Standalone GPSDO Operation of the Lucent KS-24361 REF-0

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The Lucent KS-24361 is a cell-tower GPSDO system, circa 1998, consisting of three units: REF-1 – a control box with a GPSDO; REF-0 – a box without a GPS receiver which looks similar to REF-1 but is employed for redundancy purposes; and a custom interconnecting cable. Besides its original application, a KS-24361 can be used as a laboratory time and frequency standard.

Since July 2014, the best part of 1,000 x REF-1 and 1,000 x REF-0 units have been sold on the US surplus market as "new, old stock", often at throw-out prices. As a result, the units are of particular interest to the amateur-radio and time-nut communities. While the primary output signal frequency of both units is 15MHz, the REF-0 includes a 10MHz output and the REF-1 has a latent 10MHz output that may be activated with minor hardware modification.

Outside of the original cell-tower application, the REF-0 redundancy feature of the system is usually not required and the REF-1 can be run as a standalone GPSDO. This makes the REF-0 units surplus to requirement sparking considerable interest and investigation, particularly in the time-nut community, into the possibility of converting them for standalone GPSDO operation. In this regard it is disappointing that Lucent/HP/Agilent/Symmetricom have not taken the opportunity to gain kudos by releasing the technical documentation for the units, despite them being well past their "end-of-life" and of depleted commercial value. Such documentation is no doubt of significant educational value and historical interest, and would aid environmental repurposing. As a consequence, conversion of the REF-0 for standalone operation requires significant reverse engineering.

From a superficial examination the REF-0 unit appears suitable for GPSDO conversion because the REF-0 and the REF-1 (which is a GPSDO) share the same PCB design. Intrinsically, if one correctly repopulated the REF-0 board, it could be transformed into a REF-1 unit. In reality this approach is not viable because the component differences between the units are so extensive. However, perhaps some of these differences are irrelevant and a good GPSDO can be designed without necessarily making it identical to

a REF-1. This begs the question: what is the minimum-size set of changes that are required to convert a REF-0 into a GPSDO?

The answer to this question is not necessarily an end unto itself – we don't necessarily want to turn a REF-0 unit into a "minimum change" GPSDO unit. Instead, "minimum change" is about the definition of a starting point for an improved design – it is an engineering stepping stone to producing an "enhanced REF-0" GPSDO, such as a GPSDO with a more-modern GPS receiver, for example.

This report does not cover the basic operational details of the Lucent boxes, the power-supply requirements, and the design of an interface dongle to replace the control cable, for example. If these matters are unfamiliar I recommend reading the thorough "The Sync Channel Blog" of Dan Watson and the extensive discussions on the Time-nuts Forum [key references are given in Dan's blog]. Background knowledge is assumed in this report and a good understanding would be wise before hacking the REF-0 hardware!

For the present purposes, consider the task of producing a "minimum change" design. Such a design will use the same receiver as the REF-1, the venerable Motorola Oncore UT+ GPS receiver, because, at this stage, we wish to avoid firmware incompatibility issues. It may be assumed that the REF-1 and REF-0 incorporate the same firmware (not to be confused with data permanently stored in the units: a serial number, a model description, a power-on-hours count etc).

For demonstration purposes such a REF-0 standalone GPSDO unit has been constructed. It uses a surplus Oncore receiver with a right-angle OSX connector rather than the straight-type of the REF-1 unit, as shown in Figure 1. This allows a right-angle antenna cable connection without fouling any components or interfering with the existing 10MHz output arrangements of the REF-0. The receiver is mounted in the designated position on the PCB. A 2x5-pin header/riser must be installed for the connections and 4 posts provided for support.

As a GPS receiver is to be installed, the REF-0 must be configured to communicate with it – unfortunately, there is no sensing for the presence of a receiver so communication does not start automatically. In addition, the signal line carrying the 1pps output of the receiver must be configured to discipline the REF-0. Configurations are set by appropriately positioning jumpers on the PCB and we must change a number of jumpers

and a resistor on the PCB to enable GPSDO operation. The jumpers are simply 0Ω SMD links which are soldered onto the PCB. They may be moved without specialised SMD equipment. However, a steady hand and adequate eyesight are of advantage. Jumpers removed from the PCB should be retained for reuse on the PCB. For readers without any SMD experience I suggest some preliminary practice lifting SMD components off an old circuit board by simultaneous application of two soldering irons, one at each end of the component, and a gentle flick after a second or two.

Figures 2 to 5 show photographs of the relevant parts of the REF-0 PCB. For conversion of the REF-0 unit into a GPSDO, jumpers Ja to Jf and resistor Ra outlined in red are to be removed. At this time the removal of jumper Jg is optional, see below. Jumper Ja is on the top side of the PCB while all other relevant components are on the underside of the PCB. The jumpers are to be reinstalled in positions J1 to J6 outlined in yellow. The resistor Ra is to be reinstalled in the position R1 outlined in yellow.

Jumpers Ja and J1 configure the 1pps output signal from the receiver. At this time, I am unaware of the purpose of jumper Jg. The jumper is present in the original REF-0 and absent in the REF-1 but limited testing of the standalone REF-0 GPSDO with and without the jumper has not shown any performance difference. For this reason it is optional to remove Jg. Resistors Ra and R1 control communication with the GPS receiver.

How does the modified REF-0 perform as a standalone GPSDO? At this stage only limited testing has been conducted, however, performance appears to be of the same standard as the REF-1 unit, as expected. On the other hand, some peripheral functions are not implemented – the antenna-presence alarm, for example. Figure 6 shows an unpopulated area of the REF-0 PCB. This is where the antenna-presence circuit is implemented in the REF-1. A 5V-regulator circuit supplies the antenna via an inductor for RF isolation and a current-sensing circuit, which has no effect on antenna voltage, measures the antenna load. If the load is outside the likely range of possible legitimate loads, the GPS led flashes. However, independent of the alarm state, there is no interaction with GPS performance. With the standalone REF-0, the absence of the antenna-presence circuit causes the GPS led to flash permanently. For those who do not like this personality feature, which is perfectly harmless, there is a simple method of arresting the flashing.

In the REF-1 unit the output of the current-sensing circuit is the voltage at output 2 of dual operational amplifier U209 (pin 7, LM358). This voltage is the input to channel 7 of the 8-channel MUX A/D converter U3 (pin 8, ADC0838). The antenna load is considered to be within the possible range when the channel-7 voltage is between about 0.11V and 0.97V, according to my measurement on one unit.

In a modified GPSDO REF-0 unit, the U209 position is unpopulated so the A/D converter has zero input and the GPS led flashes. To stop the flashing, a voltage between the above values must be applied to the channel-7 input. Fred Schader (WA7AII) has kindly shared (via personal communication) his simple realisation to simulate the presence of an antenna load, namely, the connection of a resistor between the supply line and the channel-7 input. The resistor, together with the load on the channel-7 input, sets the input voltage as required. For ease of circuit implementation, I recommend connecting an SMD 0603 resistor between the unpopulated pads 7 and 8 at the U209 position. The location of these pads is indicated in Figure 6. What resistor value is required? The load on the channel-7 input is 1kΩ and the voltage at pad 8 is about 12.2V, so any value between 18kΩ and 82kΩ sets the channel-7 input within the required voltage range and arrests the flashing.

Most readers will want to communicate with their standalone REF-0 GPSDO via software. A suitable popular program is Z38xx by the late Ulrich Bangert. His software has been modified by others to support the Lucent boxes. Perhaps you are already using a modified version with a REF-1 unit. Please be aware of a potential problem. Early hacks of this software only catered for the REF-1 box (Z3811A) and fail with the REF-0 box (Z3812A) that we are discussing. The software modified by Max George is recommended because it supports both boxes.

This project is based on the groundwork of many others. Why not take up the challenge to develop the REF-0 GPSDO further? Please share your own findings. The project is inspired by those who post their thoughts on the Time-nuts Forum.

References

Time-nuts Forum: https://www.febo.com/pipermail/time-nuts/
Dan Watson Blog: http://syncchannel.blogspot.com.au/
Max George Modified Software:
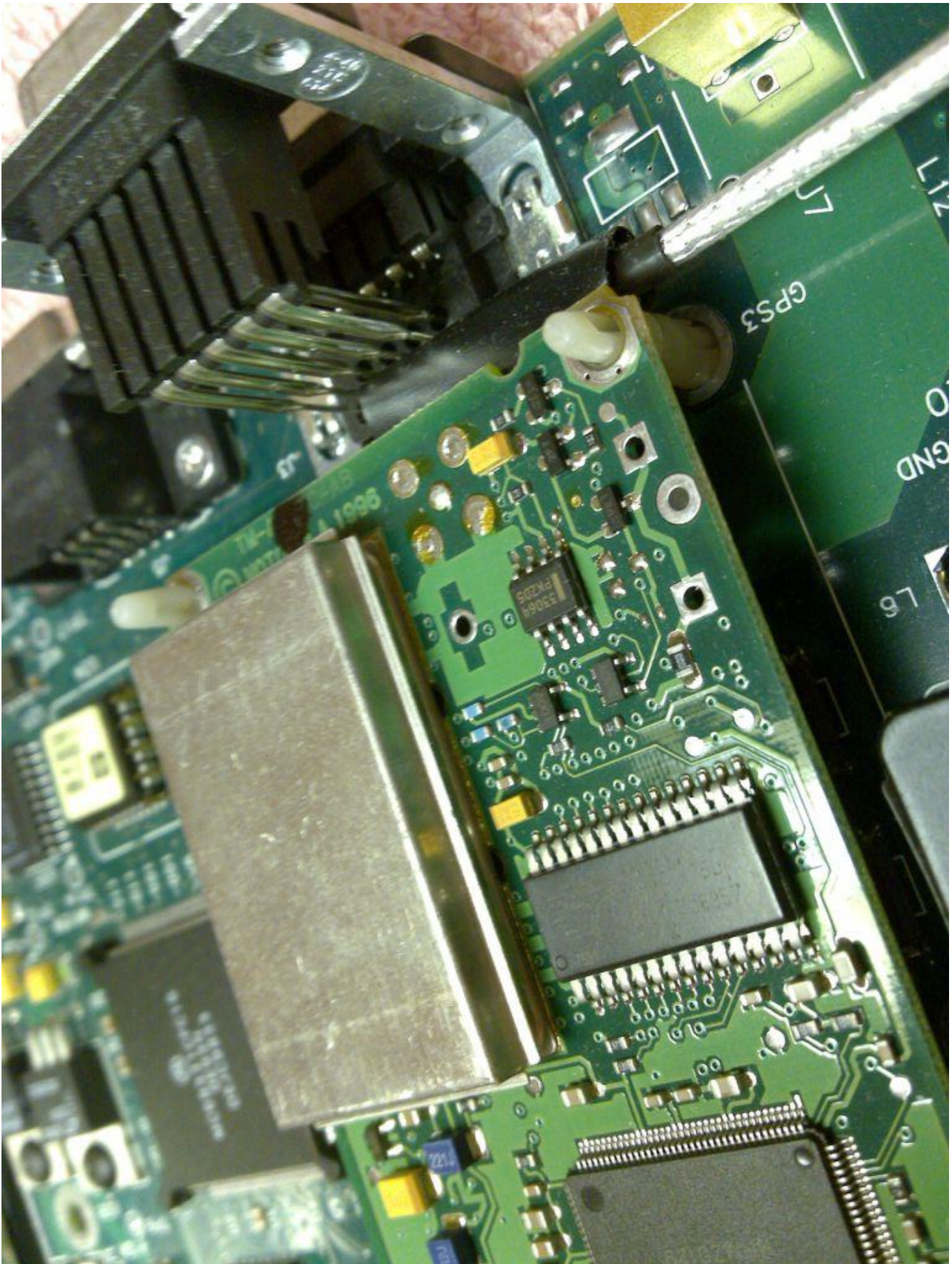http://www.nc7j.com/downloads/NG7M/Time-Nuts/Z38XX-Modified-for-Lucent-Z3811A-Z3812A/

Figure 1. Motorola Oncore UT+ GPS receiver with right-angle antenna cable connection mounted on REF-0 PCB.
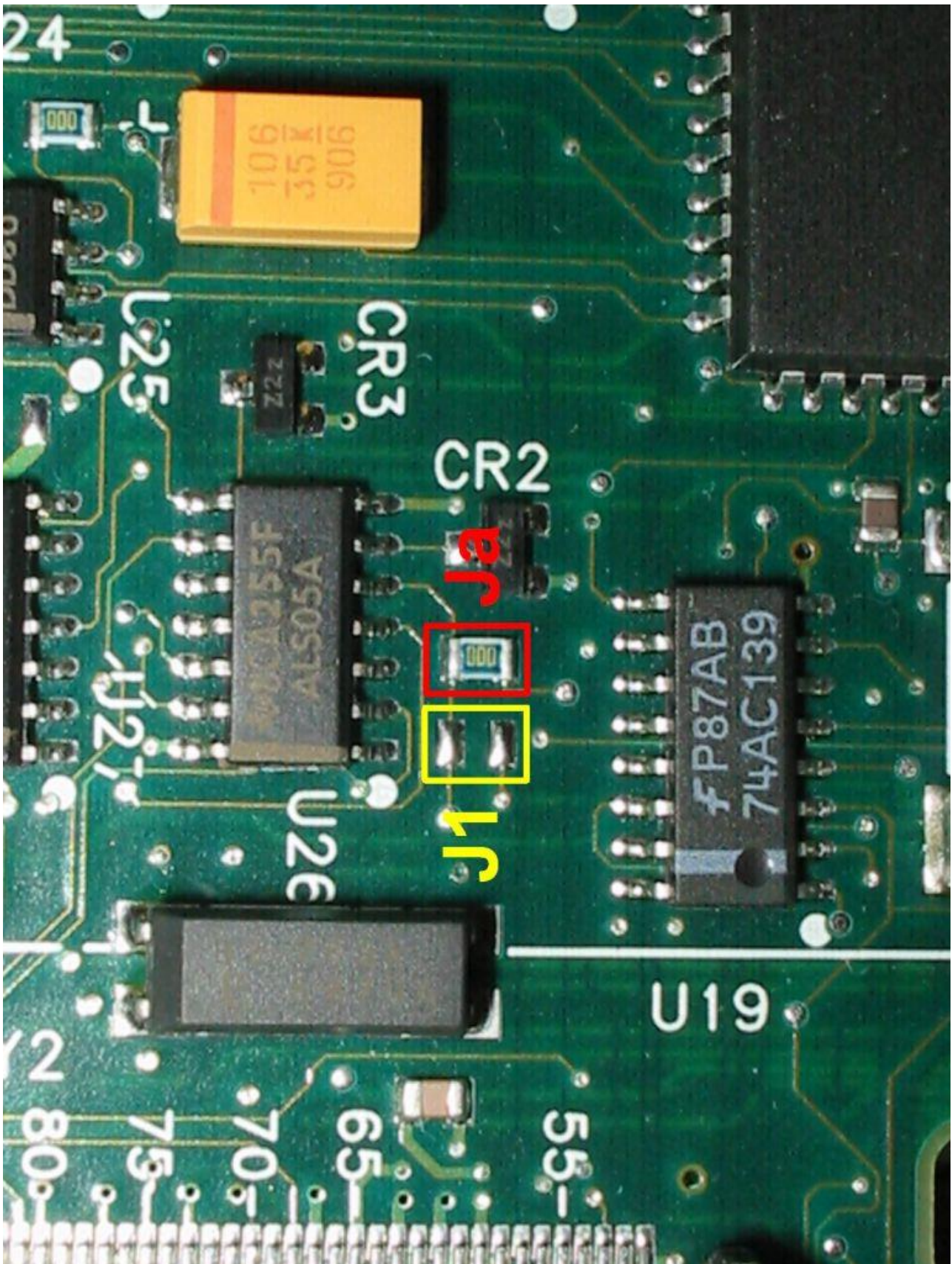
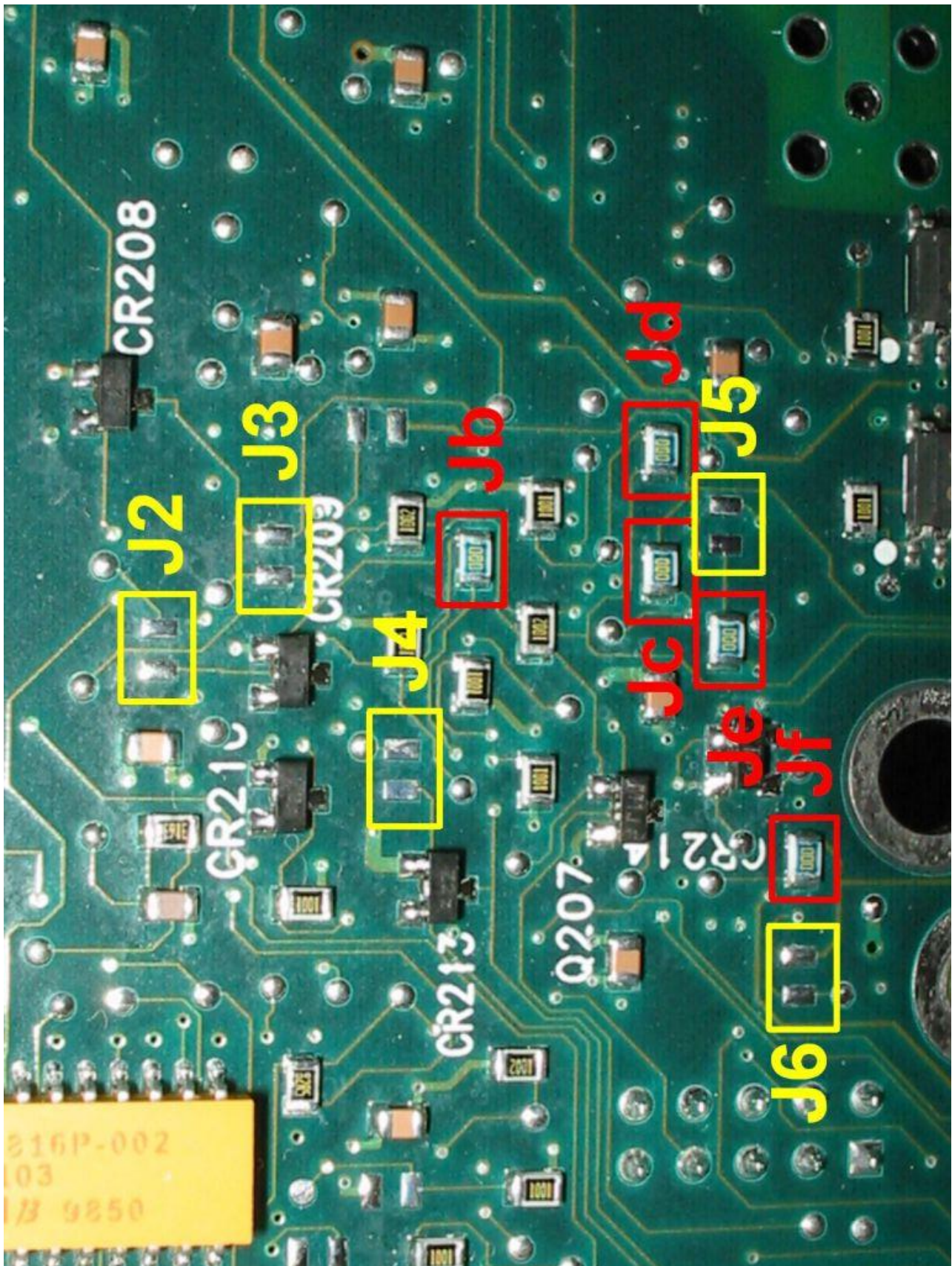Figure 2. Relevant jumper positions on the top side of the REF-0 PCB.

Figure 3. Relevant jumper positions on the underside of the REF-0 PCB.
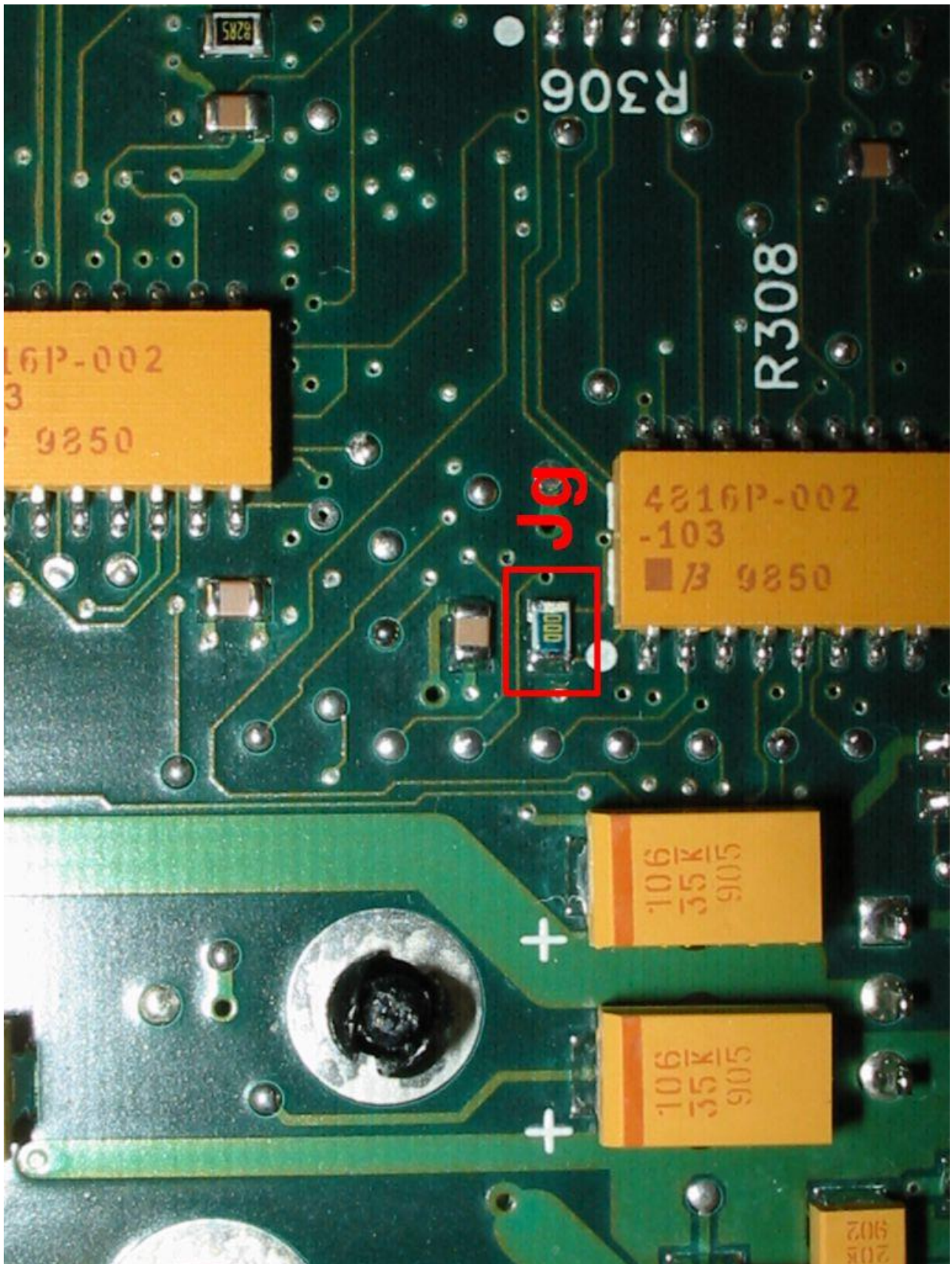
Figure 4. A relevant jumper position on the underside of the REF-0 PCB.
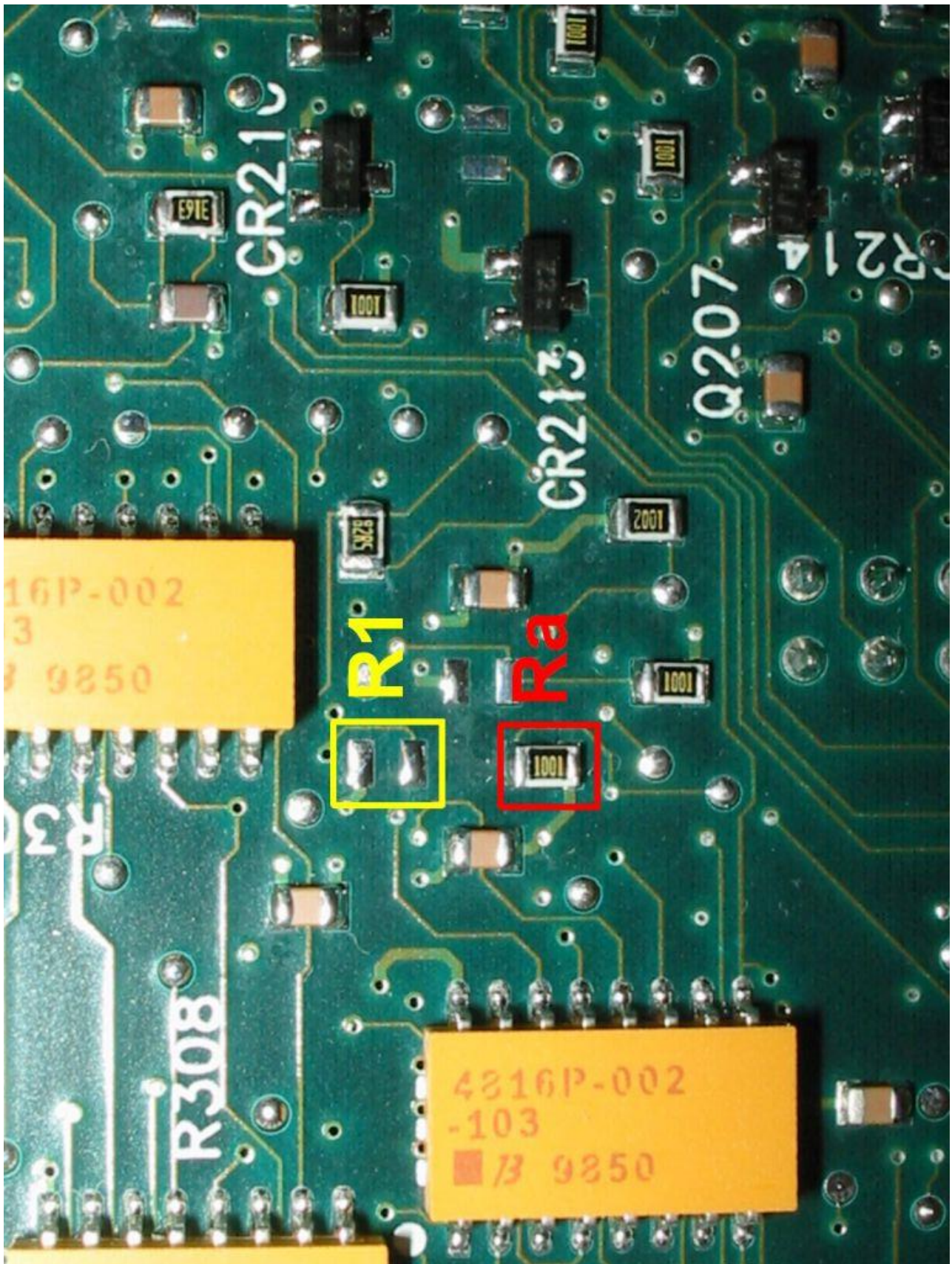
Figure 5. Relevant resistor positions on the underside of the REF-0 PCB.
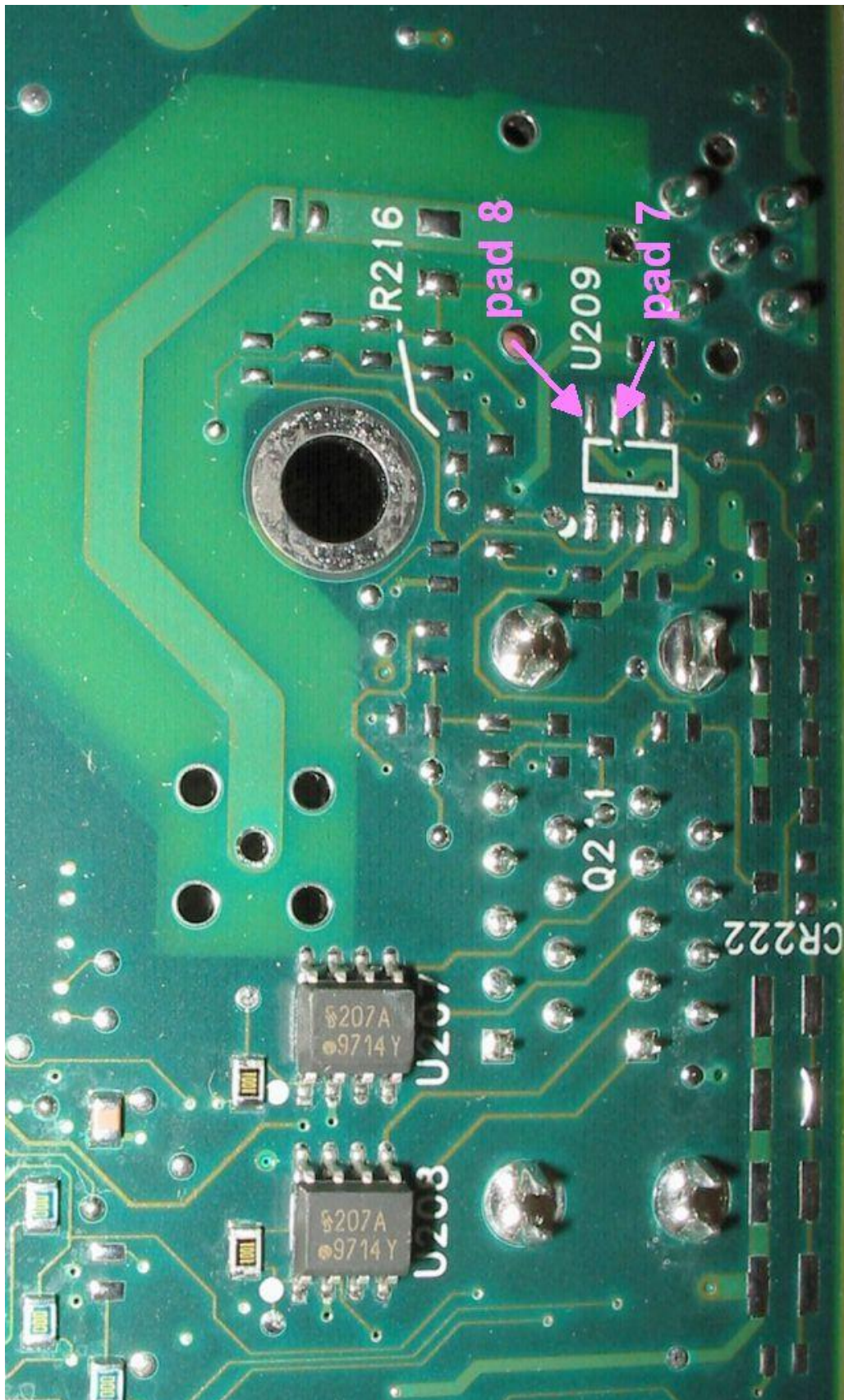
Figure 6. Unpopulated antenna-presence circuit of the REF-0 PCB showing pad positions for possible addition of an SMD resistor.