LoJack III Portable

Theory of Operation

And

Tuning Procedure

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FORWARD

This document describes the theory of operation and the transmitter tuning procedure for the portable model third generation LoJack Vehicle Locating Unit (VLU) transmitter. Please refer to Motorola Schematic 73D42114R01 for circuit and part references.

The LoJack III Poratble VLU (LJU3P) is a VHF radio transceiver controlled by a remote network of computer activated transmitters. It is meant to be the tracked device in a vehicle location and recovery system. The VLU and associated antenna assembly are mounted in a secret location within the vehicle in a standby state until activated via a radio signal broadcast. Active state transmissions consist of periodic transmissions of coded data that can be tracked by a compatible tracking receiver.

TRANSMITTER

The LJU3 transmitter is a 1.0 Watt RF output, VHF FM device operating at 173.075 MHz. The transmitter is comprised of the following subsections: dual battery power supplies, microprocessor controlled bias/modulation, baseband filter, crystal oscillator/modulator/tripler, 2^{nd} frequency tripler, preamplifier, driver amplifier, power amplifier, transmit/receive switch, and lowpass harmonic filter.

Power Supply

The LJU3 is designed to be power from two battery sources. The digital, receiver, and frequency transmit frequency generation sections are powered from an external non-rechargable 3.6 V lithium thionyl chloride battery. The transmitter power is provided from an internal non-rechargable 6 V lithium manganese battery cell. Before activating the transmitter or receiver the microprocessor measures the external battery supply power supply voltage and adjusts bias values accordingly. Before transmitting data the microprocessor measures the value of the internal transmit power battery and shuts the transmitter down, if the value is too low.

A precision voltage reference is also provided to the transmitter to provide for increased oscillator frequency stability and to provide for controlled biasing of the preamplifier stage. This reference voltage is switched on by the microprocessor.

A precision reset controller is used to insure that the unit shuts down when the external battery voltage falls below 2.9 V (nominal). This insures that the unit will not attempt to operate at voltages where the microprocessor could become unstable.

Microprocessor

The microprocessor is a Motorola MC68HCL11E9 microcontroller. It uses an external 8 MHz crystal and an internal 2 MHz bus. The microcontroller performs the following functions related to the transmitter: power switching, voltage measurement and compensation, PA bias control, reference voltage switching, generation of the modulation signal, and carrier frequency tuning.

The micro also uses a 6-bit discrete digital to analog circuit to provide a DC bias to the MOSFET power amplifier device and controls a voltage reference circuit that is used in the transmitter section. Finally the micro uses a discrete 8-bit digital to analog circuit to provide a sinusoidal signal to the crystal oscillator/modulator via the baseband filter. The sinusoidal signal is DC offset to control the center frequency of the transmitted signal. Since the microprocessor voltage (and hence the digital to analog voltages) vary depending on the external battery voltage, both the PA bias and the modulating signal are compensated over the life of the battery. This insures frequency and power output stability over the entire operating voltage range. The digital section is protected from a low voltage condition via a low voltage reset chip. The transmitter section is

protected for a low voltage condition by actively measuring the transmit voltage to insure it is within limit.

Baseband Filter

The baseband filter is a passive two-pole low-pass filter. The filter smoothes the output of the 8-bit D/A to reduce the high frequency components in the sinusoidal MSK signal used to modulate the carrier frequency.

Crystal Oscillator/Modulator/Tripler

The transmitter crystal oscillator tripples the 19.23055MHz crystal frequency to 57.69165 MHz. The frequency is pulled using a varactor diode in series with the oscillator crystal. A buffer circuit isolates the crystal oscillator from the next tripler stage and a cap-coupled three-stage band-pass filter provides harmonic attenuation. The frequency generation is controlled by a voltage delivered from the microprocessor and is not affected by the voltage of the transmit battery. Variations in the primary battery voltage are compensated for by the microprocessor.

2nd Tripler

The 2nd Tripler stage tripples the 57.69165 MHz frequency to the173.075 MHz carrier frequency and provides power gain before the transmitter signal is fed to the preamplifier stage. The 2nd tripler also provides additional harmonic filtering using a three-stage cap-coupled band-pass filter.

Preamplifier

The output of the 2nd tripler is fed into the preamplifier stage. This stage uses the voltage provided by the voltage reference to bias a bipolar transistor into Class A. The stage amplifies the signal provided by the 2nd tripler and provides the higher amplitude signal to the driver stage of the transmitter. The preamplifier stage uses a fixed value 'T' matching circuit to match the output of the 2nd tripler to the input of the transistor and a 'shunt L series C' combination to match to the input impedance of the driver device.

Driver

The driver stage consists of a Class C biased bipolar device. The device uses feedback to insure stability and amplifies the signal delivered by the preamplifier stage for delivery to the power amplifier (PA) stage. The driver is matched to the PA using capacitive tapped coupling.

Power Amplifier

The power amplifier (PA) is a MOSFET device. It is biased from the microprocessor through a 6 bit digital to analog converter. The digital to analog circuit has bypass capacitance in the form of C3 and C75 to minimize any transference of RF between the micro and the PA and vice versa. The PA is matched to the transmitter switch via the first section of the low pass harmonic filtering. PA bias is compensated for primary battery variations by the microprocessor.

Harmonic Filter

The harmonic filter in the transmitter consists of two sections. The first section consists of two 'series L, shunt C' circuits (L25, C109, L24, C107) that provides both low pass filtering and matching from the PA to the transmitter switch. After the transmitter switching diode a second section of filtering consists of a 'T' circuit (C114, L23, C117). This circuit (coupled to the antenna via C113) provides filtering for the transmitter and receiver and insures that the antenna is matched to the transmitter and receiver circuits.

Transmit/Receive Switch

The transmit/receive switch allows the use of a single antenna for both transmit and receive functions. PIN diodes D13 and D10 are unbiased in the receive mode. In this mode both diodes are of high impedance which isolates the transmitter from the antenna. When the transmitter is powered, both diodes are biased "on" via L18 and R123. This causes both diodes to look like low impedance circuits, D13 then connects the transmitter to the antenna.

TRANSMITTER TUNING

The LoJack III will be electronically tuned in a manufacturing test bay. The tuning procedure is as follows:

Center Frequency Tuning:

Establish two way serial communications to the LJIII unit. Command the unit to turn on the transmitter with no PA bias and no modulation. Measure the center frequency. Move the transmitter tuning digital to analog value until the center frequency is as close to 173.075 MHz as digital to analog step size allows. The center frequency must be within 5 ppm of 173.075. Measure the voltage being delivered to the module via the module's LINE_VOLTAGE analog to digital converter. Multiply the tuning value and the LINE_VOLTAGE reading. Store the computed value into EEPROM. If center frequency is not within limits, fail the unit. If measured LINE_VOLTAGE value is not within limits fail unit.

Modulation Tuning:

At the same input voltage as used in the previous step, establish two way serial communications to the LJIII unit. Command the unit to turn on the transmitter with no PA bias and no modulation. Measure the frequency. Move the transmitter tuning digital to analog value until the frequency is as close to the measured center frequency plus 4 kHz as step size allows. Measure the voltage being delivered to the module via the module's LINE_VOLTAGE analog to digital converter. Subtract the center frequency tuning value from the positive deviation tuning value. Multiply this value and the LINE_VOLTAGE reading. Store the computed value into EEPROM. Command the unit to transmit with modulation. The modulating frequency must be within 3.9 to 4.2 kHz of the center frequency. If deviation tuning value is not within limits adjust the stored value up or down until deviation is within limits. If unit is not tunable within limits, fail the unit.

PA Bias:

Establish two way serial communications to the LJIII unit. Command the unit to turn on the transmitter with no PA bias and no reference voltage. This will bias the transmitter with no RF present. Measure the current into the unit from the trasmit battery. Increase the PA bias digital to analog value until the current level increases by 25 to 55 mA. Measure the voltage being delivered to the module via the module's LINE_VOLTAGE analog to digital converter. The bias level that is the highest in the range should be multiplied by the LINE_VOLTAGE reading and stored in EEPROM. If bias level between 25 to 55 mA is not obtained fail unit.

Turn on transmitter including PA bias and reference. Measure the power out of the transmitter. If the power is out of spec adjust the PA bias until the power out is in spec. If power is not in spec within two digital to analog step sizes of the original measurement, fail unit.