REVISIONS

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916.5MHz Short Range Radio (with RFM TR1000 IC) – Theory of Operation

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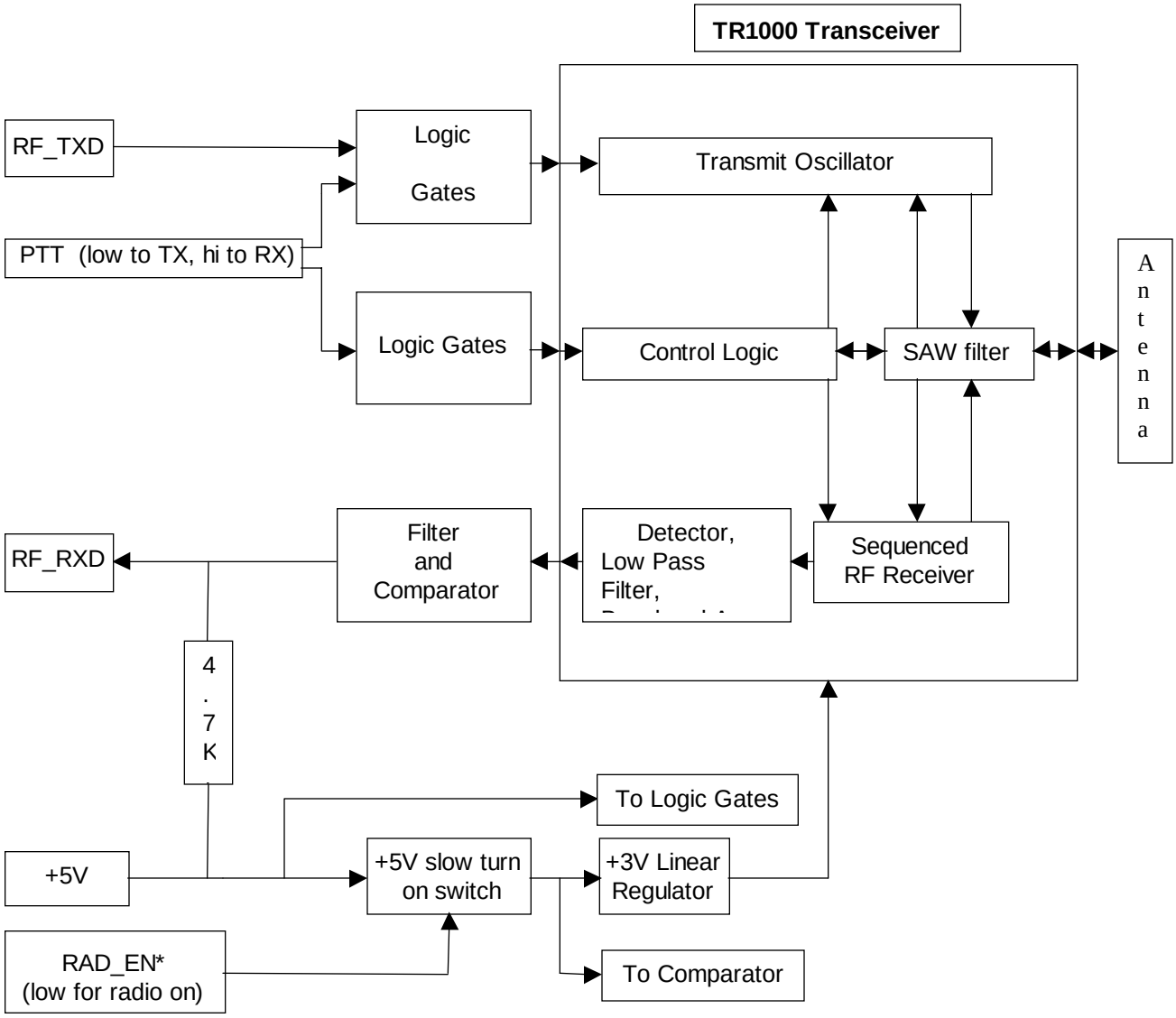
BLOCK DIAGRAM: 916.5MHz Short Range Radio (with RFM TR1000 IC)



RADIO DESCRIPTION

The radio is a half duplex OOK-modulated (On/Off Keyed) homodyne transceiver operating over a narrow band centered at 916.5MHz. Operating only as a portable device, its antenna and ground plane are internal to the unit in which it is installed and therefore inaccessible to users. Its major functional blocks are listed below (please refer to the block diagram above.)

An antenna;

A Hybrid 916.5MHz Transceiver (TR1000)

A data-slicing comparator preceded by a filter;

A 3.0V linear voltage regulator plus a voltage switch operating from a single 5V supply (both of which can be enabled or disabled by the externally provided RAD_EN signal);

And logic gates.

Power Supplies, Control Logic and Data

A single +5V supply powers the entire radio. The +5V supply directly powers a P-channel MOSFET switch which implements a +5V slow turn on switched supply rail. The switched supply is controlled by the RAD_EN* signal, which controls power to most of the radio and affords a power saving mode. A +3V LDO linear regulator receives power through the switched supply and in turn provides power to the TR1000 transceiver. Some circuitry is powered all the time. A 4.7K pull up resistor on the receive data lead is powered directly from the +5V supply. In this manner, a logic high (idle) out can be generated toward the UART to which the radio is connected even when the radio is powered off. 74HC03 logic gates serve as level translators between the +5V level signals which interface with the radio and the +3V-powered TR1000 RF Monolithics radio transceiver. These gates are powered from the unswitched supply to prevent current from being drawn during radio power down from the control leads which drive the gates.

Two control signals are supplied to the radio. The RAD_EN* signal activates the radio power supplies when low. PTT selects the receive mode of transceiver operation when high and the transmit mode when low.

TXD and RXD signals are serial data streams connected to a standard 8 data bit, one start bit, one stop bit asynchronous UART not contained in the radio. Nothing in the radio itself precludes other formats such as synchronous protocols. However, there are some restraints on the nature of the signals being handled by the radio. These will be discussed in the later section on communications protocol.

Transceiver: Transmitter Path

When signal PTT is low, a low is applied to the CNTRL_1 pin of the TR1000, deactivating the RF receive amplifiers and causing the TR1000 to operate in the transmit mode by enabling the transmit oscillator. With PTT low, IC TR1000 pin 8 (TXMOD) is controlled by the RF_TXD signal. When RF_TXD is low, the transmitter is on; when RF_TXD is high, the transmitter is off.

The transmitter is a homodyne “CW” SAW-based oscillator running at 916.5MHz. The SAW filter is placed in the feedback loop of the transmit RF amplifier to establish the oscillating frequency. Output power is supplied to the antenna at a maximum level of less than .75mW.

Transceiver: Receiver Path

When signal PTT is high, a high is applied to the CNTRL_1 pin of the TR1000, activating the RF receive amplifiers. At the same time, a PTT high forces a low at the TX_MOD pin, deactivating the transmitter amplifiers.

The Receiver is a homodyne. It incorporates a narrow band 916.5MHz SAW filter in its front end for RF selectivity. All of its pre-detector gain is provided at this frequency. Instability is precluded by a unique sampling design employing two cascaded and sequenced amplifiers. The first amplifier drives a SAW delay line and is turned on only for the time it takes a signal to propagate through the line. As the signal emerges from that line, the first amplifier is turned off and a second amplifier fed by the line is turned on. After the end of the sampled signal emerges from the second amplifier, that amplifier is turned off and the cycle repeats. Since the total amount of amplifier gain active at any one time is only the square root of the total gain provided, stray parasitics are prevented from causing oscillation.

The remainder of the receiver design is unremarkable. The second RF amplifier drives a square law detector (logarithmic at higher signal levels). The output of this detector is low pass filtered and presented to a baseband amplifier. Normally, the baseband output would then be AC-coupled to one of several comparators available on the TR1000 chip. However, these comparators are not used in this design because measurements have shown that their thresholds are sensitive to temperature. Instead, the baseband amplifier output is brought off the chip for further processing by the Filter and Comparator.

It is worthwhile mentioning a few other aspects of the TR1000:

A baseband filter with programmable bandwidth is available. A resistor connected from pin 9 (LPFADJ) to ground sets the bandwidth. Unfortunately, slew rate is reduced with bandwidth and causes demonstrable bias distortion in the recovered receive data and slow recovery from a signal overload. It was determined that the best design approach would be to set the bandwidth above that needed to recover a 19.2KbpS data signal so as to retain as high as possible a high slew rate, and to employ a special technique to deal with the remainder of this problem (see next section).

An AGC is provided, but it is disabled in the design by tying pin 3 (AGCCAP) high. This is done because an active AGC can respond to noise by reducing the received signal level and does so for a time well after the noise has disappeared, thereby adversely affecting data recovery.

Several different data slicers (comparators) and threshold-setting options are also available. These are not discussed because our design does not use them in favor of the circuitry discussed in the section entitled “Filter and Comparator”.

PDWIDTH and PRATE pins allow the programming of the receiver sequencing amplifiers to optimize them for high data rate or low power operation. A discussion of the available options is beyond the scope of this document. Please refer to RFM documents “ASH Transceiver Designer’s Guide” and the TR1000 data sheet for further information. These documents can be found at http//www.rfm.com.

Filter & Comparator

This circuit operates exclusively at baseband (under 100KHz). As is typical in Amplitude Shift Keying receivers, the received signal follows a path which proceeds from an RF amplitude detector through a filter and baseband amplifier before it is presented to a comparator, where it is converted into logic-level received data.

The RF detector invariably generates an unpredictable DC offset. If the path to the comparator input were DC-coupled, this offset would typically be large enough in comparison to the comparator slicing threshold to yield unpredictable results. For this reason, the path is AC-coupled. A capacitor is typically placed at the comparator input to remove the offset.

Another problem exists at the output of the baseband amplifier. This problem is a design flaw which cannot be eradicated by the introduction of AC coupling. The problem is that the baseband amplifier in the TR1000 is noticeably limited in slew rate. If the signal were applied to a simple comparator with a fixed DC threshold, the slow moving transitions would take different amounts of time while travelling in different directions to cross a fixed threshold. The result would be pulses of recovered data which vary in width depending on the amplitude of the baseband signal. At data rates when slew time approaches 50% of a bit, unreliable data recovery results.

One ameliorative solution is to provide a threshold which combines a DC offset with an attenuated and delayed (low pass filtered) version of the baseband signal being sliced. Since the threshold tends to follow the signal to which it is being compared, switching of the comparator occurs soon after the transition of the baseband signal in either direction begins. This means that the transition at the comparator output does not need to wait for the slew-limited baseband output to nearly finish its transition.

COMMUNICATIONS PROTOCOL

The radio is capable of transmitting and receiving a wide range of protocols. The application for which it is intended employs a “Quasi-Manchester” protocol detailed in an unreleased Symbol document entitled *Short Range RF Printer Protocol and Library,* revision 2.02, document number SRRFSPEC.DOC, written by Paul Seiter. The radio is connected to a standard asynchronous UART supporting an 8 data bit start/stop data stream running at 9600bpS. Each adjacent pair of data bits contains the sequence 01 or 10 to encode a 1 or a 0. Thus, it takes two bytes to convey one byte of information, and the effective data rate is 4800bpS. In this way, a 50% DC balance is maintained for each byte transmitted. It is important that no net DC signal builds up because it is necessary to AC-couple the recovered baseband data signal to remove the unpredictable DC signal presented at the output of the RF detector.

SPECIFICATIONS

FREQUENCY :	916.5 +/- .20MHz
TYPICAL TX LEVEL:	0.75mW
RECEIVER SELECTIVITY:	better than 55dB at +/- 30MHz
MODULATION:	AM, ON-OFF KEYING
BAUD RATE:	to 9.6KbpS