THE DESIGN OF A SINGLE CARD TELEMETRY MODULE FOR SMART MUNITION TESTING

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ABSTRACT

M/A-COM, Inc. has developed a miniature Tactical Telemetry Module (TTM) for medium power (500 mW and 1 W) telemetry applications. The TTM demonstrates system integration of a multi-channel PCM encoder, lower S-band transmitter, and power regulation onto a single printed wiring board (PWB). The module is smaller than a standard business card and utilizes both COTS and M/A-COM proprietary technologies. The PCM encoder is designed for eight (8) analog inputs, eight (8) discrete inputs, and one (1) synchronous RS-422 serial interface. Data rates of 300 kbps to 6 Mbps are supported. The module incorporates a frequency programmable, phase-locked FM S-band transmitter. The transmitter utilizes M/A-COM's new dual port VCO and high efficiency 500 mW and 1 W power amplifier MMIC's. Additionally, switching power regulation circuits were implemented within the module to provide maximum operating efficiency. This paper reviews the design and manufacturing of the Tactical Telemetry Module (TTM) and its major components, and presents system performance data.

KEY WORDS

Single Card Telemetry Module, Transmitter, Power Amplifier, PCM Encoder, Voltage Controlled Oscillator, Power Regulation.

INTRODUCTION

M/A-COM has produced a set of rugged, small, low cost transmitter modules for use in ballistic and commercial telemetry applications. These transmitters utilize direct frequency modulation, which results in a miniaturized system. These transmitters are compliant with IRIG 106-01, and can provide an output power level of up to 1 watt.

There is a need for highly integrated, low cost telemetry systems for munitions testing that can measure analog, digital, and discrete signals and provide 1 W to 2 W of RF output power. These telemetry systems must withstand setback accelerations of 30,000 G's, vibration levels of 30 G's in any direction up to 20 kHz, and temperature extremes of -40°C to +85°C. This paper describes the design of a single card telemetry system combining M/A-COM's transmitter technology, a CPLD based PCM encoder, and power regulation circuitry on a business card size printed wiring board. The performance data for this single card telemetry solution is included, and a system block diagram is shown in Figure 1.

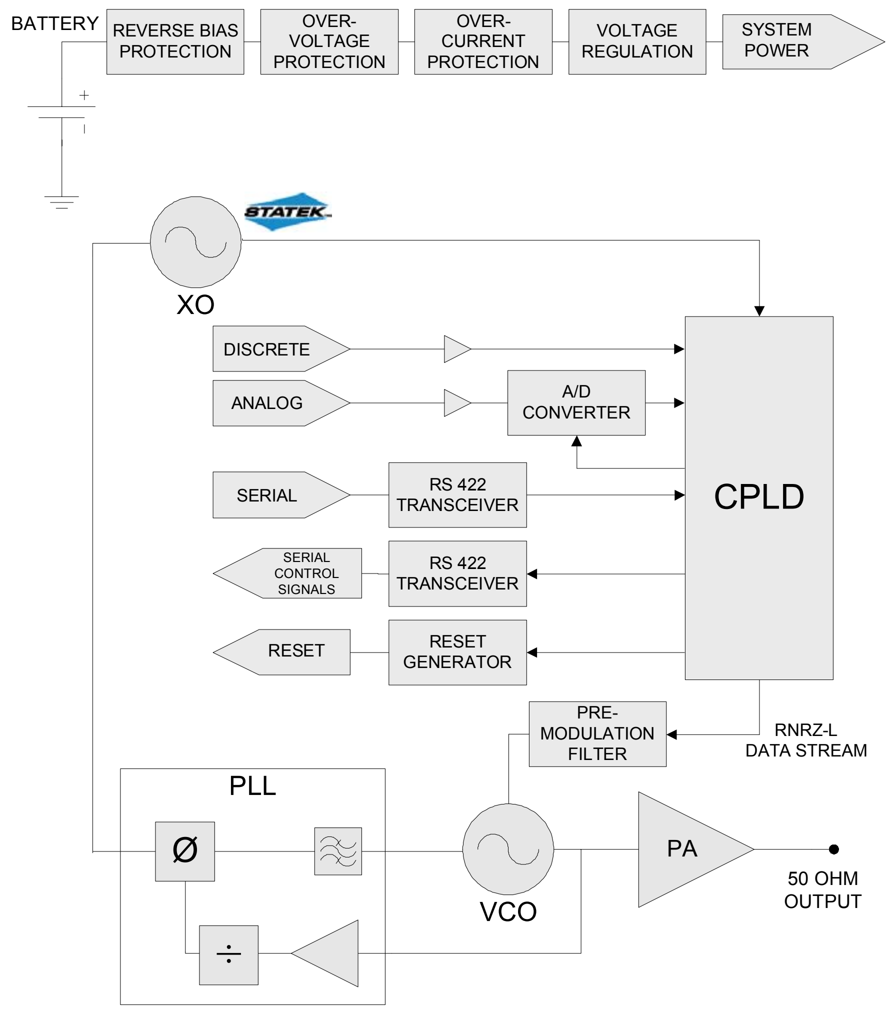

Figure 1 – TTM System Block Diagram

PCM ENCODER

The PCM encoder receives analog and digital data from several sources, organizes the data into a data frame, and sends a randomized serial data stream to the transmitter for modulation and transmission. The PCM encoder has an overall data rate of 1 Mbps and provides eight (8) analog channels that are sampled at 200 samples per second (sps), with 12 bit resolution. There are eight (8) discrete channels sampled at 400 sps and a serial RS-422 interface that can process data at 1 Mbps, and a 6-pole Bessel pre-modulation filter is provided to limit the transmitted bandwidth per IRIG 106-01.

Figure 1 shows a block diagram of the PCM encoder. The analog data is level-shifted to +5.0 V maximum and then buffered and filtered to prevent aliasing. It is then processed through a parallel interface A/D converter, and the 12-bit digital word is input to the CPLD at a maximum sampling rate of 62.2 ksps. The discrete data is buffered and then sent to the CPLD, and the RS-422 serial data is interfaced through RS-422 transceivers, along with the clock, load pulse and frame synchronization signal.

The CPLD is the heart of the PCM encoder, and it organizes the input data into the data frame format. It uses a state machine to control the assembly and routing of the data, and it implements all of the logic to control the interfaces to the A/D converter, RS-422 data interface, discrete interface, and the randomized output data stream. It uses the onboard 20 MHz crystal oscillator, and divides it down to 2 MHz to supply the A/D converter and to 1 MHz for the PCM encoder system clock.

The randomized PCM serial data stream is then processed through a 6-pole Bessel filter to limit the transmitted RF bandwidth. It is set to a break frequency of 0.7 times the data rate, as stipulated in IRIG 106-01. The Bessel filter characteristic is chosen for its maximally flat delay characteristics over the filter pass-band. Figure 2 presents the measured frequency response of a prototype pre-modulation filter.

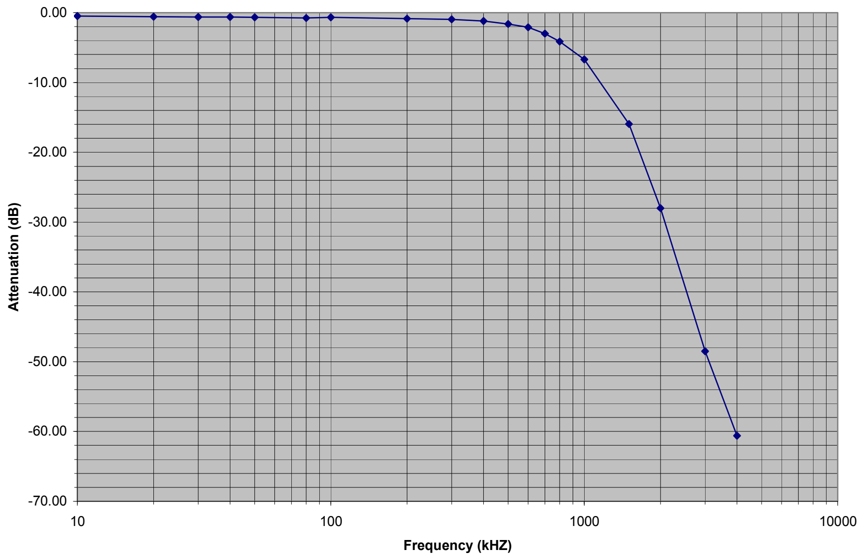

Figure 2 – Frequency Response of Pre-Modulation Filter

TRANSMITTER

The transmitter implements a 1 W power amplifier, a dual port voltage controlled oscillator, and a digitally programmable phase-locked loop.

The 1 W MMIC power amplifier is a 3-stage device, which is designed using small signal and nonlinear FET models, and loadpull data obtained at the operating bias point. The product is fully matched to 50 ohms on both the input and output. The first stage FET uses a 0.6 mm gate periphery driving a 2.4 mm second stage FET, and two 5.8 mm gate periphery FETS are used in the third and final stage. This amplifier is fabricated using M/A-COM's GaAs MSAG^{TM} process. The process features full passivation for increased performance and reliability. The devices on this repeatable, near-enhancement mode process operate from a single +5 V supply voltage. A negative voltage is not required because the FET is designed to operate with a 0 V gate bias. The only external components required for the power amplifier are for supply line bypassing. The bias networks are implemented on the MMIC, minimizing the number of external components required. Additional biasing chokes and DC blocking capacitors are not required.

Figure 3 shows the typical measured performance. The amplifier has greater than 31 dBm (1.26 W) output power and greater than 45% power added efficiency (PAE).

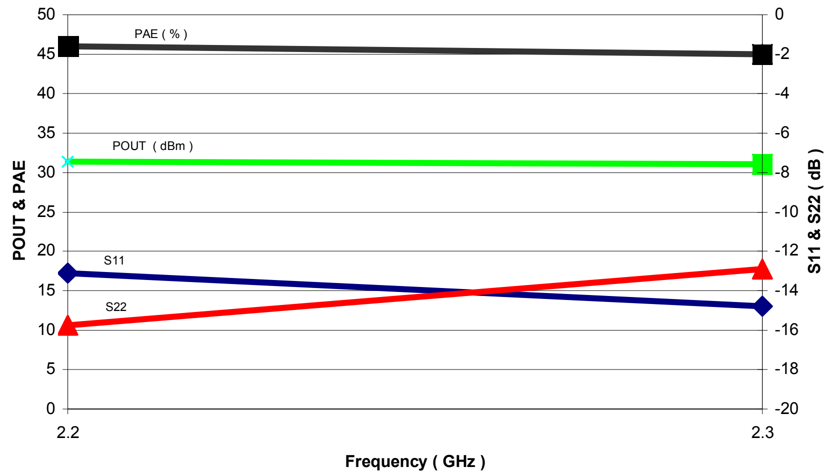

Figure 3 – Measured performance of the 1 W MMIC HPA @ V_{DS} = 5.0V

The dual port VCO is based on M/A-COM's existing lower S-band single port heterojunciton bipolar transistor (HBT) VCO (FE55-0006). The dual port design has a second independent input for modulation (data) in addition to the traditional tune input. This architecture allows each input to be optimized for its intended function. The modulation input sensitivity can now be optimized for the data rate of the system while the tuning input sensitivity is large enough so the VCO can tune across the entire lower S-band. The high-sensitivity tuning input of a single port VCO can be used for both tuning and modulation when the data rate is high enough (10 Mbps). However for lower data rates, the amplitude of the data signal must be divided down significantly for optimum frequency deviation of the carrier signal. The signal-to-noise ratio at the VCO is degraded and this causes a higher bit error rate. The dual port VCO alleviates this problem by allowing the data signal to stay at a much higher amplitude when it is input to the VCO.

Another issue with using a single input VCO for a directly modulated PCM/FM system is when the transmitter is tuned across the band rather than operating at a single frequency. The sensitivity of the tuning input varies greatly over the band of operation, which means the frequency deviation of the carrier does not remain at the value for optimal bit error rate of 0.35 times the data rate when different frequencies are used. The DC voltage on the modulation input is a constant value, unlike the DC tuning voltage, which changes with frequency. Therefore the sensitivity of the modulation input and the deviation are much more stable when the frequency is changed.

The new design is packaged in the same 4mm 16-lead FQFP-N type package as the FE55-0006 with the same pinout except for the addition of the modulation input. This way either VCO can be used on the same transmitter, allowing for a range of data rates to be used without sacrificing bit error rate performance.

M/A-COM has implemented a new COTS phase-locked loop (PLL) into the design of the MATMTMU004. The PLL contains an embedded field programmable EEPROM, providing non-volatile storage of the transmitter frequency. M/A-COM's graphical user interface (GUI) utilizes a simple drop-down menu that allows the user to change the frequency of the PLL through the use of a standard PC parallel port and the M/A-COM programming box. (See Figure 4) In addition, a test pin has been added for the user to monitor signal lock detect.

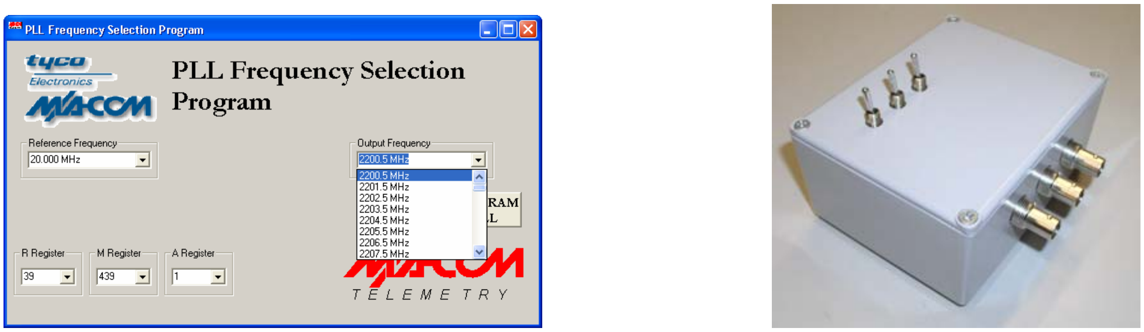

Figure 4 – M/A-COM GUI and Programming Box

Figure 5 shows the modulated output spectrum of the TTM centered at 2210.5 MHz. The spectrum shows that the peak frequency deviation is set to the optimum value of 0.35 times the bit rate or 350 kHz. The deviation is calculated using the RCC Document 118-98 Pseudo-Random Pattern Method. The null spacing is measured, which is the frequency spacing between the first two nulls on either side of the center frequency. The frequency deviation is calculated by subtracting the null spacing divided by two from the bit rate. In this case the null spacing is 1.3 MHz and the bit rate is 1 Mbps, yielding a peak deviation of 350 kHz.

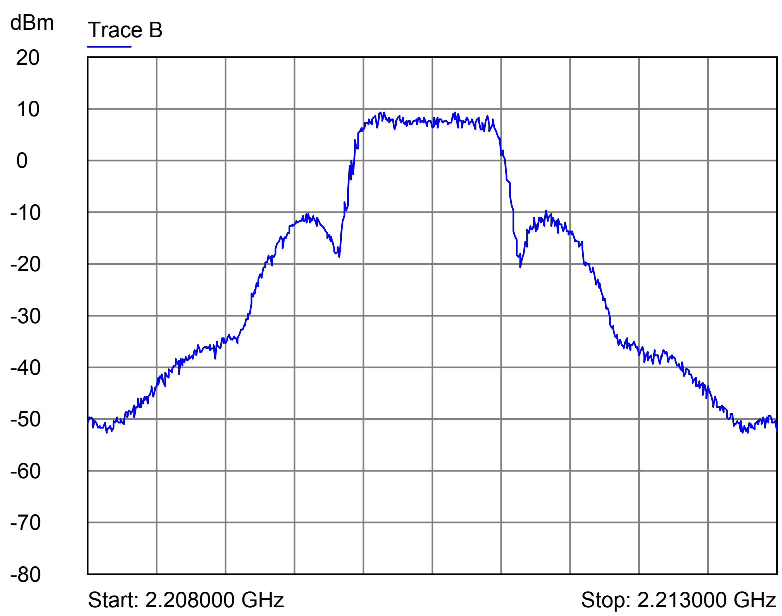

Figure 5 – TTM Modulated RF Output Spectrum

POWER CONDITIONING

The power conditioning circuitry allows the TTM to be operated from an unregulated system battery. The TTM has an input voltage range of +9.0 to +17.0 V_{DC}. The components on the TTM operate from either +5.0 V_{DC} or +3.3 V_{DC}. In order to implement the TTM on a small circuit board, the power dissipation must be kept to a minimum. The input supply voltage is dropped down to +5.0 V_{DC} using a switching regulator. A switching regulator provides a very efficient way to drop the input voltage down to the required voltage. The switching regulator has an internal power switch and comes in a small surface mount package. The high switching frequency of 1.25 MHz allows for filtering of the spurs to be implemented with small surface mount components. This is important since any noise on the transmitter power input can modulate the transmitter and show up in the RF output. A low dropout, linear regulator generates +3.3 V_{DC} from the +5.0 V_{DC} switching regulator output.

There is voltage protection circuitry on the TTM to prevent damage when the applied input voltage is outside of the operating range. A voltage monitoring circuit switches off the input to the switching regulator when the voltage goes above +18 V. Reverse bias protection up to -40 V is included on the primary input.

PRINTED WIRING BOARD DESIGN

The printed wiring board (PWB) for the single card solution is a double-sided design incorporating the transmitter, PCM encoder and power conditioning into a compact module. The three functionalities are partitioned on the board, and each has its own unique construction characteristics. The transmitter utilizes controlled-impedance lines and thermal vias to spread heat from the power amplifier. The power conditioning uses large copper runs to reduce inductance and to aid in heat dissipation, while the PCM encoder has high interconnect density and a component layout that enables a smooth flow of signals through the board, which minimizes crosstalk. A picture of the front and back sides of the board is shown in Figure 6.

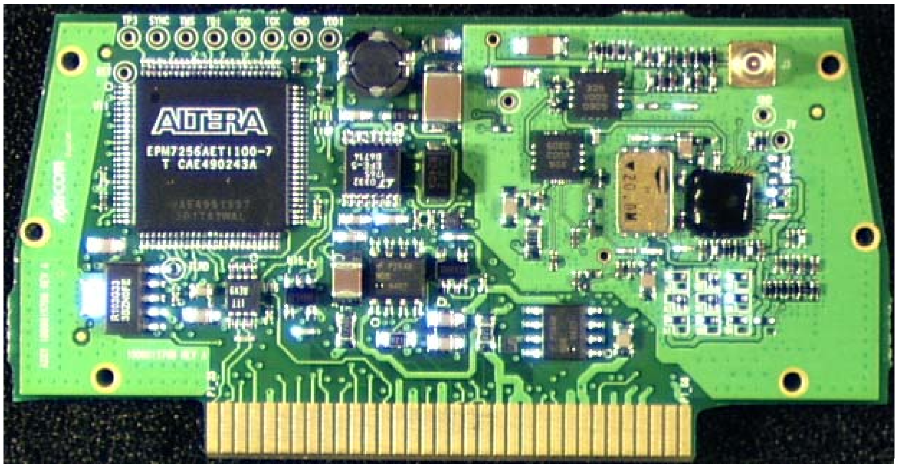

Figure 6a – Front View of Single Card Solution PWB

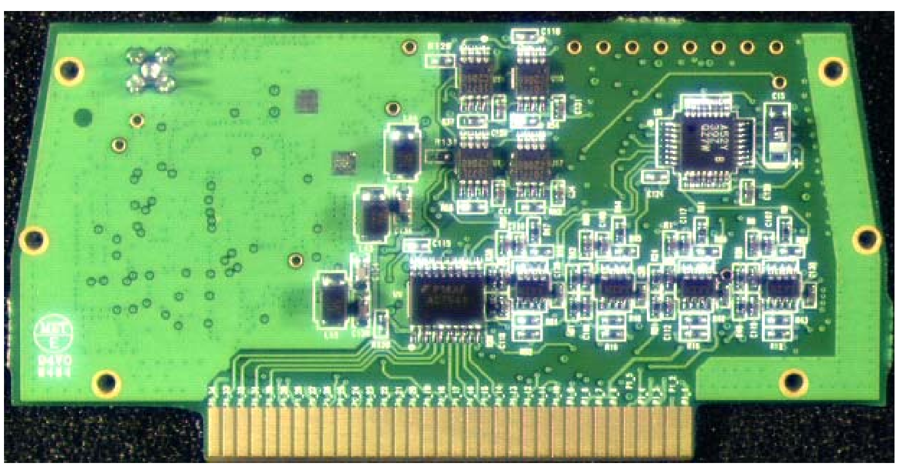

Figure 6b – Back View of Single Card Solution PWB

CONCLUSIONS

M/A-COM is working with multiple customers on small telemetry transmitters and telemetry systems for advanced munitions. Our most challenging design task has been the development of 1 W high efficiency power amplifiers. The 1 W power amplifier described in this paper represents significant technology advancement for small, high power telemetry systems. By packaging this 1 W transmitter on a circuit board along with a PCM encoder and power conditioning, M/A-COM is able to provide a compact, low cost telemetry design solution for projectile and missile applications.

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