Design and Performance of Card Level Telemetry Receivers and Combiners

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ABSTRACT

This paper will discuss the design and performance of card level telemetry receivers and combiners. This will include products that have been designed to operate in compact computer controlled environments such as VME chassis, VXI chassis and personal computers using ISA buses. The paper will discuss design considerations required to overcome limitation of this environment such as noise and space. The paper will also discuss the performance of a telemetry receiver and combiner in this environment. This will include performance test results such as bit error rate test, phase noise measurements and combiner improvement measurements. Finally, the paper will discuss typical applications of card level telemetry receivers and combiners.

KEYWORDS

Telemetry Receiver, Telemetry Combiners, VME, VXI, PC-AT

INTRODUCTION

Many telemetry applications today have the requirements to be small and portable. This has been aided by the continual miniaturization of modern electronic components. The advent of the personal computer and the single board computer in chassis environments, such as VME and VXI platforms, has seen a natural migration to telemetry systems. For several years many components used in telemetry systems have been available for use in personal computers, VME and VXI environments. However, the two components that have not been available are the telemetry receiver and combiner. Although some manufacturers have made telemetry receivers, they have placed limits on the user that compromised performance of the telemetry system. Microdyne recognized this and developed a telemetry receiver and combiner that would adhere to the space and portability requirement but would not limit the functionality of the telemetry system or compromise the performance.

DESIGN GOALS

The following design goals were set for the telemetry receiver:

- A Minimum Tuning Range of 100 MHz
- A Maximum Tuning Step of 100 kHz
- A Minimum of 3 IF Filters
- A Minimum of 3 Video Filters
- Two FM Discriminators
- An AM Demodulator for Tracking
- A Single Frequency Record Down Converter
- No Larger Than a Double Width 6U VME Card or AT Style PC Card

The following design goals were set for the telemetry combiner:

- Pre-Demodulator Combining
- Post-Demodulator Combining
- Single Frequency Record Down Converter
- No Larger Than a Double Width 6U VME or AT Style PC Card

The following were indicated as critical design issues:

- Noise Due To Switching Supplies
- RF Noise From Digital Sources In The Environment
- Lack Of Space

DESIGN IMPLEMENTATION

The telemetry receiver design was split into two parts. All RF related functions are performed in a shielded box to isolate it from noise sources in the environment. In addition, the RF module is further compartmentalized for isolation between receiver modules. The output of the RF module is a demodulated video signal that is routed to a processing printed circuit board. The printed circuit board provides all unit control, video processing and pre-demodulator down converting. The discussion of the telemetry receiver RF module will be based on the on the block diagram, Figure 1.

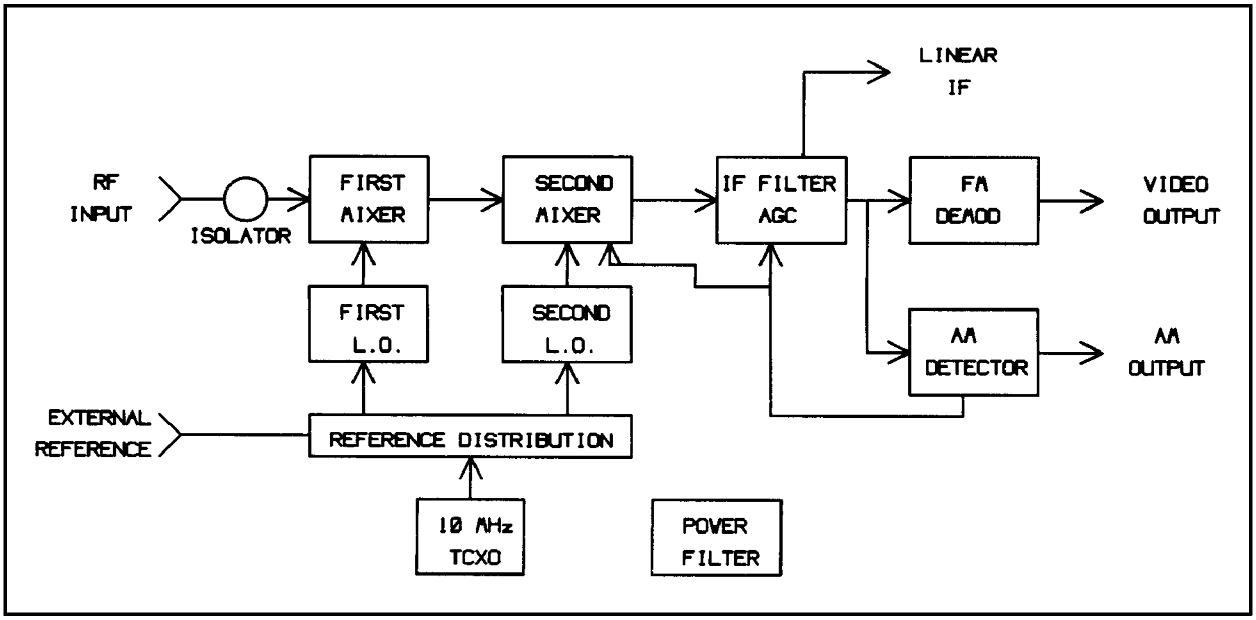

Figure 1 VMR-2000 RF Box Block Diagram

The RF signal is routed through an isolator. This is used to provide a good input VSWR. The signal is then routed to the first mixer for the first down conversion. The signal is then routed to the second mixer for the second down conversion. Custom ceramic filters were made for the first and second mixers. This provided superior out-of-band rejection while using minimal space. The first IF frequency is 450 MHz. This allows the use of smaller components without compromising the performance of the receiver. The effects of switching power supply noise on the synthesizers are reduced by double and triple regulation of the input power. The second IF frequency is dependent on the type of receiver being built. Narrow band units have a second IF frequency of 20 MHz while wideband units have a second IF frequency of 70 MHz. The second IF filters are 10 pole lumped element Gaussian Filters. In order to preserve space, precision 1% components were used in the IF Filters. This allows the use of small inductors for the IF Filter. The IF Filters have a maximum bandwidth of 12 MHz for the narrow band receivers and 36 MHz for the wideband receivers. The final design of the receiver provides 4 IF filters selectable from 750 kHz to 12 MHz for the narrow band unit. The IF Filter module also provides automatic/manual gain and AGC Time Constants functions for the receiver. The IF Filter gain circuitry provides 110 dB of gain and 5 AGC Time Constants. The output of the second IF Filter is then routed to the demodulator. Units containing an FM demodulator provides medium and wide discriminators. The medium discriminator is used for IF bandwidths of 4 MHz or less with the wide discriminator used for all others. The FM demodulator is a quadrature style demod which provides wide demodulation capabilities while being less susceptible to environmental noise. The demodulated video signal is then routed to the video/control board.

The discussion of the video/control board will be based on the block diagram, Figure 2.

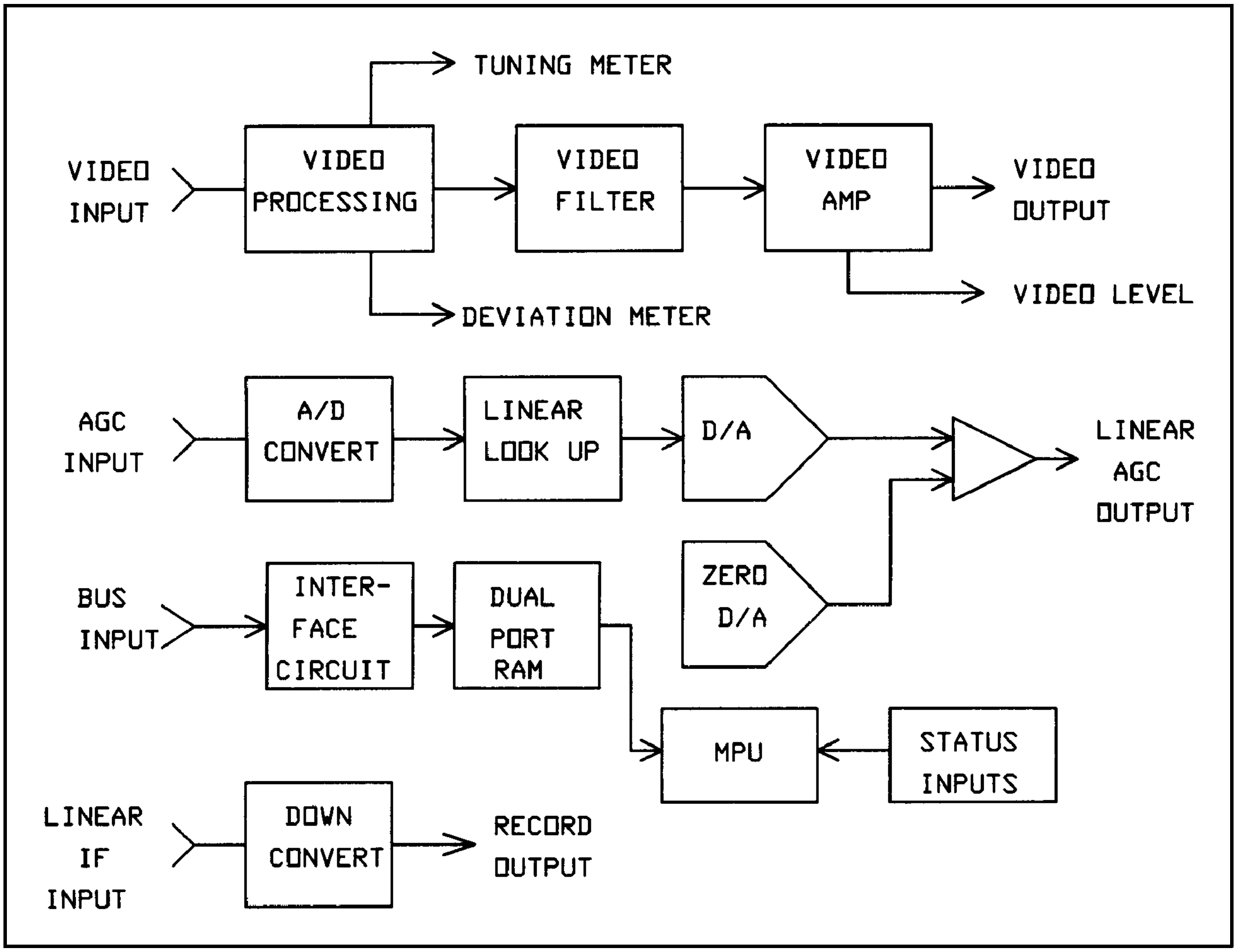

Figure 2 VMR-2000 Video/Control Block Diagram

The demodulated video signal is routed to the video processing circuitry. This provides tuning and deviation meters for the telemetry receiver. In addition, AC or DC video coupling is performed in this module. The signal is then routed to the video filter module. The receiver provides 3 active video filters and a video filter bypass. The signal is then routed to a video amplifier that provides 63 dB of video level adjustments. The signal is then routed to the front panel as a video output signal. The video/control board also contains the circuitry for pre-demodulation record down converting. A filtered 20 MHz IF signal is routed to the video/control board. The down converter contains a local oscillator and the required mixer and filters to down convert the IF to the user specified record frequency. AGC linearization is also done on the video/control board. The AGC signal is routed from the RF module to the video/control board. The AGC voltage is digitized via a 12-bit Analog-to-Digital (A/D) converter. The output of the A/D converter is routed to the linearization circuitry that contains logic and a linearization look up table. The output of the linearization circuitry is routed to a 12-bit Digital-to-Analog (D/A) converter. The output of the D/A converter is summed with the output of an offset D/A converter. The offset D/A converter provides AGC zeroing functions. The summed output is routed to the front panel as the linear AGC output. The output is scaled for a 20 dB/volt output that can be used for a weighting signal for a telemetry combiner or as an indication of received signal strength. Figure 3 is a plot of typical linear AGC output.

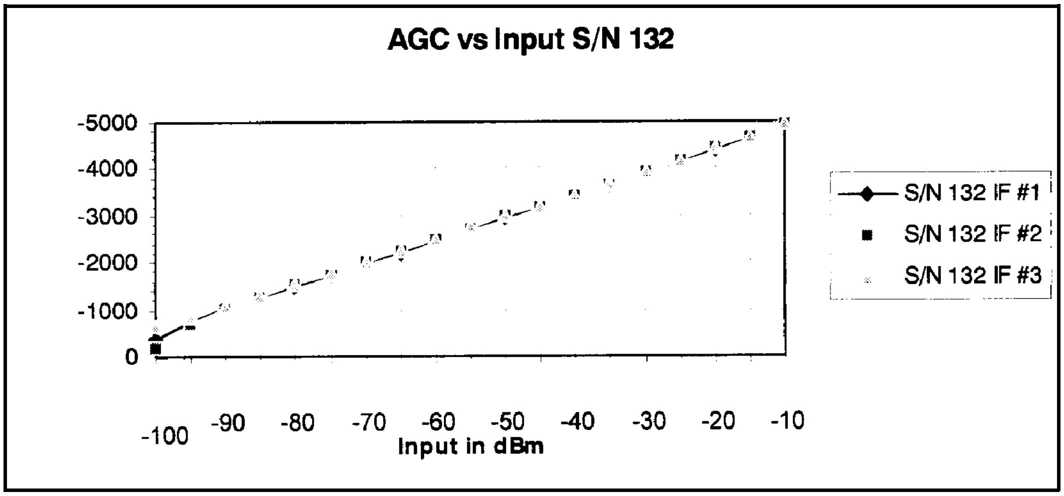

Figure 3 Typical Linear AGC Output

The bus interface is also contained on the video/control board. Receiver control is independent of the bus interface and remains the same for any control environment. The receiver has an embedded signal chip microcontroller that allows all circuitry to remain the same with only the bus interface changing. The control bus is routed to interface circuitry which provides data decoding. The output of the bus interface is routed to a dual port RAM. This functions as a “mailbox” to pass control and status information between the receiver and the control bus. The microprocessor places status data into the RAM. When control information is written to the RAM an interrupt is generated to signal the microprocessor that new control data is available. The microprocessor then reads the data and configures the associated receiver module. Status information for the receiver is obtained by reading the status A/D converter. Status is available for the AGC level, Video level, Tuning Meter, Deviation Meter and Receiver Lock.

Performance in applications that have severe signal fading or low signal level can be improved by using a diversity combiner. Diversity combiners sum the video (post-D) or IF (pre-D) signal from two receivers. The sum of the signals is weighted based on the AGC voltages from the receivers. The weighted sum means that as the signal quality increases (more AGC Voltage) the combiner uses more of that signal. Since the data input from both receivers is the same, then the information increases by being summed together. However, the noise in each channel will be different and will not increase by adding them together. This effectively increases the signal-to-noise-ratio (SNR) of the receiving system.

A block diagram of the combiner is shown as Figure 4.

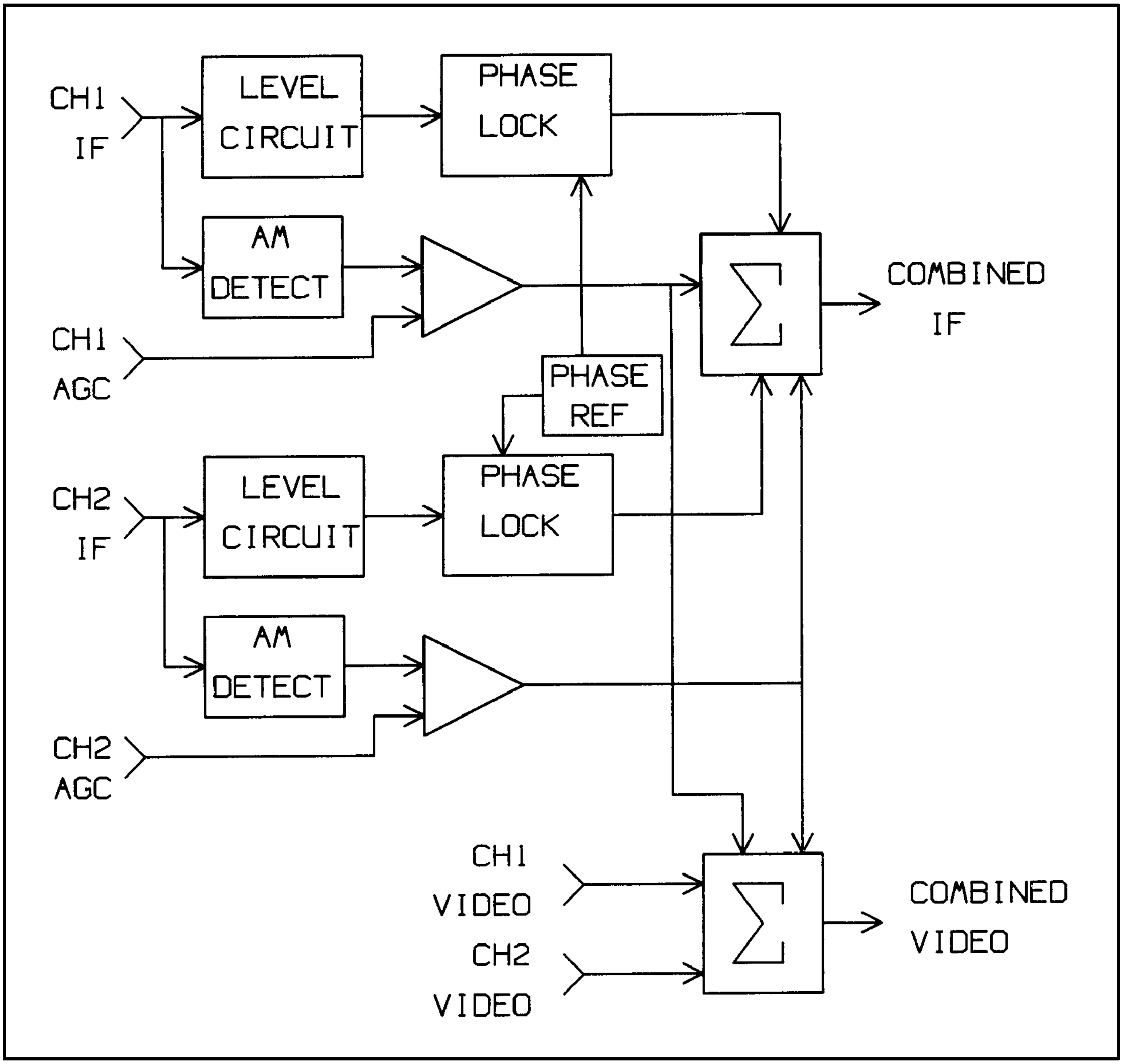

Figure 4 Combiner Block Diagram

The combiner receives the linear IF output, video output and AGC signals from two receivers. The IF outputs from both receivers are routed to level control circuitry to ensure that the IF outputs are combined at the same level. The level control circuitry provides approximately 30 dB of range. AM extraction circuitry is also provided to compensate for any high speed fading. This fading would not be seen in the receiver AGC due to the AGC time constant. This signal is summed with the AGC signal from the receivers to generate the weighting signal for each channel of the combiner. The two linear IFs are then phase locked to each other. The signals have to be phase locked when summing the two channels. Out-of-phase channels would cancel the data and decrease the SNR. The phase locked IFs are then combined by the channel summers using the weighting signals to determine the amount of each channel to combine. The combined IF is then routed to the front panel as the Combined IF Output. The two video signals from the receivers can be combined to give an improvement of the data from each receiver. Theoretical improvement from a weighted ratio diversity combiner is 3 dB. The user can generally realize improvements up to 2.5 dB.

PERFORMANCE

Card level receivers provide superior performance in what is typically a bad environment for receiver products. Typical noise figures for the VMR-2000 product line are 10 dB. The real test for any receiver product is the Bit-Error-Rate (BER) test. This will predict how well the receiver will work with a given signal. Figure 5 shows typical BER performance. This BER data was taken with a 2047 pseudo random data pattern PCM/FM modulated at a rate of 2 Mbps with 700 kHz deviation. The receiver had a 2.4 MHz filter selected with a 2 MHz video filter. Data encoding was NRZ-L.

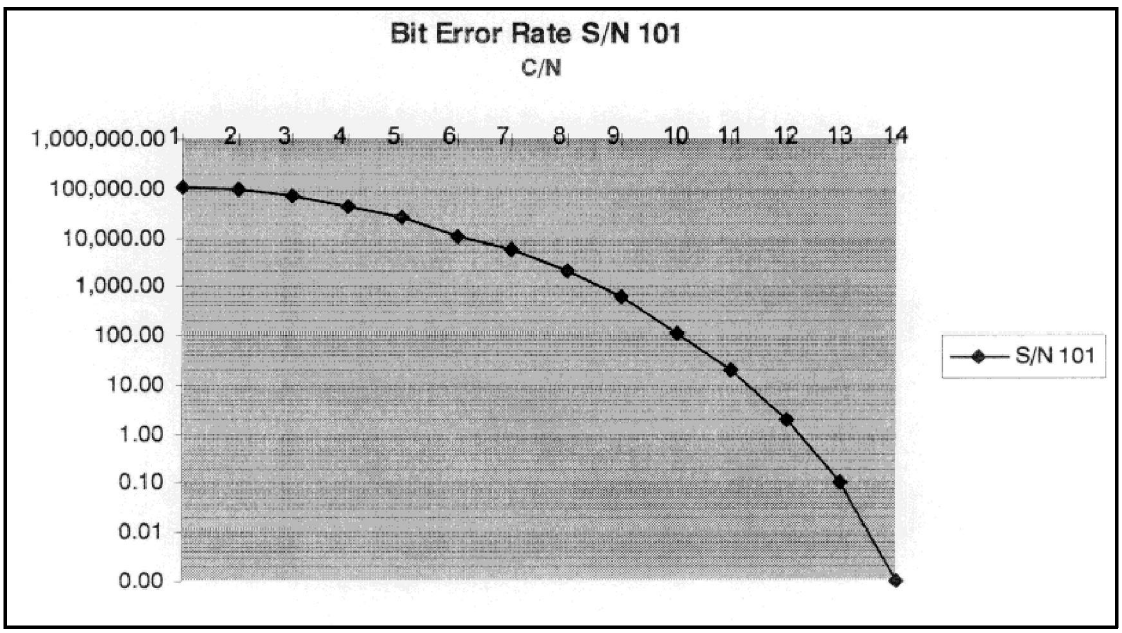

Figure 5 Typical BER Performance

APPLICATION

The typical applications for card level telemetry products are in portable telemetry systems. In this environment the telemetry receiver and combiner can be placed in the same chassis as the bit sync and decomutation equipment. This combined with the available computer cards, for PC, VXI and VME bus systems, provide an excellent base for a small portable telemetry system. These systems often times can be carried and deployed with minimal personnel. The card level products are also excellent choices for small flight line test systems used for pre-mission verification of telemetry transmission systems.

CONCLUSION

Microdyne has been successful in developing a line of card level telemetry receivers and combiners for use in small portable telemetry systems without degrading system performance. The telemetry receivers provide tuning steps of 100 kHz, three IF Filters, three Video Filters, two FM discriminators, an AM demodulator and a single frequency record down converter. The receivers make these features available in a VME chassis by occupying two 6U slots or in an AT personal computer by occupying two AT slots. A companion combiner is available for use in signal fading environments to increase data recovery. The combiners provide pre- and post-demodulator combining and record down converting. The effect of the harsh environment of the VME or PC chassis has been reduced with the use of shielding and regulation of the card level power inputs.