:

- 1 Firstly, the supporting force from centralisers decreases as they close further. Thus, centralisation becomes more difficult as the casing diameter decreases. However, even in 7" casing, de-centralisation can still be very significant if care is not taken.
- 2 Secondly, toolstrings flex as they become longer. This can cause significant decentralisation of the RAT if there are too many tools between the RAT and its centralisers.
- 3 Thirdly, when self-supported on the ground, there will be two arms of a centraliser supporting the tool. In a horizontal well, the centraliser may be oriented such that only one arm is supporting the tool.

- 4 Finally, it is believed that the supporting force of Centralisers decreases when moving. This is due to the frictional component between the casing and centraliser roller being less when moving than when stationary, i.e the static friction is greater than the dynamic friction.

As a minimum therefore:

- There should be no tools between the RAT and its nearest centraliser.
- Consider the use of strong centralisers (e.g. 70-100lbs) at each end of the RAT; 40lb centralisers may not be sufficient in small (3" diameter) casing.

Great care must be taken when other tools are added to the toolstring. If possible, assemble the string in sections, based on casing diameters found in the well to be logged. If this cannot be done, use more centralisers than thought to be absolutely necessary.

Knuckle joints may also be used as appropriate, particularly if weight bars are used.

It is a useful exercise to assemble the tool horizontally in sections of 6" casing to see the effect of adding extra tools. Even the effect of adding an extra tool between the RAT and a centraliser is usually quite significant. In 3" casing or tubing the centralisation problems are even greater.

4.2.3 ALIGNMENT OF MULTIPLE ARRAY TOOLS

When more than one flow imaging tool (i.e. SAT & RAT) are run in one string, it is advisable to keep the distance between the imaging tools to a minimum.

When multiple array tools are combined in a toolstring, a Rotational Alignment Sub (RAS001) can be used to ensure all sensors on the array tools are aligned with each other.

Refer to [A.1 Ancillary Equipment](#) for part numbers and O-ring replacement for the RAS001.

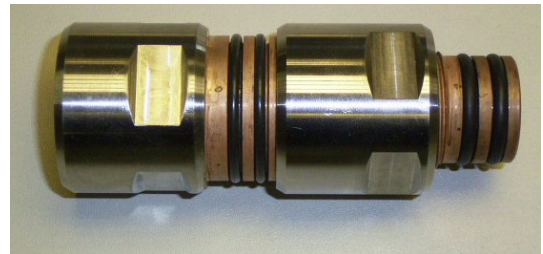


Figure 4.2 RAS001

4.3 LOGGING

The following are guidelines only and must be used in conjunction with local policy and specific well site conditions both downhole and at surface. The table below is appropriate for near vertical wells and must be adjusted accordingly when in deviated wells. Use of a Head Tension Unit is highly recommended.

Note: Do not exceed the calculated safe working load of your selected weakpoint. If in doubt, use a head tension unit, especially in deviated wells where calculation from surface tension is less accurate.

Depth (ft)	Speed Pulling Out of Hole	Speed Running in Hole
In/out of catcher (pressure rig up only)	Dead slow or manual.	
30 to 150	30ft/min	
150 to 400	60ft/min	
>400 clear cased hole	Surface tension not to exceed 120% of tension when tool stationary. Speed not to exceed 150ft/min.	Surface tension should not be less than 80% of tension when tool stationary. Speed not to exceed 150ft/min.
>400 clear open hole	Surface tension not to exceed 130% of tension when tool stationary. Speed not to exceed 150ft/min.	Surface tension should not be less than 70% of tension when tool stationary. Speed not to exceed 150ft/min.
Approaching potential obstacles ^a	30ft/min	
Logging Data	Do not exceed the above speeds. Recommended speed is <30ft/min.	

a. For example: Reduced diameters, gas lift mandrels, fluid levels, valves, tubing shoes, packers, cross overs and other downhole equipment.

Logging can (and normally would) be done whilst logging both up and down. However, the down-passes can sometimes produce superior data to the up-passes. This is because the relative fluid velocity is greater when running downhole. Also, due to the unique design of the tool, it is recommended that stationary passes are taken at zones of particular interest.

4.4 POST LOGGING DISASSEMBLY

Clean the tool before disassembly.

Keep electrical connectors clean and dry.

Refit thread protectors.

4.5 TRANSPORT, HANDLING & STORAGE

Store with end threads lightly greased and with water tight thread protectors fitted.

When not in use, keep the tool inside the aluminium carry tube.

The tool should be transported to site in the transport case provided.

Do not subject the tool to extreme shock, such as dropping or hitting with a hard object.

5 MECHANICAL DESCRIPTION

5.1 OVERVIEW

The tool consists of three main sections:

- Electronics Section
- Sensor Assembly
- Central Shaft Assembly.

The electronics section plugs into the sensor head to allow for easy removal.

The sensor head acts as a hub for the 12 sensor assemblies; the sensors plug into the sensor head and have an O-ring Seal, which allow for easy replacement. The single wire of the sensor assembly (plus the chassis ground) provides connectivity with the main tool electronics. The chassis ground is ensured by utilising a canted spring on the sensor tube. Ensure this spring is in good condition.

The 12 flexible tubes of the sensor assembly, which flex with the springbow, are guided under its corresponding springbow by metallic clips and each springbow carry a single wire from the springbow-mounted resistivity assemblies to the sensors. The clips guide the sensor assembly tubes to allow the sensors to keep a set distance from the springbow and therefore lessen the shielding effect on the flow from the springbows.

The springbows are anchored at the sensor head end and actuated by an expansion spring at the other end. The springbows are fixed to the tool by a clamping ring at each end, which can be backed off to allow replacement of all or individual springbows.

5.2 DISASSEMBLY

5.2.1 ELECTRONICS SECTION REMOVAL & ACCESS

5.2.1.1 Electronics Section Removal

Ref.: RAT001 General Assembly 09751
Electronics Assembly 85798

Note: Item numbers refer to the General Assembly, unless stated otherwise.

- 1 Unscrew pressure housing (item 8) from the sensor head assembly (item 1).
- 2 Lightly screw in grub screws (3x item 27) **clockwise** into the electronics assembly until flush.

Note: Do not apply excessive torque, as this will hamper removal and possibly damage the Lemo connector in the Electronics Assembly.

- 3 The electronics assembly (item 2) can now be unplugged from the sensor head assembly (item 1) by simply pulling them apart, see [Figure 5.1](#).



Figure 5.1 Separating Electronics from Sensor Head Assembly

5.2.1.2 Electronics Access

Ref.: RAT001 General Assembly 09751
 Electronics Assembly 85798

Note: Item numbers refer to the Electronics Assembly, unless stated otherwise.

- 1 Unscrew pressure housing (item 8, 09751) from the sensor head assembly (item 1, 09751).
- 2 The electronics boards (items 2 & 3) can be accessed by removing the upper half shell (item 4).

Note: The lower half shell should not be removed unless access to the wiring of the relative bearing assembly (item 1) is required. The upper half shell is fitted with 7 screws (item 12); the lower half shell has 9 screws (item 12) as the additional 2 screws hold the relative bearing assembly (item 1) in place.

Note: For servicing the pressure isolation head (item 5), refer to *MN-PIH*.

5.2.2 SPRINGBOW REMOVAL

Ref.: RAT001 General Assembly
Sensor Head Assembly

09751
41113

Note: Item numbers refer to the General Assembly, unless stated otherwise.

5.2.2.1 Removing the Springbows

- 1 Using two 'C' spanners, loosen the bow clamp locking rings (item 15).

Figure 5.2 Loosen Bow Clamp Locking Rings



- 2 Slide the lower bow clamp ring (item 16) away from the springbows. It is now possible to disengage the Springbow (item 3) from its location holes.

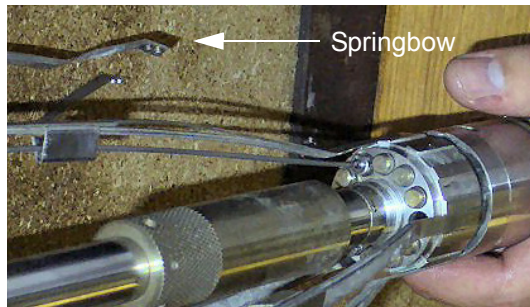
Figure 5.3 Sliding lower bow clamp ring away.

Note: If only a small number of springbows are to be removed, the lower bow clamp ring (item 16) can be used to lock the remaining springbows onto the lower bow end termination body (item 14) by retightening the bow clamp locking rings (item 15). Ensure that the pegs of each springbow are correctly aligned.



- 3 At the other end of the springbow, screw in the bow clamp inner split ring (item 7, 41113), and slide the bow clamp outer ring (item 8, 41113) and bow clamp outer ring bursting disc (item 9, 41113) away from the springbows in a similar fashion as in operation 2.

Figure 5.4 Loosening Bow Clamp Split Rings



- 4 Disengage springbow (item 3) from its location holes.

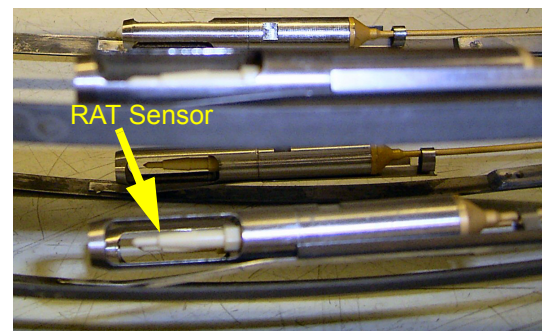
Figure 5.5 Disengage springbow.

Note: If only a small number of springbows are to be removed, the bow clamp outer ring (item 8, 41113) and bow clamp outer ring bursting disc (item 9, 41113) can be used to lock the remaining springbows onto the sensor head assembly, by unscrewing the bow clamp inner split ring (item 7, 41113). Ensure that the pegs of each springbow are correctly aligned, and that the bow clamp outer ring (item 8, 41113) is aligned with the keyway in the sensor head assembly.

5.2.2.2 Springbow removal from RAT Sensor Assembly

- 1 Carefully push the springbow assembly (item 3) towards the lower bow end termination body (item 14) until the sensor section is free from the springbow assembly (item 3).

Figure 5.6 Sensor Assembly Removal



- 2 Unclip the RAT sensor assembly (item 7) fitted to the clips on the springbow assembly (item 3).
- 3 Carefully pull the RAT sensor assembly (item 7) towards the sensor head assembly (item 1) and out of the springbow assembly (item 3).
- 4 Repeat for each springbow to be replaced.

Note: This can be done by applying sufficient force behind the tube to overcome the spring force of the clip, and simultaneously levering the clip open. The RAT sensor assembly should first be released from the clip closest to the sensor.

5.2.3 REPLACING SENSORS

Ref.: Sensor Head Assembly 41113
Single Pin Sensor Assembly 40330

Note: Item numbers refer to the Sensor Head Assembly, unless stated otherwise.

- 1 Remove the springbows as described in [Section 5.2.2](#).

Note: If only a small number of sensors are to be removed, it is not necessary to remove every springbow.

- 2 Slacken the grub screws (item 18) in the locking ring (item 4).
- 3 Prior to unscrewing the locking ring, rotate the RAT radially so the marker, indicating the first sensor, is facing down.

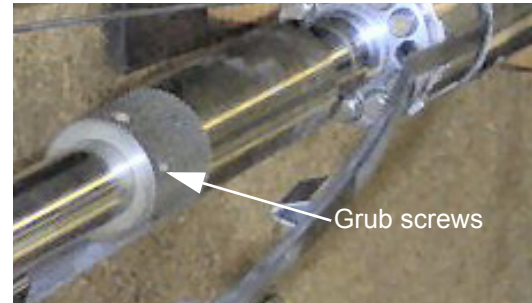


Figure 5.7 Slackening Grub Screws

Note: Failing to do so might cause the bearing ball (located under the locking ring) to fall out of the assembly.

- 4 Unscrew the locking ring (item 4) from the sensor head.
- 5 Using a small screwdriver, carefully lever out the desired sensors from the sockets in the sensor head. There is a recess in each sensor for this purpose.
- 6 Clean out the corresponding sockets in the sensor head to ensure that there are no traces of well fluid left. Isopropanol or a similar solvent can be used. Dry out the socket with soft tissue paper or similar.
- 7 If a sensor has leaked, it may be necessary to service the sensor head, see [Section 5.2.5](#).
- 8 Replace sensors.

Note: When replacing the sensors, check that the connector and corresponding socket in the sensor head are clean and thoroughly dry.

- 9 When replacing the sensors, take care when inserting them back into the sensor head. This will reduce the risk of damage to O-ring (item 10, 40330) and canted coil spring (item 7, 40330).
- 10 Retighten the grub screws (item 18) in the locking ring (item 4).
- 11 Refit the springbows (see [Section 5.3.3](#)) and clip the sensors back into the springbows.

5.2.4 REPLACING SENSOR ASSEMBLY O-RINGS

Ref.: Single Pin Sensor Assembly 40330

Note: Item numbers refer to the Single Pin Sensor Assembly, unless stated otherwise.

- 1 Remove the Sensor Assembly from the springbow assembly (see [Section 5.2.2.2](#) steps 1 to 3).
- 2 Remove the O-ring (item 10) from the assembly.
- 3 Fit the O-ring fitting tool (p/n 20322) over the connector end of the sensor assembly.
- 4 Lubricate the seating and replacement O-ring (p/n 99007) and ease the O-ring along the taper of the fitting tool and into its seating.
- 5 Unscrew the sensor shield (item 2) and remove.
- 6 Using the probe removal tool (p/n 40883), unscrew the sensor probe (item 6) until the thread disengages (unnecessary rotation may damage the wiring within the sensor body). Gently withdraw the probe with the wire attached.
- 7 Remove the O-ring from the probe, lubricate and fit a replacement (p/n 99913).
- 8 With some initial anti-rotation in the wire, insert the excess wire into the body of the sensor and refit the probe back into the body by screwing it to the end stop (see **Note**).

Note: Do not overtighten when screwing it into the end stop.

- 9 Replace the sensor shield (item 2).

5.2.5 SENSOR HEAD DISASSEMBLY

Ref.: RAT001 General Assembly 09751
Sensor Head Assembly 41113
Wiring Diagram WD-41113

Note: Item numbers refer to the General Assembly, unless stated otherwise.

Note: O-rings (item 24) can be replaced without disassembling the sensor head.



Caution! The sensor head should not be removed, unless a leak occurred in a high pressure / temperature well. Servicing the sensor head assembly involves rewiring the sensor head and is not recommended, except in extreme circumstances.

- 1 Remove the Electronics Assembly (see [Section 5.2.1](#)), springbows (see [Section 5.2.2](#)) and sensors (see [Section 5.2.3](#)).
- 2 Remove locking ring (item 15) from Sensor Head (item 1, see [Figure 5.6](#)).

Note: Take care not to lose the ball bearing (item 25), located under locking ring (item 15), which lock the shaft (item 10) to the sensor head.

- 3 Remove 3 ball bearings from sensor head before unscrewing shaft.

- 4 Unscrew the central shaft (item 10) from the sensor head (item 1).

Note: There is a flat spanner surface on the central shaft for this purpose. The sensor head is now isolated.

- 5 Using a punch, remove spirol pin (item 15, 41113).
- 6 Gently pull Lemo connector assembly (items 5, 6 & 2, 41113) out of sensor head (item 1, 41113).
- 7 Unscrew the Kemlon Connector (item 12, 41113), using the Kemlon Tool (p/n 10051).
- 8 Desolder the appropriate wire(s) from the Lemo Connector (item 6, 41113), refer to the Wiring Diagram.
- 9 Using a Feedthrough Retaining Nut Assembly Tool (p/n 15283), unscrew the Feedthrough Retaining Nut (item 3).

Note: When replacing the Feedthrough Retaining Nut (item x), do not tighten excessively. It should only be lightly hand-tight.

- 10 Insert the Kemlon Removal Tool (p/n 15263) into the sensor head (from the Lemo side), and using a hammer, carefully punch out the desired sensor Kemlons. Take care not to damage the wiring.

5.2.6 DISASSEMBLY OF CENTRAL SHAFT ASSEMBLY

Ref.: RAT001 General Assembly 09751

- 1 Remove the springbows (see Section 5.2.2) and unscrew central shaft assembly from the Sensor Head (see up to operation 4 of Section 5.2.5).
- 2 Unscrew grub screws (item 27) from the lower end sub (item 11) and tap the lower end sub (item 11) with a hammer to release, or at least loosen the ball bearings (item 26).
- 3 Unscrew the lower end sub (item 11) from the central shaft (item 10).

Note: This will release any of the ball bearings (item 26) that did not fall out when tapped with the hammer.

- 4 If desired, the bypass cable assembly (item 5) can now be pulled out of the central shaft (item 10).
- 5 Also if desired, the lower connector assembly (item 4) can be removed from the lower end sub (item 11) by removing the circlip (item 23) and then the spirol pin (item 22).

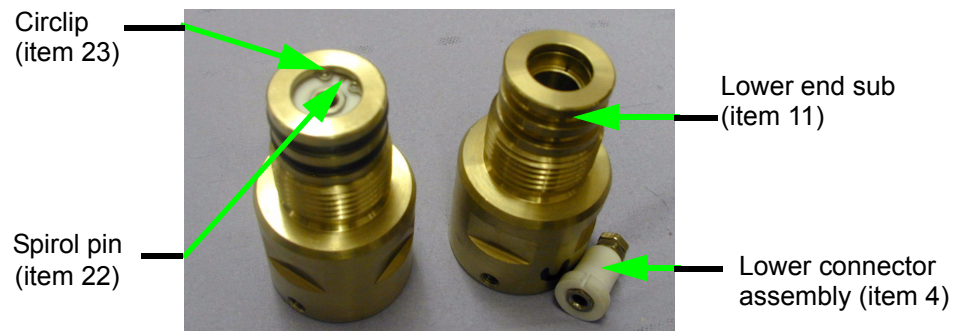


Figure 5.8 Removing Lower Connector Assembly

- 6 Using a punch, remove spirol pins (item 21) that secure the spring retaining ring (item 13) to the lower end bow termination body (item 14).
- 7 Slide back spring retaining ring (item 13) from the lower end bow termination body (item 14), and unscrew the spring (item 18) **clockwise** off the lower end bow termination body (item 14).

Note: A small 'C' spanner can be used to open up the spring in order to help this task.

- 8 The lower end bow termination body (item 14) and the assembled spring end stock (item 12) can now be removed from the central shaft (item 10).

5.3 REASSEMBLY

5.3.1 REASSEMBLY OF CENTRAL SHAFT ASSEMBLY

Ref.: RAT001 General Assembly 09751

- 1 Slide a spring retaining ring (item 13) over the extension spring (item 18) and screw spring (item 18) **anti-clockwise** onto lower end bow termination body (item 14).

Note: A small amount of grease may aid with this assembly.

- 2 Secure the spring retaining ring (item 13) to the lower end bow termination body (item 14) with spirol pins (item 21).
- 3 Slide the second spring retaining ring (item 13) over the spring (item 18) and slide the assembly onto the central shaft (item 10), along with the spring end stock (item 12) from the other end.

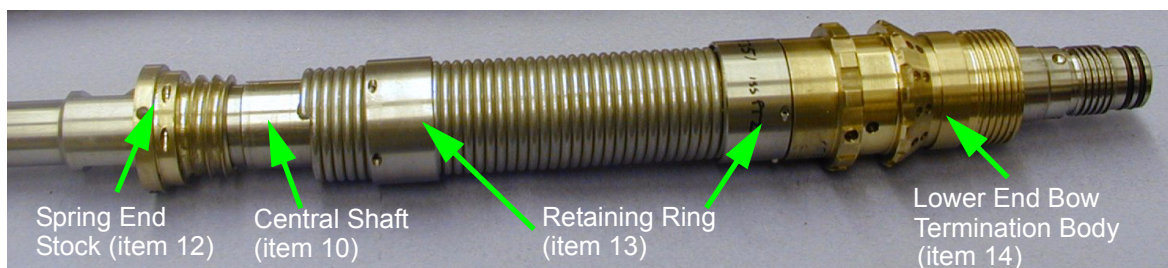


Figure 5.9 Central Shaft Assembly

- 4 Screw the extension spring (item 18) **anti-clockwise** to the spring end stock (item 12).

Note: A small amount of grease applied to the end stock will aid with this assembly.

- 5 Fit one of the retaining rings (item 13) over the spring (item 18) and secure to the spring end stock (item 12) with spirol pins (item 21).

Note: The assembly should now be assembled as shown in [Figure 5.9](#).

- 6 Fit the bow clamp ring (item 16) and clamp locking rings (item 15) to the lower end bow termination body (item 14).

- 7 Insert the bypass cable assembly (item 5) into the central shaft (item 10).

- 8 Fit O-rings (item 29) to the lower end of the central shaft (item 10).

Note: Grease the grooves on the central shaft (item 10) and the O-rings with Liquid O-ring prior to fitting the O-rings.

- 9 Fit O-ring (item 30) to lower end sub (item 11) and apply Liquid O-ring.

- 10 If removed during disassembly, fit spirol pin (item 22) to lower end sub (item 11) and insert lower connector assembly (item 4). Secure lower connector assembly to the lower end sub (item 11) using a circlip (item 23).

- 11 Screw the lower end sub (item 11) onto the end of the central shaft (item 10). Lock in position using Bearings (item 26) and Grub Screws (item 27).

Ensure the lower end sub (item 11) is fully tightened onto the central shaft (item 10).

- 12 Fit O-rings (item 24) to lower end sub (item 11). Apply Liquid O-ring prior to fitting.

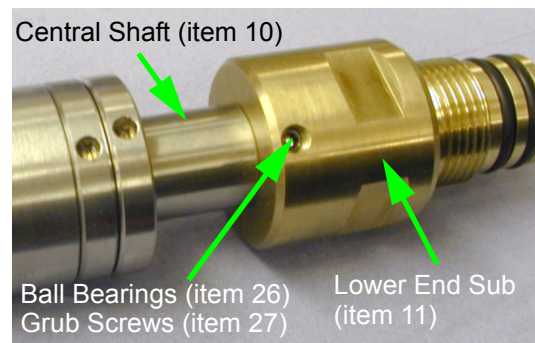


Figure 5.10 Lower End Sub screwed onto Central Shaft

- 13 Fit O-rings (item 29) to the end of the central shaft (item 10) that screws into the sensor head assembly (item 1).

Note: Lubricate the O-ring grooves on the shaft (item 10) and the O-rings with Liquid O-ring prior to fitting.

5.3.2 SENSOR HEAD REASSEMBLY

Ref.: RAT001 General Assembly 09751
Sensor Head Assembly 41113
Wiring Diagram WD-41113

Note: Item numbers refer to the Sensor Head Assembly, unless stated otherwise.

Note: O-ring (item 10) can easier be replaced when the springbows are refitted, see [Section 5.3.3](#).

- 1 Grease O-rings on the sensor Kemlons (item 12) with a little Silicone Grease.

- 2 Insert each sensor Kemlon (item 12) into the sensor head assembly (item 1) by hand as far as possible. Then, gently but firmly, punch it fully home, using the Kemlon Removal Tool (p/n 15263).
- 3 Lock it in place with a feedthrough retaining nut (item 3) using the Feedthrough Retaining Nut Assembly Tool (p/n 15283). This should be hand tightened only.
- 4 Insert the line Kemlon (item 12) into the sensor head assembly (item 1) using the Kemlon Tool (p/n 10051).
- 5 Re-solder all wires to the Lemo connector (item 12) as indicated on the wiring diagram.

Note: Ensure that the line connection is thoroughly shielded. Thoroughly check that all connections are correct.



Caution! If the line wire is inadvertently connected to a sensor, the RAT electronics is likely to be destroyed.

- 6 Carefully feed the wire loom back into the sensor head assembly (item 1).
- 7 Insert the Lemo connector assembly (items 5, 6 & 2) back into the sensor head assembly (item 1) and lock in place with spirol pin (item 15).
- 8 Fit and screw the central shaft (item 10, 09751) back onto the sensor head (item 1).

Note: There is a flat spanner surface on the central shaft for this purpose.

- 9 Insert ball bearings into each of the 3 holes in sensor head. These lock the shaft to the sensor head.
- 10 Refit the locking ring (item 4) onto the sensor head (item 1).
- 11 Refit the electronics assembly (see [Section 5.3.4](#)), springbows (see [Section 5.3.3](#)) and sensors (see [Section 5.2.3](#)).

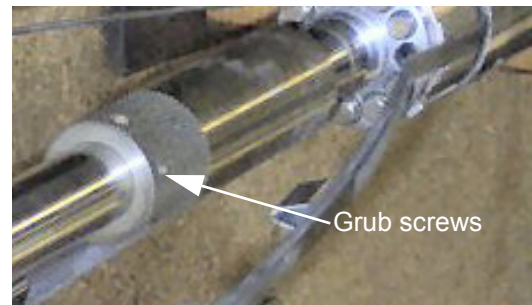


Figure 5.11 Tightening Grub Screws

5.3.3 SPRINGBOW REASSEMBLY

Ref.: RAT001 General Assembly 09751
Sensor Head Assembly 41113

Note: Item numbers refer to the General Assembly, unless stated otherwise.

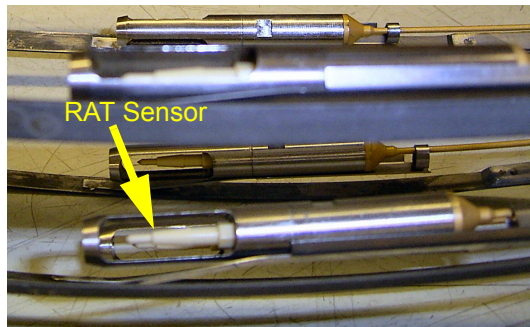
5.3.3.1 Refitting the RAT Sensor Assembly

- 1 Carefully push the RAT sensor assembly (item 1, 41113) into the sensor head assembly (item 1).

Note: The sensor tube should first be fitted into the clip nearest to the sensor head, then into the clip nearest to the sensor.

Note: Take care the sharp edges on the sensor head do not damage the sensors on the SAT sensor assemblies.

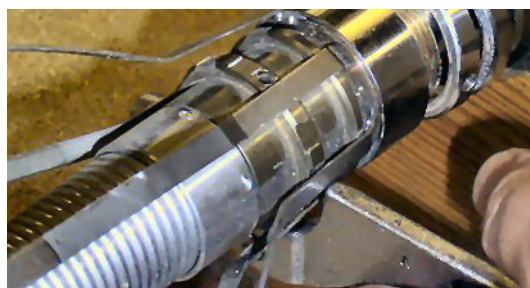
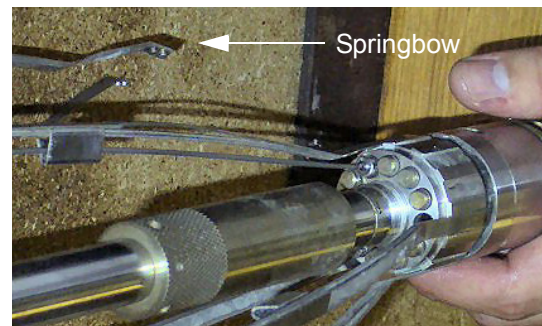
5.3.3.2 Refitting the Springbows



- 1 Carefully push the springbow assembly (item 3) over the nose of the sensor section until the nose of the sensor section is engaged in the springbow assembly (item 3).
- 2 Clip the RAT sensor assembly (item 1, 41113) into the clips on the springbow assembly (item 3).

- 3 Fit a springbow assembly (item 3) on the sensor head assembly (item 1), orientated so the sensor tube clips are at the sensor head (item 1) end.

Note that there is a keyway at the sensor head end, so care should be taken to ensure that this is correctly aligned.



- 4 Slide the bow clamp outer ring (item 8, 41113) and bow clamp outer ring bursting disc (item 9, 41113) in place and tighten the bow clamp inner split ring (item 7, 41113).

Note: If the springbows are new, it may be convenient to use an elastic band at each end to hold them in place until the bow clamp rings are tightened. This is not usually necessary once they have been tightened into place for some time. Repeat this procedure for each of the remaining springbow assemblies.

- 5 Using two 'C' spanners, loosen the bow clamp locking rings (item 15) on the lower end of the tool.
- 6 Slide the lower bow clamp ring (item 16) away from the springbows.
- 7 Fit a springbow assembly (item 3) and secure the springbows by retightening the rings with 'C'-Spanners.
- 8 Tighten the grub screws in the bow clamp inner split ring (item 7, 41113) to lock it onto the sensor head (item 1, 41113).



5.3.4 ELECTRONICS SECTION REASSEMBLY

Ref.: RAT001 General Assembly 09751
 Electronics Assembly 85798

Note: Item numbers refer to the General Assembly, unless stated otherwise.

- 1 Plug the electronics assembly (item 2) into the sensor head assembly (item 1)

Note: Note the orientation of the Lemo Connectors.



Figure 5.12 Connecting Electronics to Sensor Head

- 2 Lightly screw grub screws (item 27) **anti-clockwise**, securing the electronics assembly (item 2) to the sensor head assembly (item 1).
- 3 Refit O-ring (item 18, 85798) on the pressure isolation head (item 5, 85798). Apply liquid O-ring before refitting.
- 4 Refit Pressure Housing (item 8), using a 38mm Spanner and a 'C'-Spanner.

6 ELECTRICAL DESCRIPTION

Ref.:Block Diagram

Figure 3.1

6.1 OVERVIEW

The RAT electronics consists of 2 PCBs, the Analogue PCB ([85988](#)) and the Ultrawire™ PCB ([82333](#)).

6.2 ANALOGUE BOARD

Ref.:Analogue Board (PCB85988)

CD-85988

The analogue PCB can be divided into 5 Sections:

- Power Supply Unit (PSU).
- Processor.
- RAT sensor driver.
- Logarithmic Amplifier.
- Capacitance Array Tool (CAT) Circuit.

6.2.1 POWER SUPPLY

The Switch Mode Power Supply (SMPS) is a.c. isolated from the Ultrawire™ toolbus by an active choke, consisting of Q17 and associated circuitry. The filter, formed by this active choke together with capacitor (C1), prevents switching currents, generated by the SMPS from appearing on the Ultrawire™ bus, where they would cause data corruption, and ensures that the tool takes a steady d.c. current. The tool is protected against overvoltage and reverse connection by fuse (F1) and zener diode (D1).

The SMPS is controlled by SMPS controller IC26. MOSFET (TR1) and multi-winding inductor L1 form the core of the power supply. IC25 provides a 2.048V reference for the supply, and inductor L2 and capacitor C6 form an output filter on the 4.2V output.

The SMPS operating frequency is variable and increases with increased demand on the output rails. This design of power supply is inherently protected against a short circuit on any output rail, making it extremely robust.

L1 is tapped to provide semi-regulated outputs of +15V and -12V. The 2 semi-regulated outputs are linearly post regulated to provide the various voltages required by the analogue electronics. Some of these supplies can be switched off, to save power, if the unit is used in CAT mode.

The 4.2V supply is switched up to 5V if the board is put into program mode.

6.2.2 PROCESSOR

The processor that controls the PCB is a PIC16F874 clocked at 12MHz. The Processor uses its internal SPI interface together with IC3 to interface with the Ultrawire™ PCB. All the strobes required for the RAT driver electronics are generated by the processor. The processor also drives the 'Alcopot' to measure the orientation of the tool.

IC23 is used as a serial combination lock to ensure that the processor is not reprogrammed accidentally.

6.2.3 RAT SENSOR DRIVER

The tool has 12 RAT sensors which are multiplexed by IC20 and IC21. IC21 multiplexes the drive and IC20 multiplexes the measurement so that the resistance of the multiplexers can be eliminated from the measurement. The sensors are driven with a 10KHz, 2V peak to peak so that the DC component is close to zero. The effective impedance of the drive is 220Ω , so the maximum current when a sensor is shorted is just under 5mA. The impedance is controlled by R36 and the feed-back loop, which ensures that the voltage across R36 plus the voltage across the sensor is equal to the voltage at IC15 pin 7, the desired square wave.

ICs 13 and 14 form 2 synchronous charge pumps that extract the a.c. component of the current through and the voltage across the RAT sensor. This method cancels out any electrochemical voltages and the spontaneous potential so that these do not affect the measurement.

6.2.4 LOGARITHMIC AMPLIFIER

The 2 outputs from the analogue section are each put through a trans-linear logarithmic amplifier IC11 and IC12. The log of the current is subtracted from the log of the voltage by IC10 to give the log of the resistance of the sensor. This value is converted to digital form by the ADC in the processor.

6.2.5 CAT CIRCUIT

The CAT circuit will not be described here but is included so that the electronics is capable of being used in a CAT as well as a RAT.

6.3 DIGITAL BOARD

Ref.: Digital Board

CD-82333

The Digital Board contains 3 main functional blocks. These are the SMPS, the Ultrawire™ bus interface and the system control electronics. The SMPS takes d.c. power from the Ultrawire™ tool bus and generates 3.3V rail that powers all the analogue and digital circuitry on the Ultrawire™ PCB. A nominally 1.6V rail is also generated, but is not used on this tool. The SMPS is isolated from the Ultrawire™ toolbus by an active choke consisting of Q5 and associated circuitry. The filter formed by this active choke, together with capacitor C6, prevents switching currents, generated by the SMPS, from appearing on the Ultrawire™ bus, where they would cause data corruption, and ensures that the tool takes a steady d.c. current. The tool is protected against overvoltage and reverse connection by fuse F1 and zener diode D1.

The SMPS is controlled by SMPS controller U1. MOSFET (Q4) and transformer L1 form the core of the power supply. U8 provides a 2.048V reference for the supply, and inductor L2 and capacitor C7 form an output filter on the 3.3V output. The 1.6V rail is unfiltered.

The SMPS operating frequency is variable and increases with increased demand on the output rails. This design of power supply is inherently protected against a short circuit on either output rail, making it extremely robust.

The Ultrawire™ interface consists of PLD (U5) and the circuitry, contained in the lower right of sheet 1 of the Digital Board circuit diagram. Capacitor C3 couples the bidirectional telemetry signals between the Ultrawire™ bus and the bus interface. The Ultrawire™ PLD (U5) is effectively a UART, handling communications between the system microprocessor U7 and the Ultrawire™ bus. The

various control lines between the two enable the microprocessor to receive commands and data from the bus and to transmit data on the bus.

System control is performed by the microprocessor U7, which in addition to communicating with the Ultrawire™ bus via PLD (U5), controls the acquisition of data from the various sensors within the sensing section.

Control lines D3, D4, TX, RX and CLK communicate with the Analogue Board, using SPI protocol.

U3 is a voltage monitor and system reset generator that only allows the tool to operate when the 3.3V power rail is stable.

X1 is a crystal oscillator, generating the system clock for the sensing section. Under normal operation this an 8MHz clock signal, but may be switched down to 64kHz by the microprocessor (via PLD U5 CPU_CLK_SPD line) to save power while the tool is idle. Op-amp U6 and associated components condition the signal from the temperature probe, but this is currently unused. The output of this op-amp is connected to microprocessor U7) where it is converted into a digital quantity by the processor's internal analogue to digital converter.

7 EXTENDED CHECKS

7.1 PREVENTATIVE MAINTENANCE

7.1.1 GREASE & LUBRICANTS

Sondex recommends the use of “Liquid O-ring type 101” (p/n LOR101) on threads and O-rings.

All O-rings and housing threads are assumed to be and must be lightly greased, unless specifically indicated otherwise.

Correct use of grease and lubricants is essential to the maintenance of all Sondex downhole equipment.

Note that some threads are internal, which can cause grease to get inside the tool. Do not use excessive quantities.

Sondex does not recommend Copper loaded greases since some types can cause electrical leaks. Some types for grease are not suitable for use on O-rings. Silicone grease may be used on O-rings, but must be kept clear of threads, especially stainless steel to stainless steel. Cavities, e.g. spring housings, should be filled with a suitable heavy high melting point grease. like Castrol Spheerol L-EP2 or Castrol LMX.



Caution!

The use of certain greases, which contain volatile content, (e.g. some types of Lubriplate) can cause electrical failure due to production of corrosive gasses inside the tool when burned off.

7.1.2 MECHANICAL

Refer to [Section 5](#) as required for disassembly / re-assembly instructions.

- 1 Remove dirt and old grease from pressure housing threads and O-rings and replace with fresh.
- 2 Inspect O-rings for damage or ageing/hardening and replace where required.
- 3 Check for:
 - Damaged wires.
 - Wires that are loose and likely to be crushed on re-assembly.
 - Damaged components.
 - Loose screws/nuts/components/connectors.

Note: If RTV or similar compound is used to secure loose components, it must be fully cured before housing is replaced.

- Electrical components shorting to chassis.
 - Heat or chemical damage (discoloured components).
 - Incorrect thread grease or excessive quantity, see [Section 7.1.1](#).
- 4 Check any connectors for cleanliness and loose / bent pins before replacing.
 - 5 Check all fixings for tightness.

7.1.3 ELECTRICAL

Ref.: RAT Electronics Wiring Diagram

- 1 With the electronics cartridge removed, make the following meter checks at the Lemo connection at the bottom of the electronics assembly. Use a standard Multimeter and not a high voltage Megohm Meter for these tests. See [Figure 7.1](#) below for pin/socket position.

Pin 13 to chassis	Sensor #1	> 1M Ω
Pin 14 to chassis	Sensor #2	> 1M Ω
Pin 15 to chassis	Sensor #3	> 1M Ω
Pin 16 to chassis	Sensor #4	> 1M Ω
Pin 9 to chassis	Sensor #5	> 1M Ω
Pin 10 to chassis	Sensor #6	> 1M Ω
Pin 11 to chassis	Sensor #7	> 1M Ω
Pin 12 to chassis	Sensor #8	> 1M Ω
Pin 5 to chassis	Sensor #9	> 1M Ω
Pin 6 to chassis	Sensor #10	> 1M Ω
Pin 1 to chassis	Sensor #11	> 1M Ω
Pin 2 to chassis	Sensor #12	> 1M Ω
Pin 3 to chassis	GND	< 0.2 Ω
Pin 4 to Upper Banana Pin	Through Line	< 0.2 Ω
Pin 4 to chassis	Through Line	> 1M Ω

Pins 7 and 8 are connected to 0v.

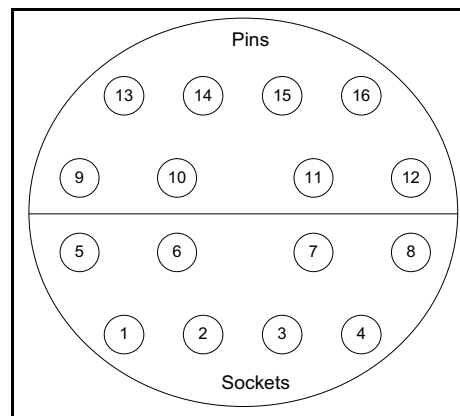


Figure 7.1 Lemo pin/socket positions (Rear View)

- 2 Replace the electronics cartridge.
- 3 Check through line resistance and tool current, see [Section 4.1.2](#).
- 4 Connect to logging system and check for correct data. Apply some gentle vibration and rotation to expose potential failure.
- 5 Take velocity and direction readings.

7.1.4 AGEING OF ELECTRONICS

At 150°C, significant electronic ageing failures are expected after 4000hrs typical use, hence PCB replacement should be considered at this point. Every additional 10°C halves the time. Life of the electronics is also accelerated by vibration and corrosive gas inside the chassis. Visual inspection and logging previous history is recommended, but is unlikely to predict premature failure.

Tools that may be suspected of reliability problems due to age or unusual log response may be heated to 120°C, which would not normally age the electronics, and afterwards subjected to moderate vibration. A moderately hard blow from a wooden hammer is recommended.

DO NOT USE METAL HAMMERS.

Whilst heating the tool, it is recommended that the sensors should either be removed, or be immersed in oil.

7.1.5 HEAT TESTING ABOVE 150°C

This is not generally recommended since it shortens tool life expectancy.

Heat testing may be required for contractual reasons, tool out of use for a long period, or job with unusually high well temperature. The test should be carried out slightly above expected well temperature only and the tool should not be kept at temperature for more than 1 hour.

7.2 EXTRAORDINARY MAINTENANCE**7.2.1 O-RING REPLACEMENT**

Ref.:	RAT001 General Assembly	09751
	Sensor Head Assembly	41113
	Single Pin Sensor Assembly	40330

Note: All item numbers refer to the General Assembly, unless stated otherwise.

The following guidelines are appropriate for normal operating conditions. If the tool experiences harsher conditions (e.g. high pressure, temperature, H₂S), then more thorough servicing is recommended.

To determine contact with H₂S, check for discoloration of the lower sub (item 11). This part is made of Al/Bronze and will turn black when in contact with H₂S. Local well site knowledge will also contribute to determine the possibility of H₂S exposure.

7.2.1.1 Every Run

Minimum recommendation is to replace the O-rings at the bottom of the tool (item 28) every time the tool joint is broken, when the tool has been under pressure. It is also recommended that the O-rings on the sensor head under the pressure housing (item 11, 41113) are replaced prior to every job.

7.2.1.2 Every 5 Runs

In addition to the O-rings that should be changed prior to every job, it is recommended that all "wet" O-rings (i.e. O-rings that experience well pressure) should be changed every 5 jobs. These are:

- 2x O-rings (item 28).
- 2x O-rings (item 29).
- 12x O-rings (item 007, *KITO-RAT001*)

When replacing the sensor O-rings, **ensure that grease is applied into the O-ring groove prior to sliding on the new O-ring. A small amount of grease should also be applied to the outer side of the O-ring.** Immersing the O-rings in hot water will also soften them and aid their insertion, refer to [Section 7.2.1](#).

During replacement of the O-rings, the tool is stripped down to its base assemblies, allowing the tool to be cleaned and serviced thoroughly.

7.2.2 SERVICING SENSOR HEAD

This should rarely be necessary, unless there has been a leak in a high pressure / temperature well. If this has happened, the Kemlons inside the sensor head can be cleaned and the O-rings on them changed. Ordinarily, none of the Kemlons are exposed to well fluid or pressure. Servicing the sensor head assembly involves rewiring the sensor head and is not recommended, except in extreme circumstances.

7.2.3 USE OF PRESSURE TEST BLANK ASSEMBLY

Pressure Test Blank Assemblies (p/n15286) can be inserted into the Sensor Head in place of a sensor.

They are primarily used for in-house testing purposes; however they can also be used in the field and there are two main reasons for this:

- If a sensor has failed and no spares are available, one of these can be inserted into the Sensor Head. This will prevent the associated Kemlon in the Sensor Head from being contaminated with well fluid.
- In very low diameter tubing, there may be concerns over whether the tool will obstruct the flow too much, possibly causing it to be blown out of the well. In such cases, one may wish to operate the tool with fewer sensors. The Pressure Test Blank Assemblies can then be inserted into the unused positions in the Sensor Head.

7.3 TROUBLESHOOTING

Refer to [Section 5](#) for disassembly instructions and [Appendix B](#) where necessary.

7.3.1 ELECTRICAL

An Oscilloscope, Multimeter and other basic test equipment will be required.

Initial Inspection	<p>Check for:</p> <ul style="list-style-type: none"> • Damaged wires. • Damaged components. • Electrical components shorting to chassis. • Heat or chemical damage (discoloured components). • Incorrect thread grease or excessive quantity; see Section 7.1.1. <p>Also check all fixings are tight.</p>
Excessive Current	<p>Remove the electronics assembly and sensor arrays from the sensor head to isolate fault to electronics or sensor head / shaft assembly or sensor array.</p> <p>Disconnect wires to isolate fault to:</p> <ul style="list-style-type: none"> • Interface board (PCB82333). • Digital board (PCB85988). • Upper head connector. • Lemo connector on electronics. • Sensor head assembly. • Shaft assembly (incl. bypass tube). <p>Fault find or replace PCB if necessary.</p> <p>With the electronics assembly removed, the line connection at the bottom of the tool may be tested 250V relative to chassis to check for electrical leak.</p> <p>Resistance should exceed 100MΩ. Disassemble to locate fault.</p>
Single faulty Sensor	<p>Swap sensors to determine if the sensor is faulty. Replace if necessary.</p> <p>If the fault is not with the sensor, check the wiring from the PCB, through the Lemo connectors, to the Kemlons on the sensor head.</p> <p>If a sensor has leaked, it should be replaced.</p>
Rotation faults	<p>With the tool horizontal, check that pendulum rotates freely.</p> <p>The voltages on ROTx and ROTy should increase as the tool rotates clockwise (looking down the tool).</p> <p>Check that they are offset by approximately 180°. This can only be checked roughly, but when ROTx is at 5V, ROTy should be approximately 2.5V.</p>

7.3.2 MECHANICAL

Damaged O-rings.	Visually inspect O-rings. Check that the O-rings are clean and greased. Replace the O-rings if the following occurs: <ul style="list-style-type: none">• Cracks or tears in the O-rings.• The O-rings will have an excessive size when taken out of the hole (due to moisture intake).• The tool experienced temperatures in excess of 150°C.• The tool experienced contact with H₂S gas.
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APPENDIX A EQUIPMENT & RECOMMENDED SPARES

Item	Part No	Description	Qty	Remarks
1	RAT001	Resistance Array Tool, 1 ¹¹ / ₁₆ " Ultrawire™	1	

A.1 ANCILLARY EQUIPMENT

Item	Part No	Description	Qty	Remarks
1	15265	Flight Case, 1 ¹¹ / ₁₆ "	1	
2	RAS001	Rotational Alignment Sub. ^a	AR	Not supplied with the tool.

a. The RAS001 has 4 O-rings in total, which might need replacing. Refer to items 5 & 6 of [Appendix A.3](#). Apply Liquid O-ring to O-rings and threads before fitting.

A.2 MAINTENANCE EQUIPMENT

Item	Part No	Description	Qty	Remarks
1	40886	Hand Tool Kit for all 1 ¹¹ / ₁₆ " tools	1	
2	15263	Kemlon Removal Tool	1	Included in 40886.
3	15283	Feedthrough Retaining Nut Assembly Tool	1	Included in 40886.
4	20332	O-ring Removal Tool	1	Included in 40886.
5	LOR101	Grease for O-rings and threads	1	5oz pot. Included in 40886.
6	LOR101L	Grease for O-rings and threads	AR	16oz pot.

A.3 RECOMMENDED SPARES

Item	Part no.	Description	Qty	Remarks
1	<i>KITB-RAT001</i>	Basic Spares Kit	1	To support one run in hole. 1off supplied with tool
2	<i>KITO-MAPS</i>	O-Rings Spares Kit	1	
3	<i>KITU-MAPS</i>	Kit Upgrade	1	
4	<i>KITR-RAT001</i>	Recommended Spares Kit	1	To support 25 runs in hole.

Recommended Spares for Rotational Alignment Sub (RAS001):

Item	Part no.	Description	Qty	Remarks
6	99124	Viton O-ring 90 Type 124.	2	Parts for RAS001 not included in spares kits.
7	99211	Viton O-ring 90 Type 211.	2	

All spares kits and parts, mentioned in this section, can be supplied upon request. However, Sondex recommends the purchase of these kits and parts to properly support your logging tools from job to job. Contact Sondex and quote the part number of the spares kit or part for additional information or when ordering the item.

As a guidance:

- A Basic Spares Kit mainly contains essential maintenance equipment, O-rings and parts, which are likely to need replacing on a run-by-run basis (including spare parts for the initial tool run) or parts that can be lost easily (like grub screws).
- A Recommended Spares Kit has got a multitude of the same parts as a Basic Spares Kit, supplemented by parts that might need replacement at a lower frequency, i.e. 5 runs and/or 25 runs.

Note that the information above is a guidance only and Sondex reserves the right to change the contents of the Spares Kits as required.

PARTS LISTING	
Part	Issue
40886	P2
Description	
HAND TOOL KIT - 1 11/16 MAPS TOOLS	

PARTS LIST					
Item	Part No	Description	Qty	Units	Remarks
0001	91005	Spanner Open Ended 42mmx38mm	2	EA	
0002	91019	Spanner C 50mm 35mm	2	EA	
0003	10038	Spanner Box 3/8 x 5/16 Modified	2	EA	
0004	94262	SCREWDRIVER FLAT BLADE 2.5 x 75MM	1	EA	
0005	91409	Spanner Open-Ended 18x19mm	1	EA	
0006	91029	Key, Hex Metric (Set)	1	EA	
0007	91030	Punch Pin Parallel set	1	EA	
0008	40883	BOX SPANNER MODIFIED	1	EA	
0009	91293	Screwdriver Parallel tip (3 0 x 75)	1	EA	
0010	91105	Toolroll With SX Badge Large Black	1	EA	
0011	91104	Screwdriver Parallel tip (5 5 x 200)	1	EA	
0012	91103	Pliers Circlip 812 Chrome/Van	1	EA	
0013	91102	Pliers Mini Flat Nose 5 Inch	1	EA	
0014	10037	Bar Tommy	2	EA	
0015	10051	Kemlon tool Sondex - 4BA Hex Socket	1	EA	
0016	91280	Hammer, 4oz ball pein	1	EA	
0017	91130	Pin C Spanner 35-50mm	1	EA	
0018	91822	Medium Flat Blade Screwdriver, 5mm	1	EA	
0019	91255	T15 Torx driver, Sandvik Belzer 8915	2	EA	
0020	20322	Assembly Tool - Sensor O'ring MTT	1	EA	
0021	15263	Tool Removal Connector Kemlon	1	EA	
0022	15283	Assy Tool Feed-Through Retaining Nut	1	EA	
0023	10099	Miniature Kemlon tool Sondex - Modified	1	EA	
0024	16210	Tool Axle Nut Screwdriver MDT	1	EA	
0025	91197	Pliers Long Nose (Small)	1	EA	
0026	91229	Medium Pozi Screwdriver	1	EA	
0027	LOR101	Film Form Lube 5oz Pot Liq O Ring typ101	1	ML	

PARTS LISTING	
Part	Issue
KITB-RAT001	NC
Description	
Kit, Spares, Basic, RAT001	

PARTS LIST					
Item	Part No	Description	Qty	Units	Remarks
0001	KITO-RAT001	Kit, Spares, O-Rings, RAT001	1	EA	
0004	91611	Bearing Ball 2mm Chrome Steel	3	EA	
0005	93043	Scr Grb Skt Hd M3x04mmLG SS-A2 (DIN 916)	3	EA	
0006	91000	Bearing Ball 3/16 Hard	6	EA	
0007	01082	Scr Grb Skt Hd M6 x 5 LG SS FLAT POINT	3	EA	
0008	01047	CIRCLIP INTERNAL 5/8 SS N1300	2	EA	
0009	01029	Screw Csk Hd(Slotted) M3 x 06mm LG SS	10	EA	
0010	92128	Spj Coil Canted 7mm Bore,4.6mm ID BeCu	4	EA	

PARTS LISTING	
Part	Issue
KITO-RAT001	P1
Description	
KIT, SPARES, O-RINGS, MAPS TOOLS	

PARTS LIST					
Item	Part No	Description	Qty	Units	Remarks
0001	95008	O-ring 008 Viton 75	1	EA	
0002	95009	O-ring 009 Viton 75	1	EA	
0003	95011	O-ring 011 Viton 75	1	EA	
0004	95111	O-ring 111 Viton 75	1	EA	
0005	95112	O-ring 112 Viton 75	1	EA	
0006	95211	O-ring 211 Viton 75	1	EA	
0007	99007	O-ring 007 Viton 90	12	EA	
0008	99012	O-ring 012 Viton 90	2	EA	
0009	99016	O-ring 016 Viton 90	2	EA	
0010	99026	O-ring 026 Viton 90	1	EA	
0011	99125	O-ring 125 Viton 90	2	EA	
0012	99211	O-ring 211 Viton 90	10	EA	

PARTS LISTING	
<i>Part</i>	<i>Issue</i>
KITU-MAPS	P1
<i>Description</i>	
Kit upgrade MAPS restricted opening kit	

PARTS LIST					
<i>Item</i>	<i>Part No</i>	<i>Description</i>	<i>Qty</i>	<i>Units</i>	<i>Remarks</i>
0001	41171	KIT-SPACER RINGS	1	EA	

PARTS LISTING	
<i>Part</i>	<i>Issue</i>
KITR-RAT001	A
<i>Description</i>	
KIT SPARES RECOMMENDED (25 RUN) RAT001	

PARTS LIST					
<i>Item</i>	<i>Part No</i>	<i>Description</i>	<i>Qty</i>	<i>Units</i>	<i>Remarks</i>
0001	KITB-RAT001	Kit, Spares, Basic, RAT001	2	EA	
0002	KITO-RAT001	Kit, Spares, O-Rings, RAT001	5	EA	
0003	40330	ASSY SINGLE PIN SENSOR RAT001	12	EA	
0004	40540	SPRINGBOW ASSEMBLY 7" RAT	12	EA	
0005	40539	SHIELD SENSOR RAT001	12	EA	
0006	92147	Conn FEEDTHROUGH SINGLE PIN Press ISO	12	EA	
0007	41063	PLUG BLANK SENSOR	6	EA	

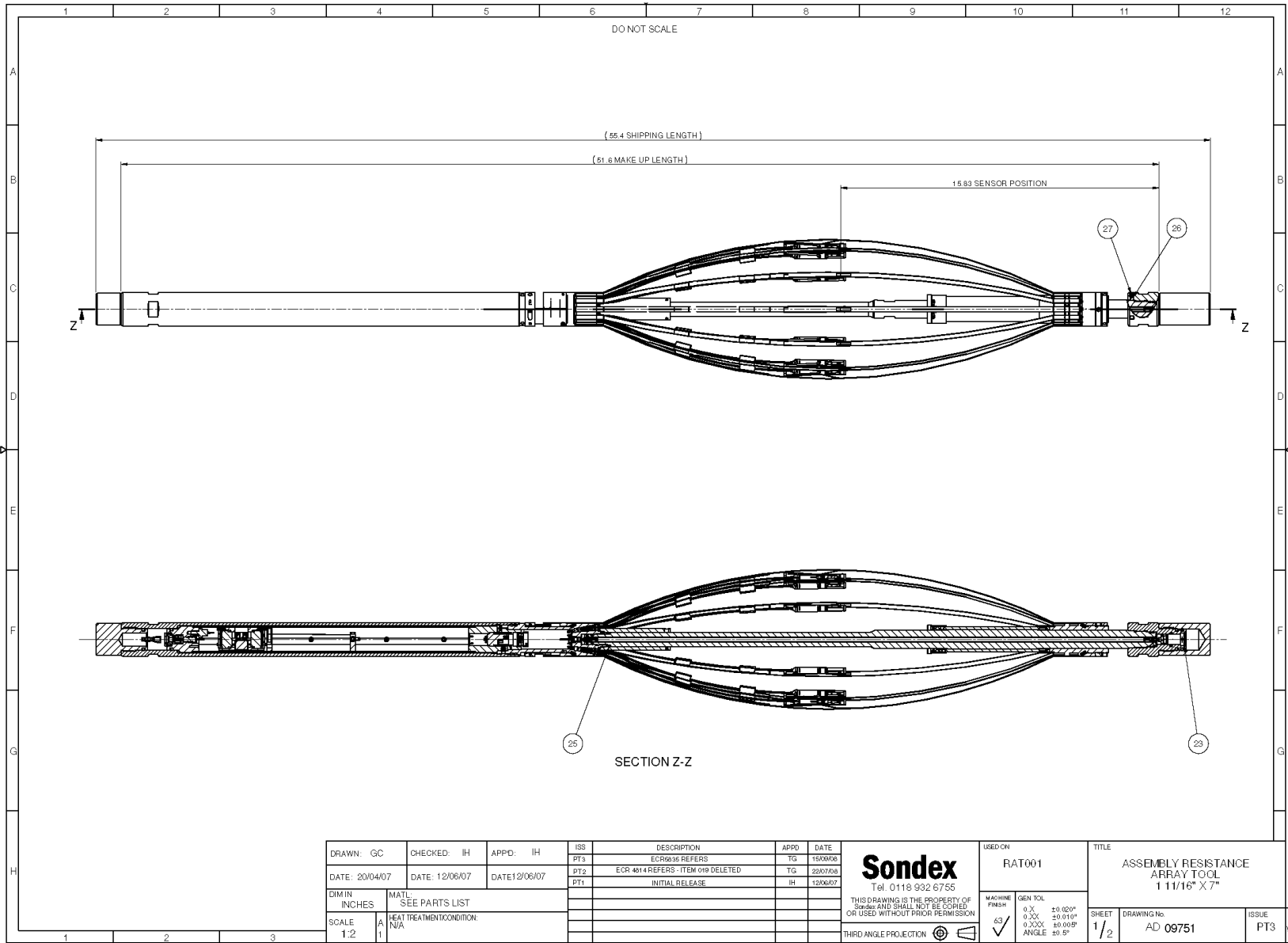
APPENDIX B DRAWINGS & PARTS LISTS

B.1 MECHANICAL DRAWINGS

Description	Drawing	Parts List
RAT001 General Assembly (2 sheets)	AD 09751-PT3	See drawing
Electronics Assembly	AD 85798-A	See drawing
Sensor Isolation Sub	AD 41113-A	See drawing
Single Pin Sensor Assembly	AD 40330-A	See drawing

B.2 ELECTRICAL DIAGRAMS

Description	Type	Drawing
Sensor Head Housing	Wiring Diagram	WD 41113-A
Electronics Assembly	Wiring Diagram	WD 85798-B
Sensor Analogue Board (PCB85988) - 5 sheets	Circuit Diagram	CD 85988-A
Digital Board (PCB82333) - 2 sheets	Circuit Diagram	CD 82333-G00



DRAWN: GC	CHECKED: IH	APPD: IH	ISS	DESCRIPTION	APPO	DATE
DATE: 20/04/07	DATE: 12/06/07	DATE: 12/06/07	PT3	ECR6035 REFERS	TG	15/06/06
			PT2	ECR 4814 REFERS - ITEM 019 DELETED	TG	22/07/06
			PT1	INITIAL RELEASE	IH	12/06/07
DIM IN INCHES	MATERIAL: SEE PARTS LIST					
SCALE 1:2	HEAT TREATMENT CONDITION: N/A					

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THIRD ANGLE PROJECTION

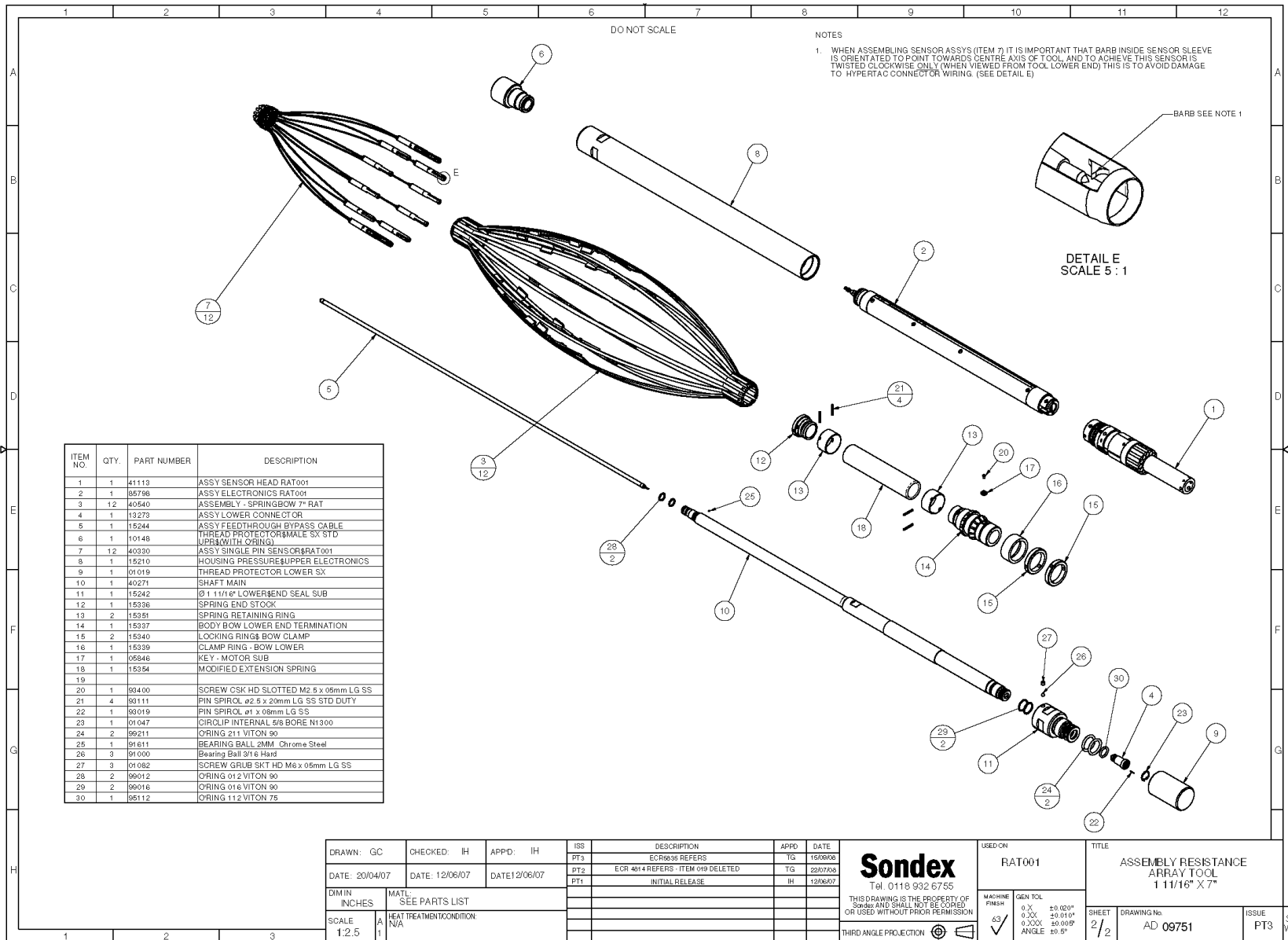
USED ON	RAT001	TITLE	ASSEMBLY RESISTANCE ARRAY TOOL 1 1/16" X 7"
MACHINE FINISH	63	GEN TOL	9 X ±0.020" 0.3X ±0.010" 0.30X ±0.005" ANGLE ±0.5°
SHEET	1/2	DRAWING No.	AD 09751
ISSUE	PT3	S	WV

Resistance Array Tool

RAT001

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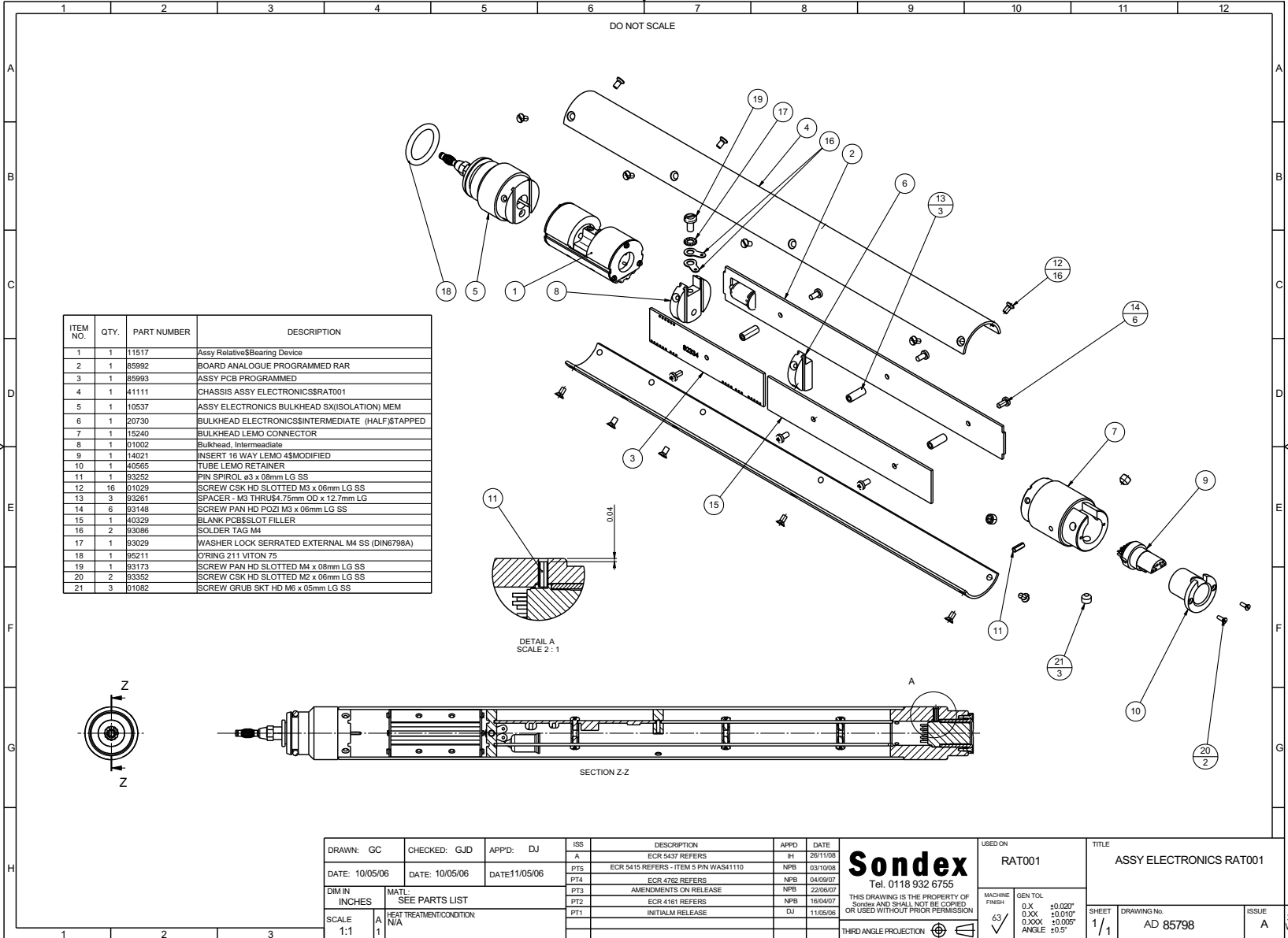
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Resistance Array Tool

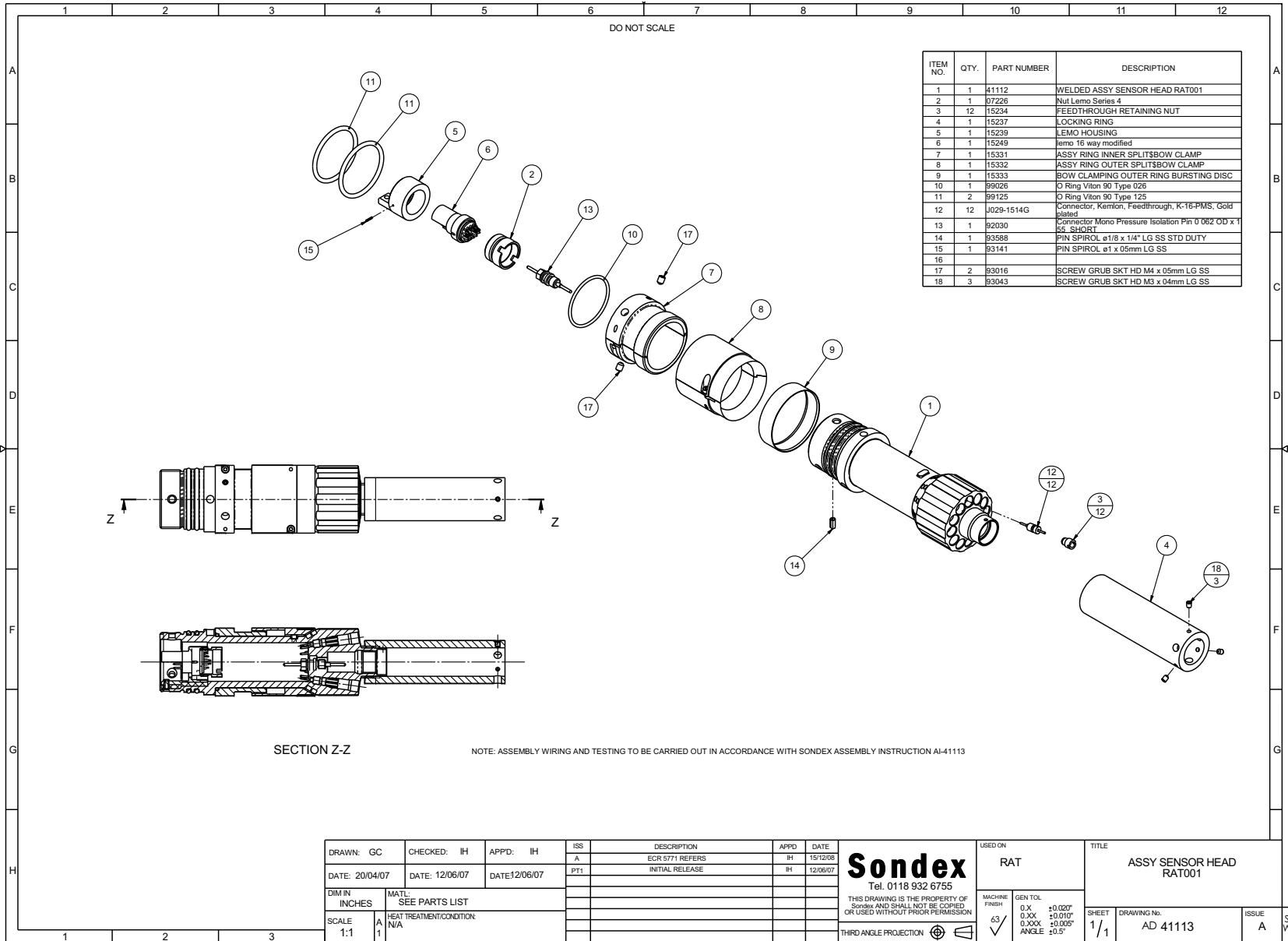
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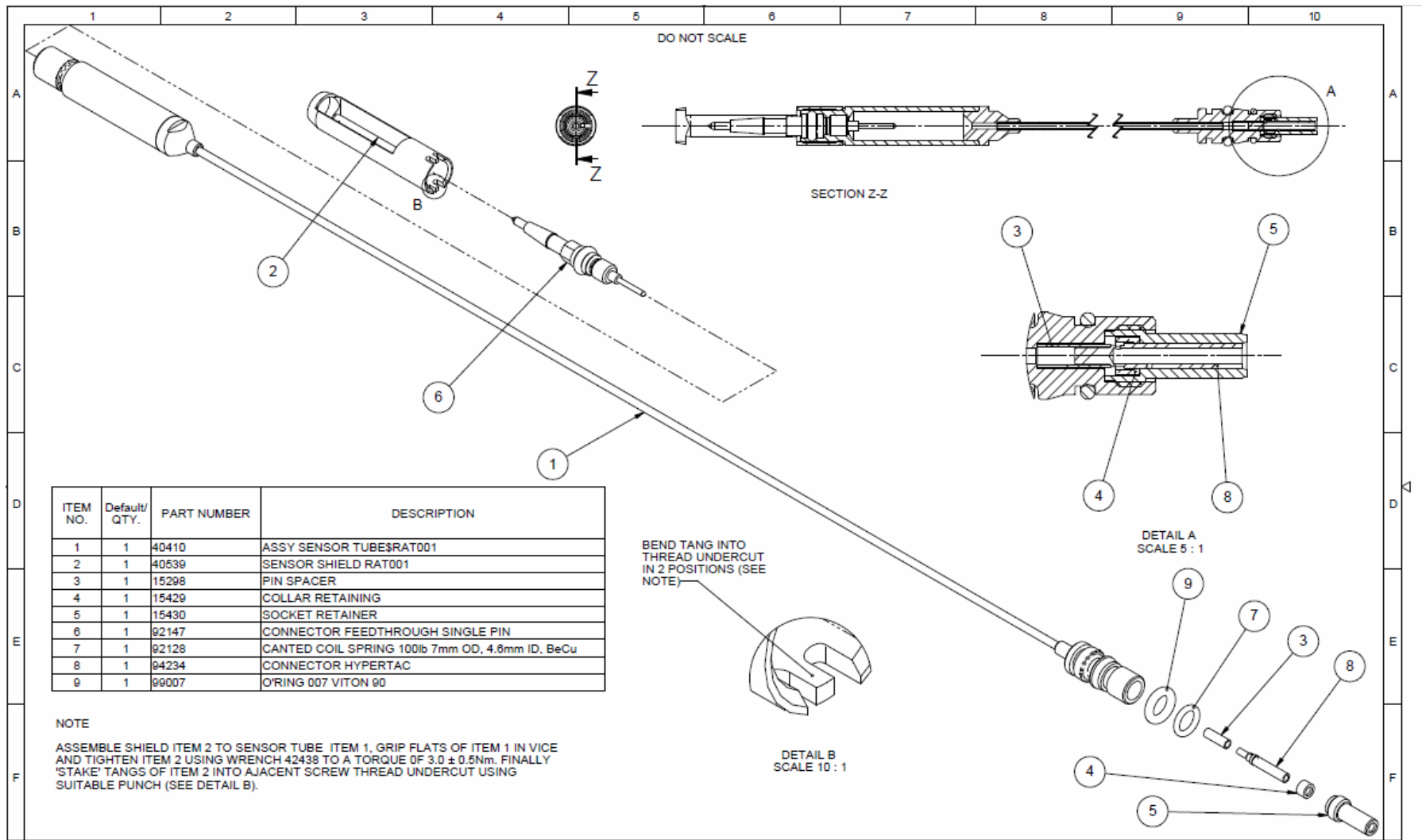
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Resistance Array Tool

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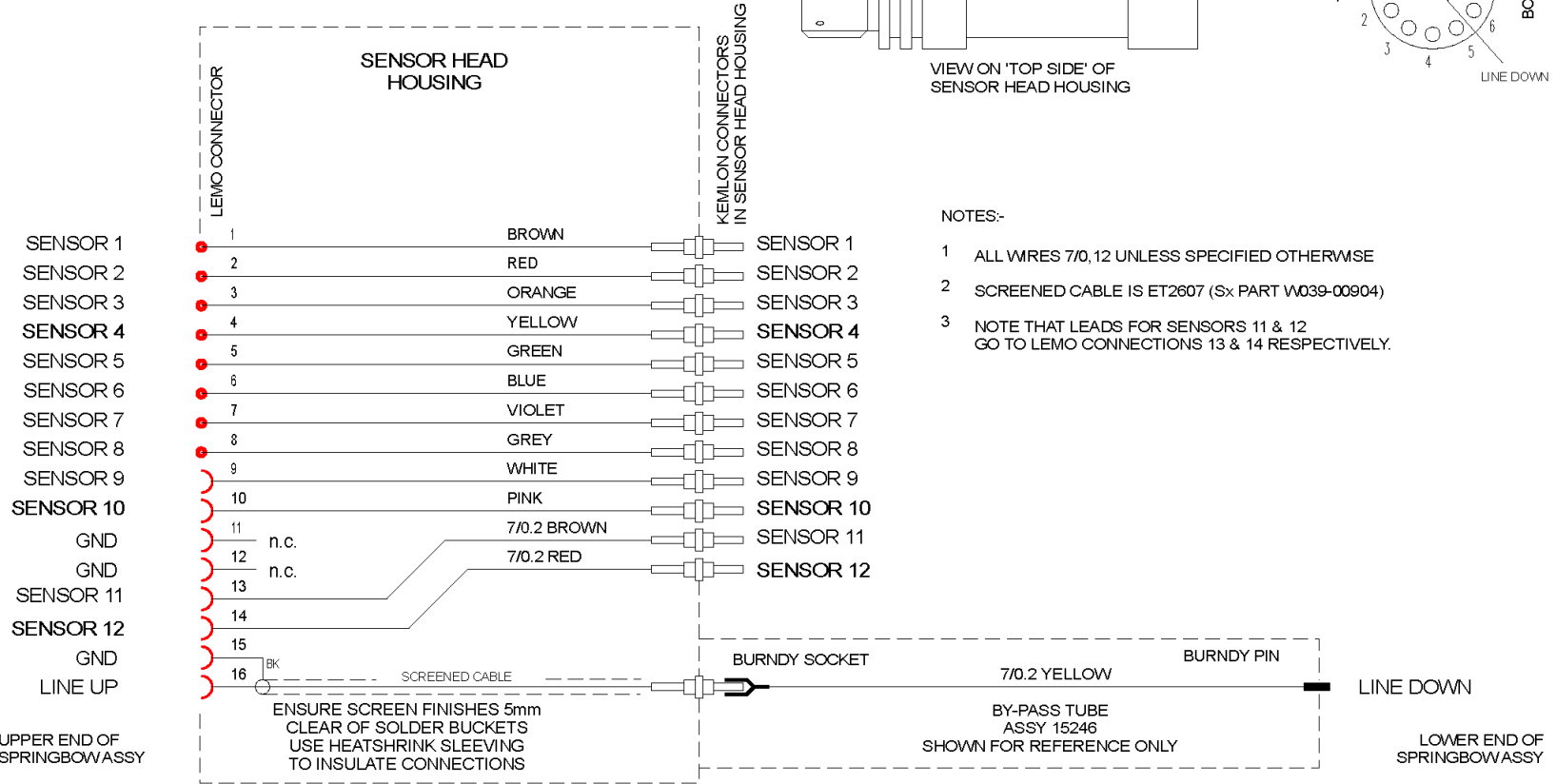
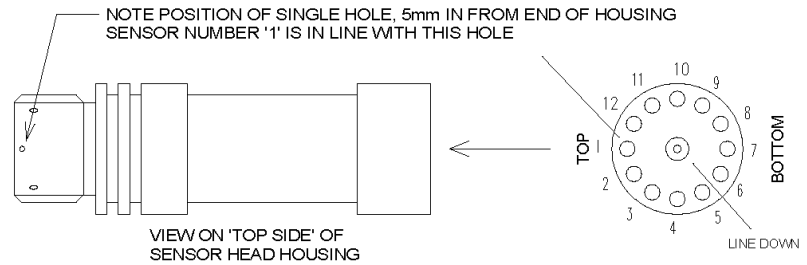
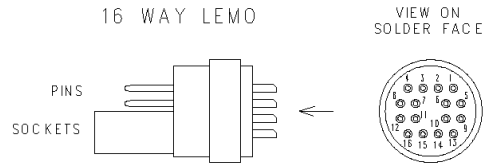


DRAWN: GC	CHECKED: GJD	APPD: DJ	ISS	DESCRIPTION	APPD	DATE	MACHINE FINISH	USED ON	TITLE		
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DIM IN INCHES	MATL: SEE PARTS LIST		PT2	ASSY REDESIGNED	IH	12/08/07	GEN TOL				
SCALE 2:1	A 2	HEAT TREATMENT/CONDITION: N/A	PT1	INITIAL RELEASE	DJ	17/05/06	0.X 0.020" 0.XX 0.010" 0.XXX 0.005" ANGLE $\pm 0.5^\circ$				
THIS DRAWING IS THE PROPERTY OF Sondex AND SHALL NOT BE COPIED OR USED WITHOUT PRIOR PERMISSION THIRD ANGLE PROJECTION							SHEET 1/1		DRAWING No. AD 40330	ISSUE A	S W

Resistance Array Tool

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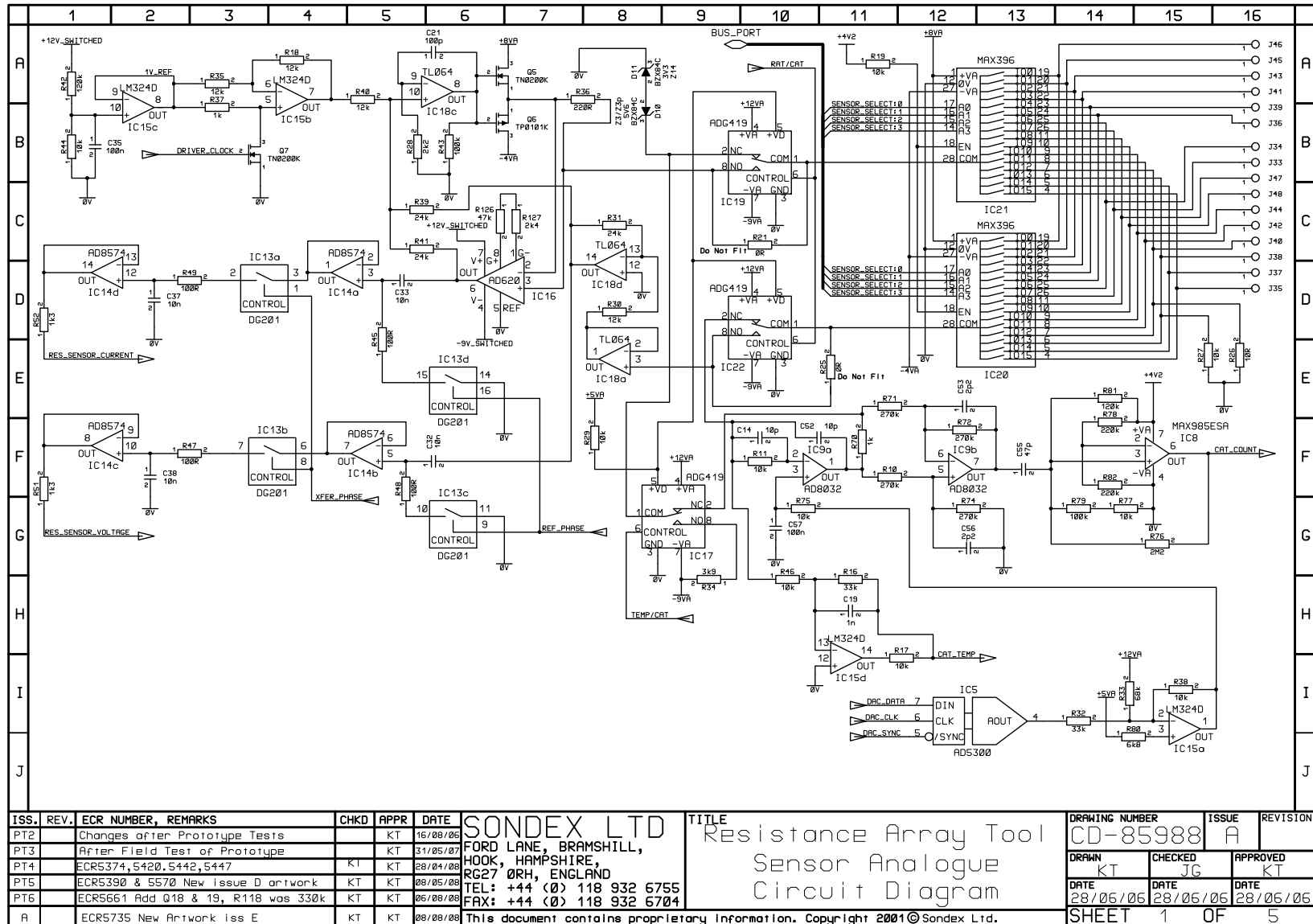
- NOTES:-
- 1 ALL WIRES 7/0, 12 UNLESS SPECIFIED OTHERWISE
 - 2 SCREENED CABLE IS ET2607 (Sx PART W039-00904)
 - 3 NOTE THAT LEADS FOR SENSORS 11 & 12 GO TO LEMO CONNECTIONS 13 & 14 RESPECTIVELY.

ISS	REV	DATE	CHANGES	CHKD	APPD	TITLE	DRAWN	CHECKED	APPROVED	
PT1		7.9.07	Initial Release	KT	KT	SONDEX FORD LANE, BRAMSHILL, HOOK RG27 0RH, ENGLAND. tel 44 118 9326755 fax 9326704	MP	KT	KT	
A		23/07/08	ECR5706 Screened cable was Wire	MT	KT		WIRING DIAGRAM SENSORS & BYPASS 12 FINGER SPRINGBOW UMW RAT	7/09/07	19/09/07	19/09/07
							DRAWING No. WD-41113	ISSUE A	REVISION	

Resistance Array Tool

RAT001

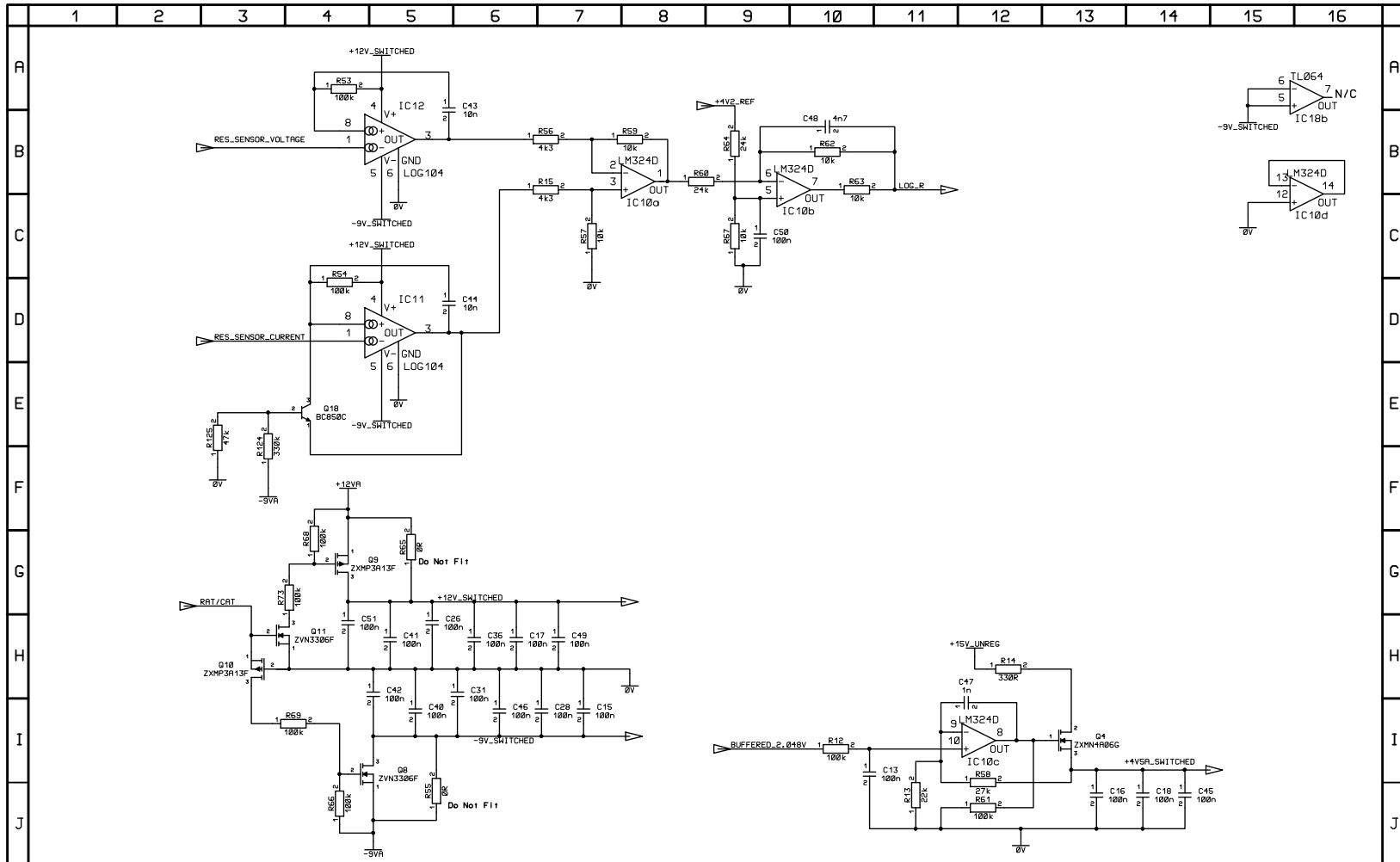
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Resistance Array Tool

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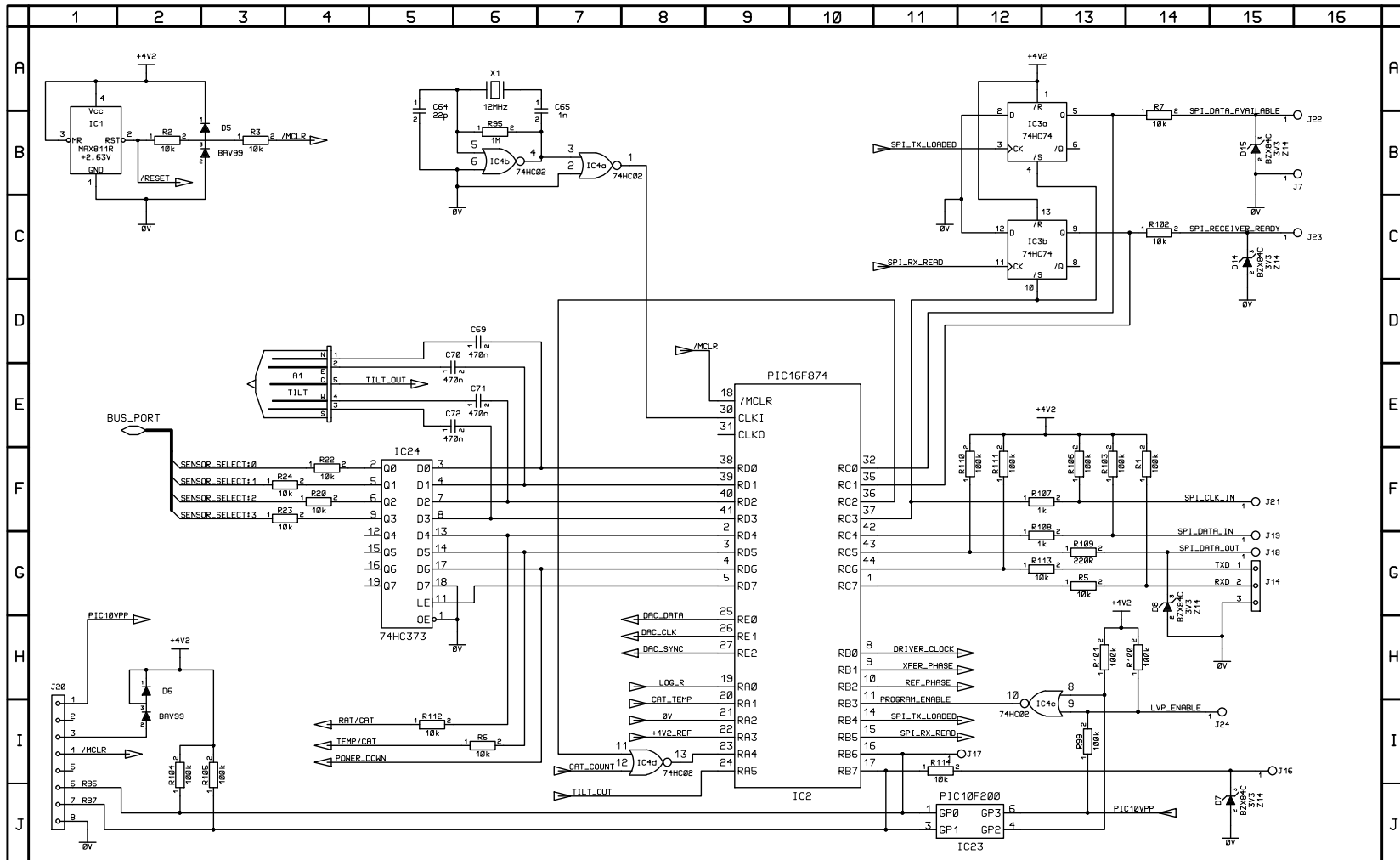
ISS. REV.	ECR NUMBER, REMARKS	CHKD	APPR	DATE	SONDEX LTD	TITLE	DRAWING NUMBER	ISSUE	REVISION	
PT2	Changes after Prototype Tests		KT	16/08/06	SONDEX LTD FORD LANE, BRAMSHILL, HOOK, HAMPSHIRE, RG27 0RH, ENGLAND TEL: +44 (0) 118 932 6755 FAX: +44 (0) 118 932 6704	Resistance Array Tool Sensor Analogue Circuit Diagram	CD-85988	A		
PT3	After Field Test of Prototype		KT	31/05/07						
PT4	ECRS374, 5420, 5442, 5447		KT	28/04/08						
PT5	ECRS390 & 5570 New issue D artwork		KT	09/05/08						
PT6	ECRS561 Add Q18 & 19, R118 was 330k		KT	05/08/08						
A	ECRS735 New Artwork iss E		KT	08/08/08			This document contains proprietary information. Copyright 2001 © Sondex Ltd.		DATE	DATE
							23/06/06	28/06/06	28/06/06	
							DRAWN	CHECKED	APPROVED	
							KT	JG	KT	
							SHEET 2 OF 5			

B-10

Resistance Array Tool

RAT001

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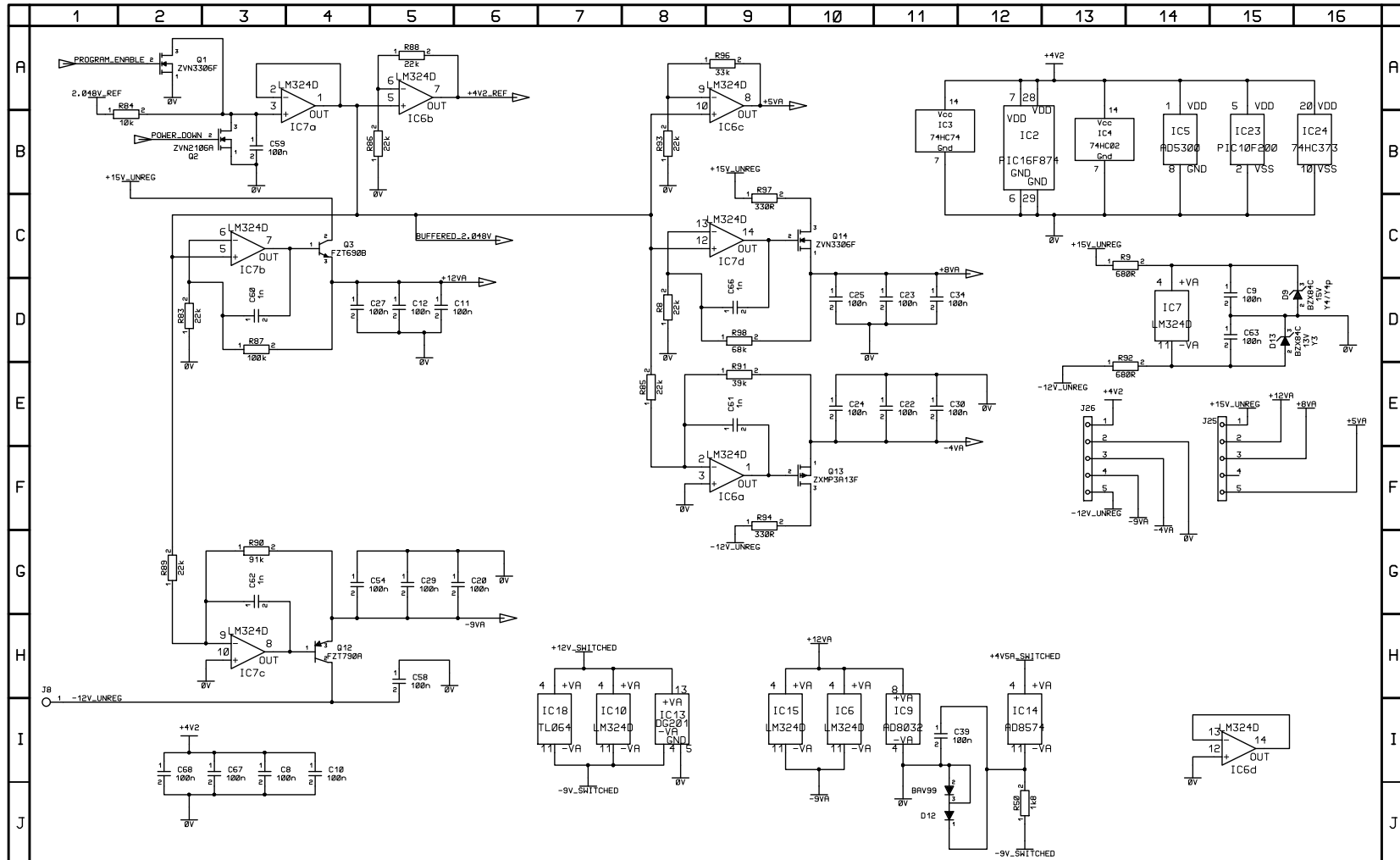
ISS. REV.	ECR NUMBER, REMARKS	CHKD	APPR	DATE	SONDEX LTD	TITLE	DRAWING NUMBER	ISSUE	REVISION
PT2	Changes after Prototype Tests		KT	16/08/06	FORD LANE, BRAMSHILL, HOOK, HAMPSHIRE, RG27 0RH, ENGLAND	Resistance Array Tool	CD-85988	A	
PT3	After Field Test of Prototype		KT	31/05/07	TEL: +44 (0) 118 932 6755	Sensor Analogue			
PT4	ECRS374, 5420, 5442, 5447		KT	28/04/08	FAX: +44 (0) 118 932 6704	Circuit Diagram			
PTS	ECRS390 & 5570 New Issue D artwork		KT	08/05/08					
PT6	ECRS561 Add Q18 & 19, R118 was 330k		KT	06/08/08					
A	ECRS735 New Artwork Iss E		KT	08/08/08	This document contains proprietary information. Copyright 2001 © Sondex Ltd.				
							DRAWN KT	CHECKED JG	APPROVED KT
							DATE 28/06/06	DATE 28/06/06	DATE 28/06/06
							SHEET 3 OF 5		

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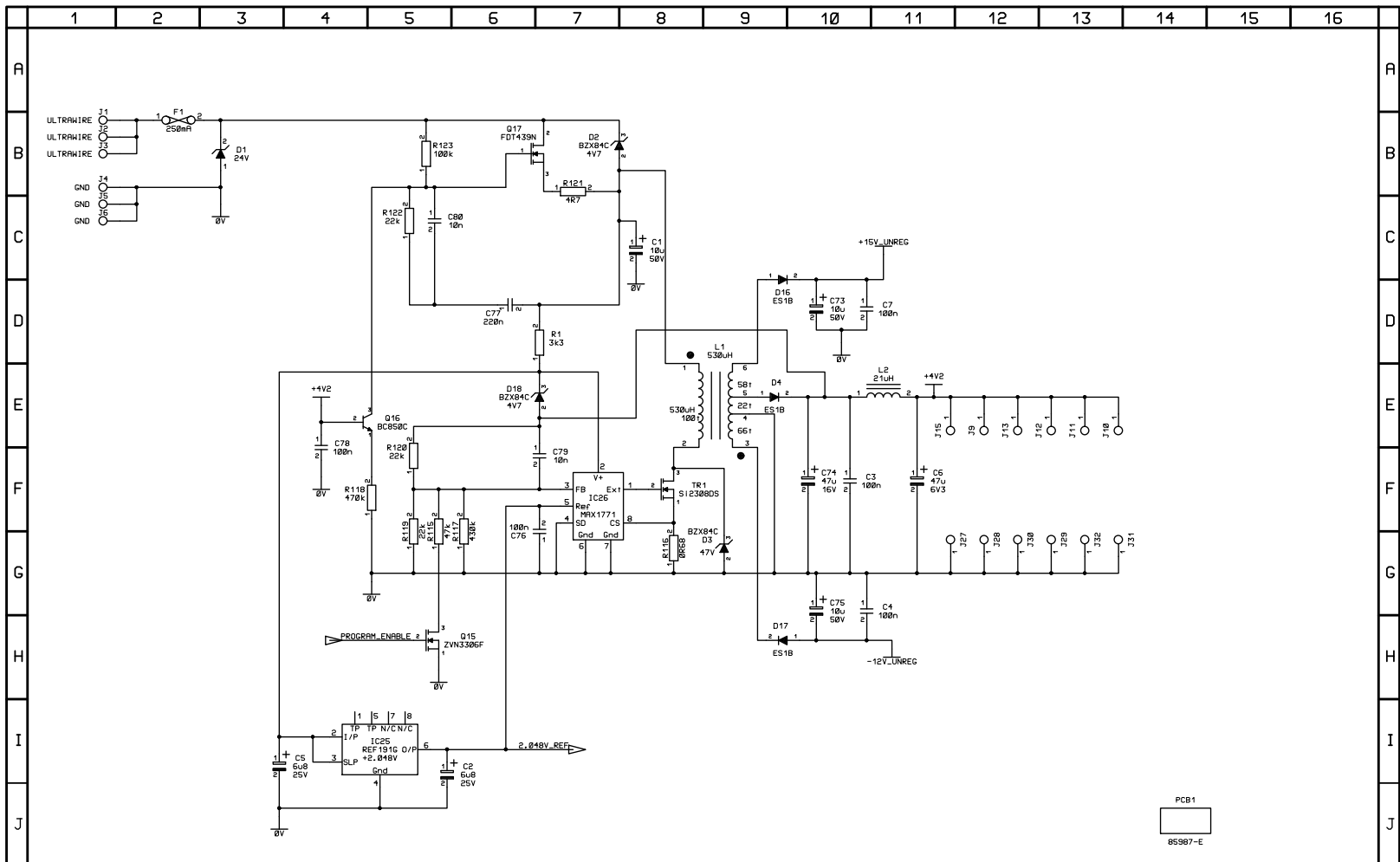
Resistance Array Tool

RAT001

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ISS.	REV.	ECR NUMBER, REMARKS	CHKD	APPR	DATE	SONDEX LTD	TITLE	DRAWING NUMBER	ISSUE	REVISION
PT2		Changes after Prototype Tests		KT	16/08/06	FORD LANE, BRAMSHILL,	Resistance Array Tool	CD-85988	A	
PT3		After Field Test of Prototype		KT	31/05/07	HOOK, HAMPSHIRE,	Sensor Analogue			
PT4		ECRS374, 5420, 5442, 5447		KT	28/04/08	RG27 ØRH, ENGLAND	Circuit Diagram			
PT5		ECRS390 & 5570 New Issue D artwork		KT	28/05/08	TEL: +44 (0) 118 932 6755				
PT6		ECRS661 Add Q18 & 19, R118 was 330k		KT	26/08/08	FAX: +44 (0) 118 932 6704				
A		ECRS735 New Artwork iss E		KT	08/08/08	This document contains proprietary information. Copyright 2001 © Sondex Ltd.				
								DRAWN	CHECKED	APPROVED
								KT	JG	KT
								DATE	DATE	DATE
								28/06/06	28/06/06	28/06/06
								SHEET	4	OF 5

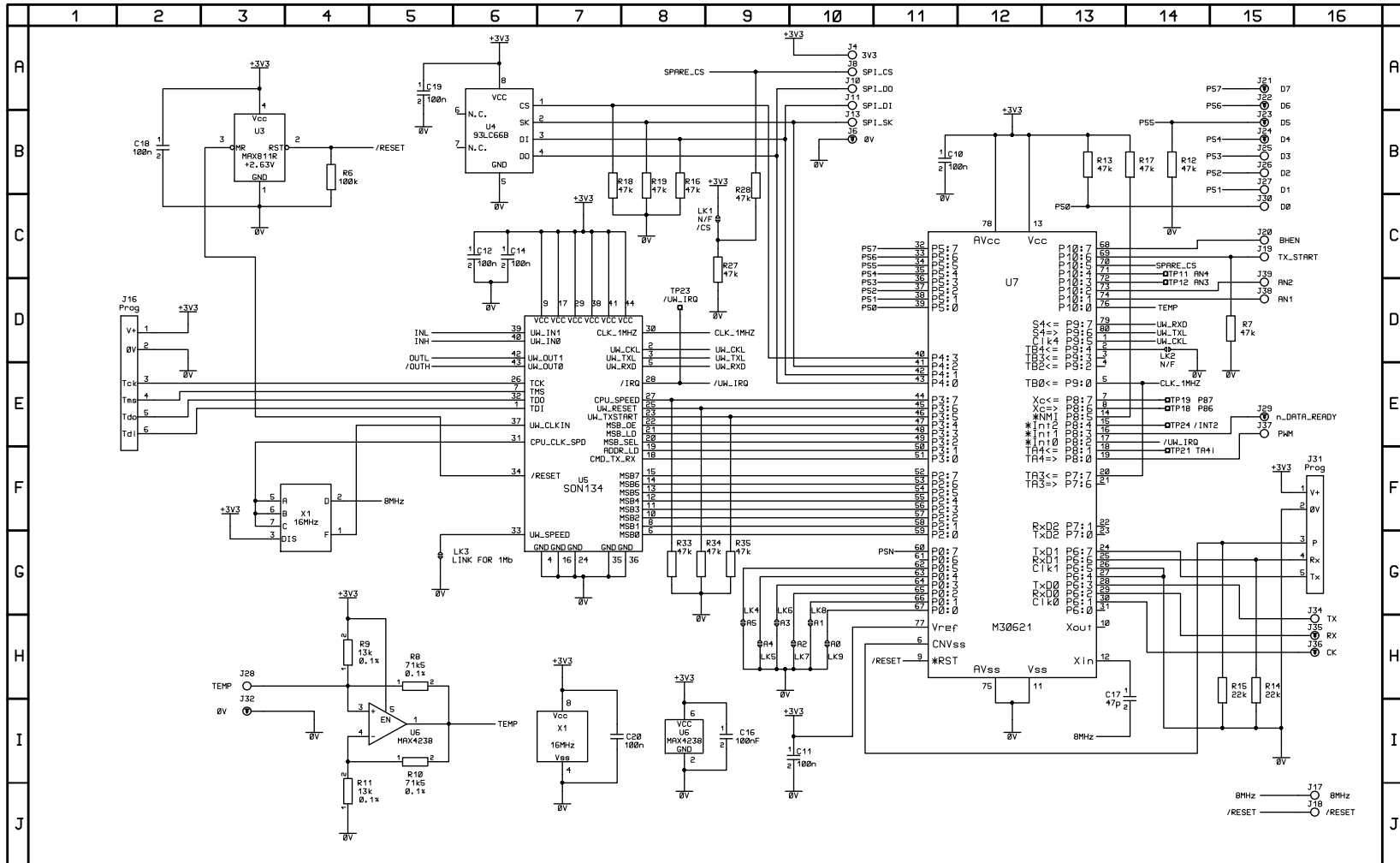


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ISS. REV.	ECR NUMBER, REMARKS	CHKD	APPR	DATE	TITLE	DRAWING NUMBER	ISSUE	REVISION	
PT2	Changes after Prototype Tests		KT	16/08/06	SONDEX LTD FORD LANE, BRAMSHILL, HOOK, HAMPSHIRE, RG27 0RH, ENGLAND TEL: +44 (0) 118 932 6755 FAX: +44 (0) 118 932 6704	CD-85988	A		
PT3	After Field Test of Prototype		KT	31/05/07		Resistance Array Tool Sensor Analogue Circuit Diagram			
PT4	ECR5374, 5420, 5442, 5447		KT	28/04/08					
PT5	ECR5390 & 5570 New Issue D artwork		KT	08/05/08					
PT6	ECR5661 Add Q18 & 19, R118 was 330k		KT	06/08/08					
	ECR5735 New Artwork Iss E		KT	08/08/08					
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						KT	JG	KT	
						DATE	DATE	DATE	
						28/06/06	28/06/06	28/06/06	
						SHEET	5	OF 5	

Resistance Array Tool

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ISS.	REV.	ECR NUMBER, REMARKS	CHKD	APPR	DATE	TITLE	DRAWING NUMBER	ISSUE	REVISION
G	00	ECR5525 C7,C8,C25 was 47U 5v3	PEJR	PEJR	22/04/08	SONDEX LTD FORD LANE, BRAMSHILL, HOOK, HAMPSHIRE, RG27 0RH, ENGLAND TEL: +44 (0) 118 932 6755 FAX: +44 (0) 118 932 6704	CD-82333	G	00
PT2		Circuit Updated	APB	APB	15/07/04				
C	00	Minor Update	APB	APB	23/11/04				
D	00	ECR2840 Hole size ECR2718 Ident C25	BET	PEJR	08/07/05				
E	00	ECR3011 I/O pads moved	APB	APB	05/08/05				
F	00	ECR4594 C9 Added	KT	KT	19/04/07				
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							DATE 10/12/03	DATE 10/03/04	DATE 12/03/04
							SHEET 2 OF 2		