RCF/RSGB BUILDING BRIEFING FOR BRITISH SCIENCE WEEK

This briefing has been prepared specifically in support of building the Walford Electronics Spaxton receiver, sponsored by the Radio Communications Foundation in support of British Science Week 2019. However, most of the briefing can be used for any group build.

This briefing includes:

- Guidance on preparing for the event
- Advice on running the event
- Technical info about the kit
- Common kit building faults and resolutions
- Acknowledgments and further information links/contacts

Preparation

Liaising with the school you are working with as soon as possible in advance of the event is a good idea. A site visit is even better. The host will have questions for you as much as you have questions for them. The RSGB Events Pack contains good information about planning, promotion, risk assessment, risk management, insurance and reporting success in the press afterwards. You can find the pack here: https://rsgb.org/main/clubs/events-pack/

Key areas you need to consider and explore with school:

- **People**
  - Who are you going to get to help you? Helpers need to be confident in radio/electronics construction and be able to answer questions if asked. If you can have young radio amateurs in your team so much the better – role models work wonders!
  - How many youngsters will be building? That will determine how many helpers you need. Experience has shown 1 helper can supervise 3 or 4 builders if sat around a table but 1 helper to 2 builders is optimum. If working in pairs (1 kit between 2 builders), a ratio of 1 helper to 2 or 3 pairs has also worked OK in the past.
  - Will the youngsters be working solo or in pairs? Working in pairs does work well as each youngster will act as a checker on the other half of the pair. A group of 3 can work if 1 picks the part, another fits it and the other solders and they rotate after each stage. Larger groups per kit are not recommended due to drift in concentration; groups of 4 or more are definitely a recipe for 'idle hands'.
  - Do the youngsters have any soldering experience? If not you will need to spend more time demonstrating correct technique in component selection, placement,

soldering and cutting off excess leads. Having some scrap PCB material or Vero board and some spare components allows you to assess when they are ready to start building on their own.

- How many members of school staff will be in attendance? At least one teacher or teaching assistant per class is essential in case of emergency or discipline issues. They are likely to insist on that for Child Protection too.
- Child Protection – some schools insist on all helpers being DBS checked. This is not a legal requirement if a teacher is present but if the school has that as a local rule you need to know. For more info see the RSGB Policy on Safeguarding: http://rsgb.org/main/files/2012/11/RSGB_Child_Protection_Policy.pdf

- **Environment**
  - Lighting needs to be good enough to see what you are doing – most school classrooms are bright enough but it is worth checking.
  - Ventilation needs to be sufficient to allow fresh air in and solder fumes out. A few open windows are normally OK.
  - Heating should not be a problem but if it is cold weather, sitting building for a few hours will require breaks to move around and warm up.
  - Workspace - a table about 2m wide is OK for two builders – arranging tables so you have groups of 4 or 6 builders is a good approach.
  - Testing – having a separate test bench is useful for stage-by-stage tests and for final testing. Having it by a window so a antenna wire can be thrown out is a good move – make sure it does not create a tripping hazard if on the ground floor!

- **Equipment**
  - Who provides? Ideally the host will provide all the tools and equipment needed. Experience has shown this is not always the case. The RSGB Loan Tool Kit is available on a first come, first served basis. See here: https://rsgb.org/main/about-us/committees/training-and-education-committee/members/rsgb-construction-tool-kit/ If your Club or radio group is going to provide tools it is worth checking you have everything you need well in advance.
  - What is needed? Ideally you want a set of tools for each kit. However, a ratio of 1 set of tools to 2 kits has been found to work in the past. Tools required include:
    - Soldering irons and stands. 18W Antex appear to be standard school issue. Those with silicone cables are better. Low voltage irons are safer still.
    - Side cutters
    - Small nose pliers
    - De-solder pump and/or de-solder braid
    - Wire strippers
    - 3mm flat blade screwdrivers
    - Magnifying glass – some component markings are less than clear!
    - Multimeters – there are voltage checks in the Spaxton build and a meter is always useful for confirming resistor values, fault finding, etc. One meter to three or even four kits is sufficient.

        - PCB holders are useful, especially for reworking. For example: https://cpc.farnell.com Part No SD0212607
        - PCB drill with 1mm drill bit – useful for clearing out blocked holes
        - Mains extension leads with multi-way sockets – not required if school has work benches with mains outlets. If using long leads, gaffer tape or rubber cable covers need to be factored in.
        - Table protection – if using a workshop the benches are likely to be fine as they are but some sheets of hardboard, about 600mm x 400mm, are ideal for protecting 'good' school tables.
        - Safety spectacles – RSGB advice is that safety spectacles should be worn if corrective lenses are not already worn. This is to protect against solder splashes and flying objects when excess component leads are cut off. The host may have their own rules on this; their site, their rules.
    - Back up? Even if the school provides everything, it is useful to have spare soldering irons, stands, de-solder pumps and multi-meters available for re-working/testing. Irons should be in good physical condition and ideally PAT Tested. The host may insist on PAT testing. It is their site so they are entitled to make the rules!
    - Specific test gear - An AF Amp is useful for testing without headphones so builder and mentor can both hear what is happening and an AM signal source so you can confirm if the receiver is actually inhaling RF is useful. The plan for British Science Week 19 is to provide a small kit to each radio club/group, the Walford Spade, which includes an AF amp to drive a loudspeaker and an AM modulated signal source.

- **Materials**
    - Each school will receive fifteen Walford Electronics Spaxton receiver kits. These come with all components, instructions and some aerial wire.
    - Each school will also receive a spares kit with some replacement transistors, diodes and electrolytic capacitors. The spares kit includes only those parts most likely to be needed – do be careful about static when handling the MOSFET transistors!
    - Instructions – will come with the kits. An advance copy will be provided to let the event leader do some preparation/team briefing.
    - Solder – this is for the school or radio club/group to supply. Standard 60/40 leaded solder is recommended. Some schools insist on using lead-free solder. Lead-free will work, it is just not as easy to work with. As it is their site, their rules apply.
    - An external aerial wire is a useful addition; many schools are 100% RF tight and full of RFI that can swamp a simple receiver.
    - The school or radio club/group will also have to supply a 9v battery and the builders will have to supply their own ear buds or headphones. The kit has been tested using standard mobile phone ear buds, and hi-fi headphones. The test set will allow receivers to be tested without ear buds or headphones.
    - Water for wetting solder sponges is usually available in the loo but some classrooms have sinks and taps.
    - Pens or pencils – each part needs to be ticked off as it is fitted but it is a reasonable assumption that the builders will have a pen or a pencil, even in this age of tablet and wi-fi!

On the day of the event

Depending on the age and experience of the pupils attending the workshop, the opening briefing may be limited to introducing the radio club/group team or it may be necessary to talk through the introduction pages in the instructions – what you are building, broadly how it works, the rough build order, which components you need to look out for/fit the right way round and maybe how to solder.

Health and safety should be covered by the school but it is worth checking with the youngsters what they understand are the risks from soldering and using hand tools – ask them questions like 'why do we need to be careful how we hold the soldering iron?'. Point out the pitfalls of trying to catch a falling soldering iron and explain why they need to wear safety spectacles. Again, the host may have their own rules on such matters.

Stress that they need to follow the instructions and if they are unsure, they just need to ask for help.

Also stress that they should enjoy themselves!

Congratulate and encourage as they build and receivers pass stage testing.

Get them to test the finished receivers on an outdoor antenna for better reception; indoor antennas can be silent if the classroom is in a metal frame building.

Announce the first working receiver and suggest a round of applause. Repeat as others are completed as appropriate.

Technical Information about the Spaxton kit

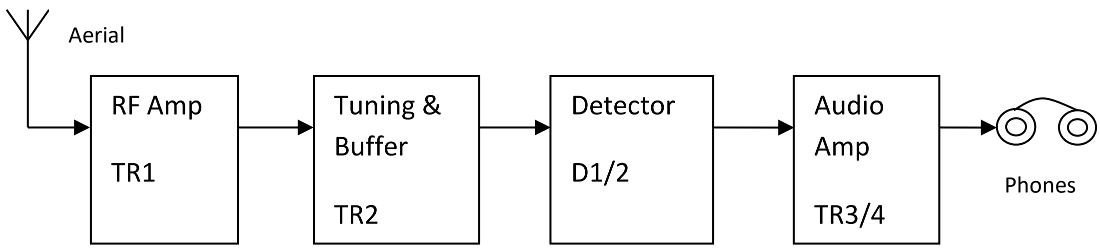
These technical notes are for the radio club/group members, rather than the builders. They include a few extra notes on points not fully covered in the kit instructions provided to the builders, the circuit diagram (Fig 1), a parts layout diagram (Fig 2), a technical description of the circuit, and a parts list.

Circuit Description

Overview: The Spaxton is a plain Tuned Radio Frequency (TRF) receiver for listening to Amplitude Modulated signals. It has four main functional blocks, as shown below.

The design uses a 9 volt battery supply which is activated by plugging in the ear phones – without the phones, the circuit is still 'live' but consumes negligible current. The circuit is also reversed supply tolerant but don't intentionally try that! Stereo 32 Ohm ear buds/headphones **must** be used and if selectable, they **must** be switched to stereo, otherwise no signals will be heard!

All four stages use the same type of transistor – the BS170 MOSFET – which can be damaged by high static voltages, so be alert to that danger!



RF Amplifier TR1: This is the first stage of amplification for the very weak radio frequency signals from the aerial – it is a grounded gate amplifier. There is a static discharge resistor R1 across the antenna input and a small capacitive coupler C3 to reduce the chance of damaging static from the aerial; they feed the device source via the RF gain control R2. The stage derives its gate bias (a little over 2 volts) from the audio output stage with RF decoupling for grounded gate operation provided by C5.

Tuning and Buffer TR2: This selects the desired reception frequency with the buffer adding power gain. The drain load of TR1 is a parallel resonant tuned circuit, comprising the two inductors L1 and L2 in series with both sections of the tuning capacitor C1; the tuning range should cover from over 1.8 MHz (160m) down to under about 1 MHz (300m) for coverage of at least part of the Medium Wave band where there are several powerful AM broadcast stations. The gate of the buffer stage TR2 is fed from the junction of L1/2 to preserve the best possible Q (hence selectivity), with the DC bias from the audio output stage. TR2 provides a low Z drive to the detector.

Detector D1/2: This stage recovers the audio signal by rectifying the incoming varying amplitude RF signal. The two diodes are in a full wave form and have a small forward voltage/current to overcome their 'threshold' of about 0.5 volts. C7 and R6 limit the output bandwidth to about 3500 Hz which is fine for voice/music.

<u>Audio Amplifier TR3&4:</u> These provide the final stage of amplification to obtain a comfortable sound level in the phones. The two devices are arranged in a DC feedback pair - the source voltage of TR4 is fed back through D1 & 2 to develop about 2 volts at the gate of TR3, so just turning it on, and hence properly biasing TR4. TR3 has high voltage gain due to the large value of R7, with C8 helping to limit the audio bandwidth. R8 is a gate stopper. The source of TR4 is heavily decoupled for audio so it also provides some gain despite the low 64R load of the phones. This feedback arrangement holds the current through the output stage at about 9 mA and is largely independent of supply voltage so making the whole circuit tolerant of a wide supply range. The source voltage of TR4 is near 3 volts (made up from about 2 volts to turn on TR3 plus two diode drops in D1 & 2), so is also suitable for the gate bias of TR1 & 2 provided via R3 & 4 - hence TR1 & 2 will not work properly if TR3 & 4 are incorrect. It is worth repeating that the phones must be for stereo use and must NOT have their common lead grounded – the two 32 Ohm earpieces in series make up the 64 Ohm load. The circuit is not suitable for driving a loud speaker but the Spade test set enables testing using a loudspeaker.

<u>General building advice:</u> Photo 1 shows a completed kit but without the main tuning knob. These will help you find the correct holes for any particular part by examining the track connection pattern from that part to others as shown in the circuit diagram.

When building the kit, constructors **<u>must</u>** build it in the sequence suggested and **<u>must</u>** also perform the tests for each stage as they proceed. This is so that any failures caused by errors, or faulty parts, can be detected and cured before moving onto the next stage.

When construction event helpers are trying to resolve failures, it is helpful to study the PCB track connection pattern and compare it with the circuit diagram.

The parts list is included so that you can check that you have all the necessary parts; particularly useful if a builder drops all parts on the floor!

<u>Supplies:</u> The assumption is that the kits will be battery powered. The instruction test point voltages are for a 9v supply. You can use a DC power supply (9 to 15v) instead of the PP3 battery if you wish. Negative to the 0v point (in rear left corner) and positive to the nearby point +V.

Adding an external power supply may improve the earthing and so give better reception of weak stations.

<u>Aerials:</u> The receiver kit includes a length of wire for an aerial which builders should drape around the room – ideally well spread out and by a window. If it is possible to have a 'long wire' going outside, so much the better.

Beware that modern re-enforced concrete buildings with structural steelwork, may act as a Faraday screening cage. If this is the case, testing is best done done by draping the aerial wire near an Amplitude Modulated signal source. This can be provided by the Spade test set or a fully set up amateur transceiver working into a dummy load on 160m AM.

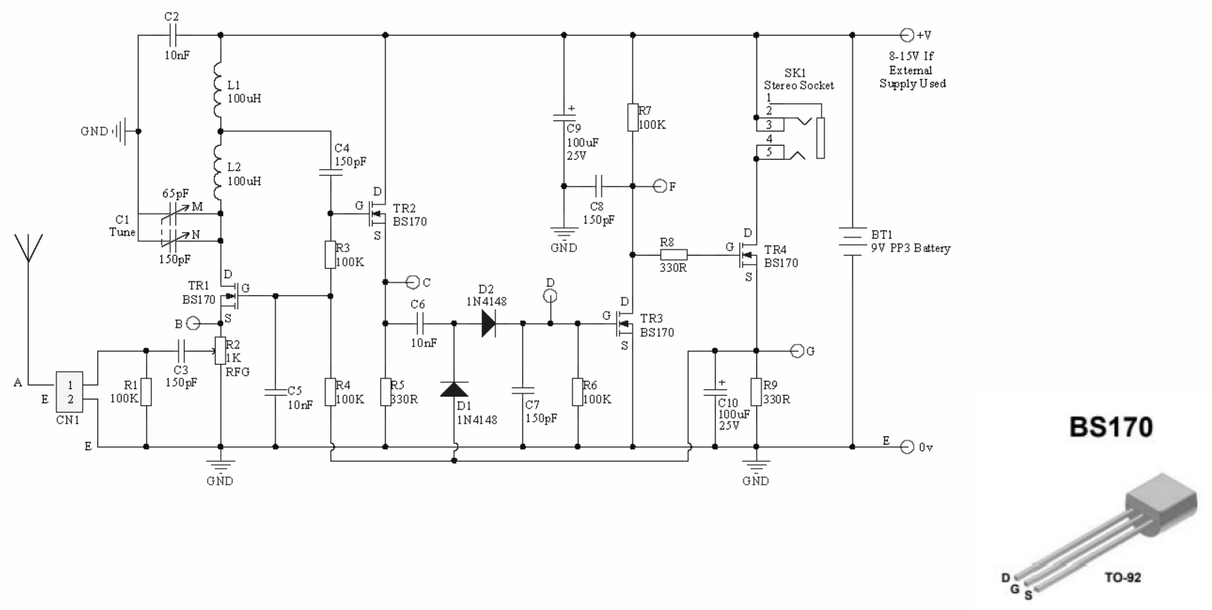


Fig 1 - Circuit of Spaxton RX

Typical Test Voltages (using 9V battery)

	Drain	Gate	Source
TR1	9V	2.7V	0.6V to 0.7V
TR2	9V	2.7V	0.5V
TR3	5.3V	1.9V	0V
TR4	8.5V	5.3V	2.7V to 2.8V

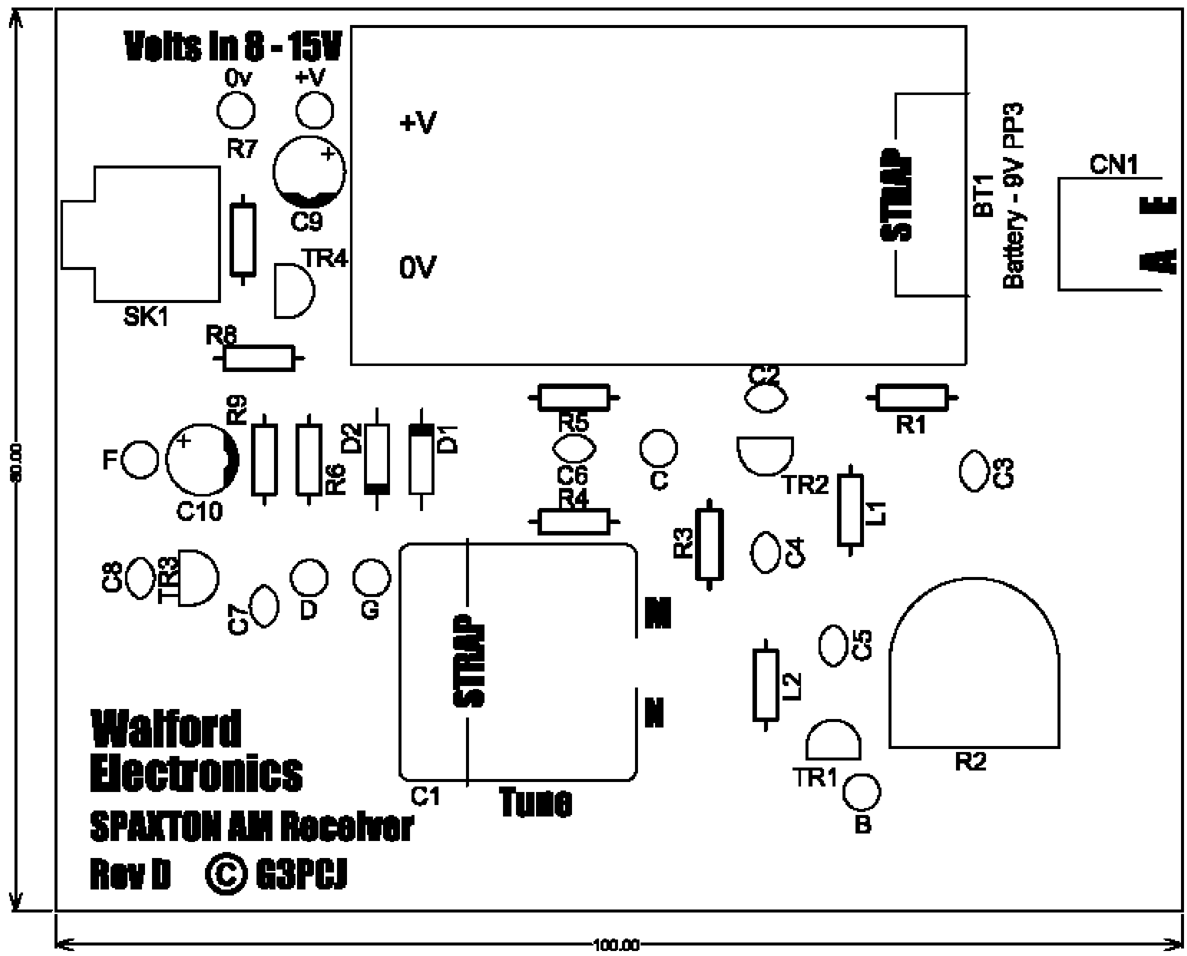


Fig 2 - Parts layout of the Spaxton RX (enlarged)

Parts list for the Spaxton RX

Resistors			Capacitors		
3	330R – OR,OR,BN,GLD	R5,8,9	4	150 pF ceramic plate – 151	C3,4,7,8
5	100K – BN,BK,YL,GLD	R1,3,4,6,7	3	10 nF small ceramic disc - 103	C2,5,6
			2	100 μF 25v electro	C9,10
1	1K - 15mm shafted preset + shaft	R2	1	65/150 pF PolyVaricon	C1
Inductors – they are like beads			Miscellaneous		
			4	Rubber feet	
2	100 μH – BN,BK,BN,SLVR	L1, 2	1	Two screw connector block	
			1	3.5mm PCB stereo skt	
Semiconductors – in anti-static bag			1	PP3 battery holder	
2	1N4148	D1, 2	1	Small 6mm knob	For R2
4	BS170	TR1,2,3,4	1	Large Knob	For C1
1	Shaft extension and long bolt	For C1	5 m	Stiff single core wire	Aerial, C1, PP3 holder
TRN Walford G3PCJ Oct 22nd 2018			1	Spaxton etched PCB	Rev D

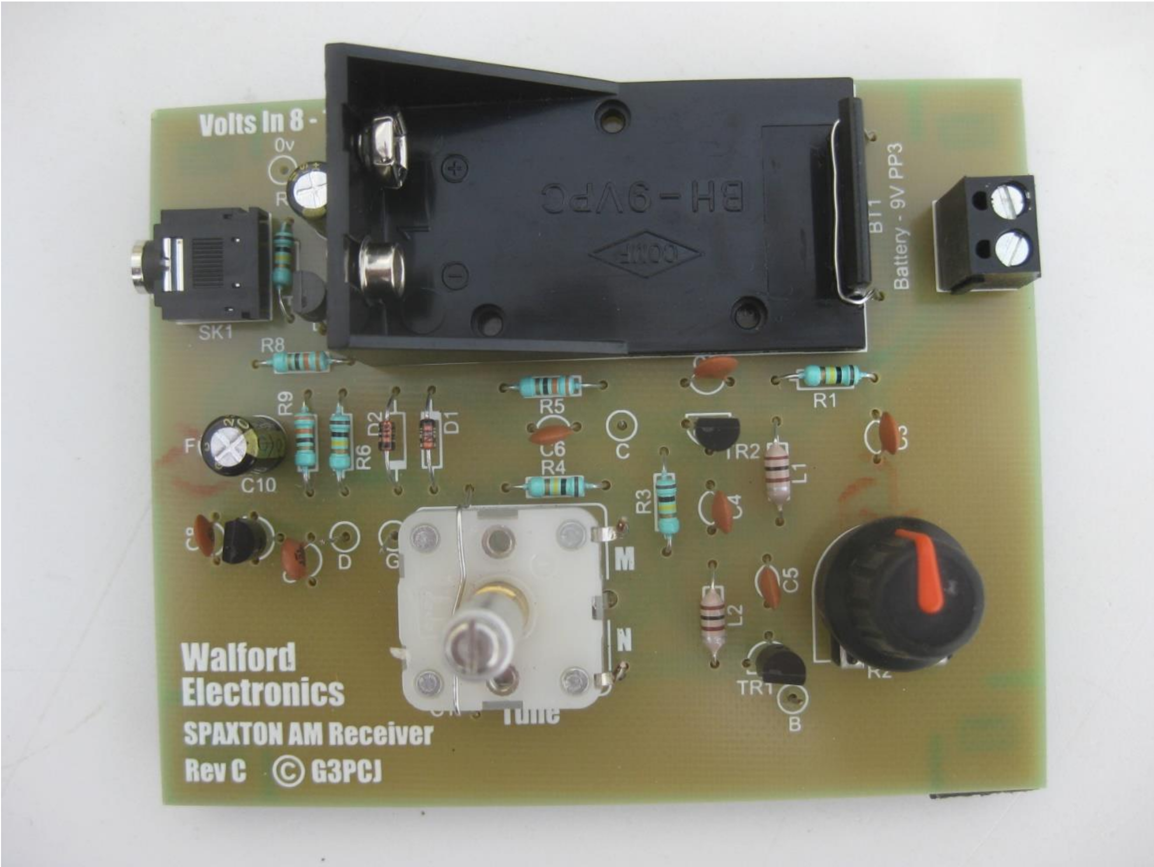


Photo 1. Spaxton without the knob of C1 fitted. (Revision D is effectively the same!)

Common build problems

Problem	Resolution
Wrong part fitted or part fitted with wrong orientation.	• De-solder, remove and replace but involve the builder(s). • Get builder to use pliers to put component under tension and helper can apply heat to track side and remove the solder. • Clean up the holes with de-solder pump and/or de-solder braid. • Sometimes the plated through holes retain some solder and block the hole; clear with a 1mm PCB drill.
Zero volts on switch on or battery getting hot.	• Usually an obvious short between solder pads • Use magnifying glass to identify where short has occurred • Use de-solder pump to remove excess solder.
Suggested test does not work or unexpected result occurs	• Usually a dry joint, a short or incorrect component orientation. • Fitting fixed inductors in place of resistors is not uncommon • De-solder, remove and replace as above.
No audio despite all voltage tests being good	• Usually a sign that the headphones have gone bad. • Try another pair of headphones.
Poor reception when completed	• Check the aerial wire is connected to correct 'Ant' socket, as opposed to the ground socket. • Make sure aerial wire is far enough outside the building to prevent building screening/RFI swamping. • Some areas have stronger MW signals than others. An external aerial wire makes a BIG difference. • In some situations, fitting the aerial wire as a loop can improve reception; connect loop ends to 'Ant' and 'Gnd' terminals. • Better results are normally had outdoors. Subject to host agreement, an experiment trying different locations around the site can be fun. Also adding a second 'ground' wire can make a big difference.

No MW reception	• Check 'poor reception' solutions above.
	• Check voltages on FET pins. If **not** broadly in line with values suggested below, remove RF amp FET and check again.
	• If values are nearer being correct without the RF Amp, fit a replacement BS170.
	• Rough values for voltage checks (based on 9V supply):
	    ○ TR1 – Source 0.6V to 0.7V, Gate 2.7V, Drain 9V
	    ○ TR2 – Source 0.5V, Gate 2.7V, Drain 9V
	    ○ TR3 - Source 0V, Gate 1.9V, Drain 5.3V
	    ○ TR3 - Source 2.7V to 2.8V, Gate 5.3V, Drain 8.5V

Acknowledgements and Further Information

The Spaxton Receiver kits provided to schools in support of British Science Week were kindly funded by the **Radio Communications Foundation**, a charity supporting the development of radio communications in the UK.

The Radio Communications Foundation is keen to support school radio projects and welcomes applications for sponsorship, and donations to help it achieve its objectives.

The Radio Communications Foundation website is at http://commsfoundation.org/

The Spaxton project was conceived and developed by Tim Walford of Walford Electronics Ltd. The circuit copyright remains the property of Tim Walford. The Walford Electronics Ltd website is at www.walfords.net/

The Spaxton Receiver kits were put together by **Walford Electronics Ltd w**ith PCB support from Alfatronix Ltd – www.Alfatronix.com

Geoff Budden, G3WZP, and Steve Hartley, G0FUW, provided assistance in building early versions of the Spaxton, and chipping in with its development.

Local help and support was provided by Radio Clubs and individuals who are member of the Radio Society of Great Britain (RSGB). The RSGB represents radio amateurs across the United Kingdom of Great Britain and Norther Ireland, the Isle of Man and the Channel Isles.

Further information about amateur radio is available from the RSGB website: http://rsgb.org/main/get-started-in-amateur-radio/what-is-amateur-radio/