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E1938A-60001 Oscillator Board Theory of Operation

Introduction

The E1938A uses a new type of oscillator circuit to attain the high stability necessary. This circuit is described in the 1997 IEEE Frequency Control Symposium (FCS) paper, "A New Type of Balanced Bridge Controlled Oscillator." (Reprints of which are available from Rick.) For maximum understanding, it is recommended that this paper be read as background material. Because this circuit has never been used before, even experienced oscillator technologists will encounter some unfamiliar concepts. However, some of the material in the FCS paper has been summarized here in order to make this document somewhat self contained.

A Note About the Schematic

The schematic has been enhanced to make it easier to follow what is going on. As a result, the schematic shows the –60002 bridge board and -60009 thermistor flex for reference only. A block diagram has also been included on the schematic for convenience. The blocks have been denoted on the schematic by dotted line boxes.

The Balanced-Bridge Control Concept

In a conventional oscillator, nearly every component has a significant effect on frequency, hence to build a very stable oscillator, the object is to minimize the sensitivity of frequency to each component and/or used components with very stable characteristics. By contrast in this oscillator, a circuit without particularly good intrinsic stability is used, but its drift is removed by comparing its frequency to the resonant frequency of the crystal in a bridge operating as a mini network analyzer. This is known as automatic frequency control (AFC).

Block Diagram

The blocks consist of the oscillator, the bridge, the RF amplifier, the AFC section, the automatic level control (ALC) section, and the reference section. The oscillator can be thought of as a VCXO, except that the crystal has been remotely connected to it through the bridge. It has a main output at 10 MHz that goes to the controller board and an auxiliary 10 MHz output to the ALC and AFC sections. Its inputs are the AFC and ALC control voltages. It also has an RF connection to the bridge. The bridge takes EFC voltage as an input and has an output consisting of an RF error voltage. The RF amplifier takes this as an input as has an output consisting of amplified RF error voltage. This drives the AFC section. The ALC and AFC section generate the ALC and AFC control voltages respectively that drive the oscillator section. Finally, the reference section generates the base bias used by all sections except the bridge, and the 2.5V reference that is used by the ALC and the thermistor bridge.

Oscillator Section

To understand how the oscillator works, imagine that a crystal is connected directly from H201 (at the bottom of C205) to ground. This is a valid assumption because the bridge has the property known as "transparency" (see FCS paper) meaning that its port characteristics mimic a crystal. Q1 is configured as a grounded emitter bridged-T oscillator. C1 provides RF grounding for this purpose. The "bridge" in the bridged-T is L4, the Q of which is reduced and stabilized by
swamping resistor R10. It is has a 2% tolerance because it affects the tuning of the oscillator tank which is critical. The tank is tuned for maximum gain at 10 MHz. Mistuning not only lowers gain, but it skews the AFC tuning range, which potentially results in loss of AFC control. The collector side of the T consists of C13 and C8. The value of this is critical for the same reasons noted for L4, so a pair of 1% capacitors is used to get the exact value needed without having to resort to non standard component values such as 330+68=398 pF. The base side
of the T consists of the combination of C5, C4, C9, CR2, CR1, and C401. It is also somewhat critical, although not as critical as C13/C8.

As explained in the FCS paper, C4 and C9 shunt the varactors so that the overall capacitance in the T is nearly independent of ALC voltage. The proportioning between C5 and the rest of the network is a tradeoff between varactor diode RF distortion (C5 too small) and excessive loading by the base impedance (CR2, CR1 too small). The ALC control voltage varies the voltage division ratio of CR2 and CR1 affecting the amount of feedback to the base, which occurs through C3.
R3 feeds in the ALC control voltage while R401 and DC blocking capacitor C401 assist with bias for CR1. R11 provides bias for CR1 and also CR3 (see below.)
It is convenient for understanding to note that if the oscillator were a non-voltage controlled, non-crystal controlled oscillator, R11 could be replaced by a direct connection to ground, thereby forming a grounded emitter Colpitts oscillator. However, as it is R11 is only a DC ground. The bottom of the bridged-T consists of tuning network CR3, C11, C6, L2 and C305. This network allows
the AFC control voltage (fed in through R4) to pull the oscillator frequency. Because the tolerances on CR3 are fairly loose, it is equipped with swamping capacitors C11 and C6, which set the minimum and maximum total capacitance respectively. The tuning capability of CR3 must be limited to avoid having the oscillator drop out of oscillation because the tank frequency has been tuned
to a frequency so far removed from 10 MHz. that the gain has dropped below the amount necessary to sustain oscillation. If this happens, the oscillator may never recover because the AFC is inoperative unless the oscillator is driving it at 10 MHz.

L2 has two functions: first, it works in conjunction with the CR3 network, making its tuning symmetrical around the 10 MHz center frequency, and second, it forms a high Q series resonant circuit with C305. The purpose of this network is to convert the relatively small crystal bridge current (2 mA) to a large voltage that is easily detected by the ALC circuit. This voltage is fed via R12 to emitter follower Q2. The purpose of R12 is to suppress high frequency oscillations in Q2. Similarly, R17 also helps to suppress these oscillations. The DC base bias for Q2 is generated by voltage divider R9/R402, which is connected to the "cooler" end of L2, the other end being very critical with respect to loading. R14 sets the bias current of Q2, and L3 prevents R14 from loading down Q2. The voltage gain of Q2 is made very stable by making it as close to unity as possible (i.e. minimum loading).

The biasing of Q1 begins with emitter bias resistor R2. Bias is fed into Q1 via L9 and R7. This bias voltage is designed to provide about .5 volts on the emitter independent of temperature (see reference section). The collector is fed
by L1 and R1.

There are a number of possible parasitic oscillations in Q1. R5 and C2 prevent GHz oscillations. C59 prevents oscillations around 100 MHz due to funny impedances at the primary of T3. L9, R7, and L1 are chosen to prevent 100 kHz. and 1 MHz oscillations. Also, making C1 smaller can affect low frequency oscillations.