THE DESIGN APPROACH TO A NEW CATV DISTRIBUTION AMPLIFIER

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ABSTRACT

Greater demands on the performance of cable television systems have imposed stringent requirements on distribution equipment. This paper discusses some of the problems encountered and solutions to meet these requirements in a low cost, high performance amplifier. Specific topics include discussion of packaging, implementation of optional accessories, return loss and response optimization, and control of loop isolation.

INTRODUCTION

Trunk to feeder ratios have been continuously increasing, because of extended bandwidths and increased subscriber density, making it desireable to cascade more line extenders in order to reduce the system cost. Distribution line extenders have generally been high gain devices with simple manual gain and slope control. The lack of high performance automatic gain and slope amplifiers having two way capability has limited the number of units that can be cascaded due to the attenuation of cable and passives changing with temperature. Set top converter and television receiver performance determine the maximum allowable signal variations on the feeder system. With tighter feeder response control, more feeder amplifiers can be cascaded and the number of trunk stations reduced, resulting in lower system cost.

To provide increased system control and flexibility a distribution amplifier was designed to meet the following goals:

- Improved frequency response
- Flexible configuration/modular construction
- High forward and return gain capability
- Optional AGC
- Optional switching regulated power supply
- Standard and extended bandwidth capability
- Multiple split frequencies
- Increased reliability
- Cost effective

These design goals pose numerous technical and mechanical problems, some of which are discussed in the following sections.

TECHNICAL CONSIDERATIONS

High forward and return gain capability with extended bandwidth complicates the implementation of improved frequency response. Present day hybrid amplifiers have extremely good frequency response and return loss specifications. However, when the hybrid is interfaced with a printed wiring board (PWB) mounted in a module, both specifications are affected by ground currents. Most broadband CATV line extenders utilize coplanar transmission lines. Discontinuities cause some of the signal to be propagated across the ground plane where it combines at sensitive portions of the circuit and distorts the frequency response.

Discontinuities occur primarily where circuits such as diplex filters built on the main RF circuit board disrupt ground plane and at the interface of the hybrid amplifier. The pin arrangement for commonly used hybrids has ground connections only on one side of the RF input/output pins. A coplanar transmission line requires a large continuous ground surface on each side of the center conductor. If some method is not provided to contact both sides of the hybrid ground, stray currents around the hybrid will be set up causing a poor frequency response. Oscillations can occur when the module is being inserted into the housing if proper grounding is not maintained at all times. The problem is compounded when using higher gain hybrids or hybrids in cascade. Connecting the ground to the hybrid by a small clip contacting the hybrid heat sink substantially reduces the problem.

A reduction of stray ground currents is realized by constructing the diplex filter and trim networks as plug-in units and using an interface which is an extension of the transmission line. The coaxial connector shown in Figure 1A and the pin arrangement in Figure 1B provide excellent interfaces. Plug-in accessories are helpful in controlling stray current paths because they maintain large ground areas on the main RF board. When circuits are constructed directly on the RF board the ground area is broken up, increasing stray ground paths.

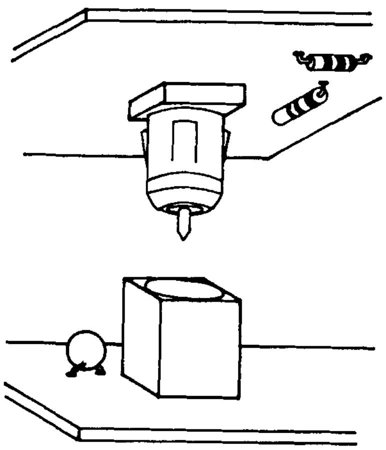

Figure 1A

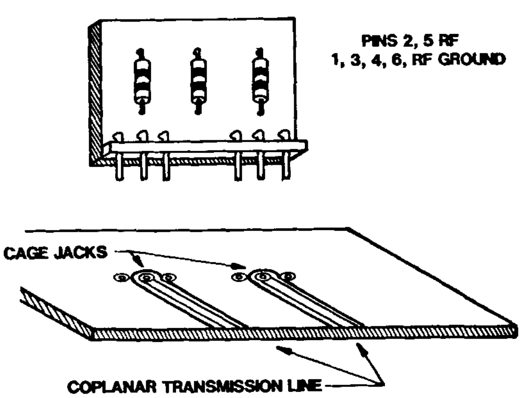

Figure 1B

The ground current problem is more critical in bi-directional amplifiers. When a single PWB is used a common ground exists between the forward and reverse circuits. This causes poor isolation between amplifiers resulting in distortion in both forward and reverse frequency responses. The magnitude of the distortion is again a function of hybrid gain and isolation. By providing a septum as shown in Figure 2 and separating the single PWB into two parts, the common ground is eliminated. The septum must be electrically grounded directly to the module input/output coaxial connectors to be most effective.

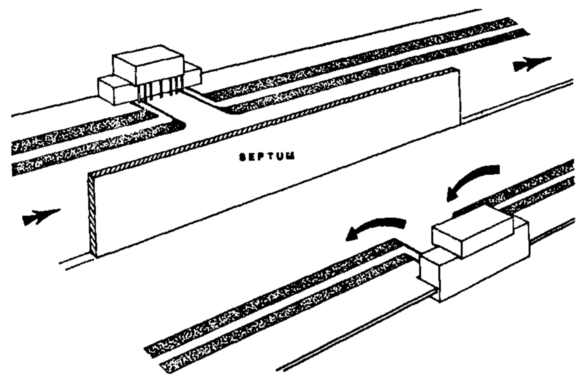

Figure 2

The RF module interface to the seizure system is also affected by stray ground currents. The module-to-housing interface must have a reliable continuous electrical ground and the seizure system should have minimal impact on input/output return loss. Cable powering and lightning induced surges necessitate an AC bypass coil and high pass filter. Separate PWB's with coaxial connectors were used to closely approximate a continuous transmission system. This arrangement produced greater than 30dB return loss for the seizure and also provided for a simple powering arrangement. Removal of the RF module does not interrupt the system AC power. Care must be exercised in the design of the AC bypass coil to prevent self resonances or resonance with parasitic capacity to ground.

Even with these precautions, stray currents will exist at low levels causing small variations in the amplifier response when metal covers are removed and replaced. This can be annoying during balance and alignment. By utilizing a noncunductive cover the effect is eliminated.

Having minimized the stray currents, attention can be focused on the direct path loop isolation. Two desired paths exist through the forward and return amplifiers as shown in Figure 3. These paths are established by the diplex filters which consist of high and low pass filters with high isolation (better than -40dB) between the low and high ports and minimum attenuation (less than .5dB) for the desired paths. An undesired loop exists which is shown in Figure 4. The gain around this loop is the sum of all gains and losses defined by equation (1).

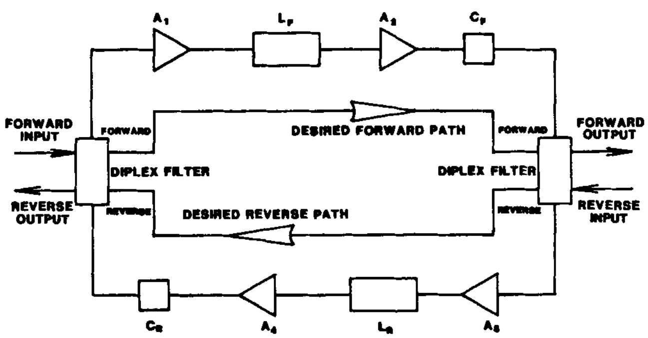

Figure 3

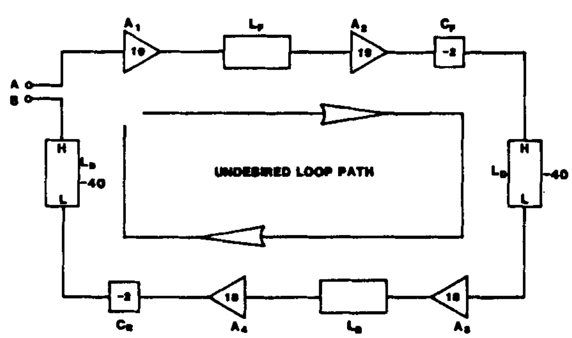

Figure 4

$$GL = A1 + LF + A2 + CF + LD + A3 + LR + A4 + CR + LD \quad (1)$$

GL = Loop Gain

A1-4 = Respective hybrid gains

LD = Diplex filter isolation losses

LF, LR = Forward and reverse filter losses

CF, CR = Forward and reverse PWB losses

If this number is greater than unity oscillation may occur. Loop gains less than unity will not produce oscillations but the frequency response will exhibit ripple. Equation (2) is an expression for the peak-to-peak ripple that can be expected for a given loop gain.

$$Rpp = 20 \log \frac{(1 + 10^{GL/20})}{(1 - 10^{GL/20})}, \quad (2)$$

where Rpp is the peak-to-peak ripple in dB, and GL is the loop gain determined by (1).

Using equation (2) for a GL of -45dB yields the following Rpp:

$$Rpp = 20 \log \frac{(1 + 10^{-45/20})}{(1 - 10^{-45/20})} \quad (3)$$

$$= .098 \simeq .1\text{dB}.$$

For -45dB loop gain a maximum of .1dB peak-to-peak ripple can be expected. Using the realistic numbers shown in Figure 4 the loop gain is:

$$GL = 19 + 19 - 2 - 40 + 18 + 18 - 2 - 40 = -10\text{dB}. \quad (4)$$

(LF and LR assumed equal to 0)
This would produce a peak-to-peak ripple of 5.7dB, and therefore additional filtering is required. Plug-in interstage filters were designed which have more than 40dB attenuation in the reject band. Two filters are required, one high pass and one low pass. Notice that as the gain of the hybrids increases the filtering requirement increases. However, filter stop-band attenuation of 40dB is more than necessary for the maximum practical Distribution Amplifier gain.

Automatic gain and slope control requires greater hybrid gain to make up for losses in the gain and slope networks as they compensate for cable and system temperature dependent losses.

AGC CAPABILITY

Performance and new applications dictate AGC capability in the Distribution Amplifier. In order to implement this feature in a cost effective manner a modular package was developed. This allowed a voltage controlled RF circuit to be designed as a plug-in unit for the RF module PWB. This unit can be easily replaced by a jumper where automatic control is not required. A separate module located in the housing lid develops the control voltages for the RF circuit. A cable harness provides the required interconnections. This method makes maximum use of available space so the overall amplifier dimensions can be minimized.

RELIABILITY

The power supply and AC transformer were also located in the housing lid which allowed for more even distribution of the heat sources resulting in cooler heat sink temperatures. This directly affects hybrid reliability. The graph of Figure 5 [REF 1] is a plot of hybrid failure rate multiplier verses heat sink temperature. The graph indicates the reliability of a hybrid operating at 90°C verses 110°C heat sink temperature is 30% better, and would significantly reduce system down time due to hybrid failures.

The switching regulated power supply reduces system power consumption and increases reliability by dissipating less heat than a linear regulated supply. To provide a low thermal resistance path for the hybrids and power supply heat sinks to the ambient air the hybrid mounting technique of Figure 6 was used. This provides a short thermal path to the housing through two large surface areas reducing operating temperatures. The result is a maximum thermal rise of less than 15°C between the hybrid heat sink and housing. Cooling fins cast into the housing bottom and top increase the housing surface area which transfers the heat into the ambient air. The pass transistors in both switching and linear power supplies are connected directly to heat sinks cast into the power supply frames. The heat sinks in turn fit flush against the inside of the housing lid. The 60 Hz AC transformer is mounted directly to housing bosses that provide heat sinking and allow for an optional 50 Hz transformer (Figure 7A and B).

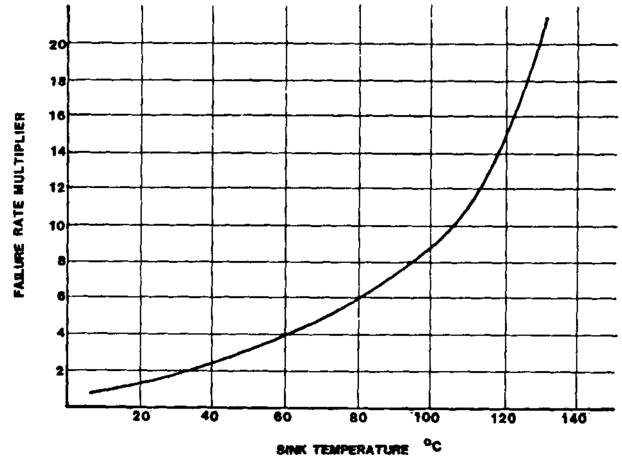

Figure 5

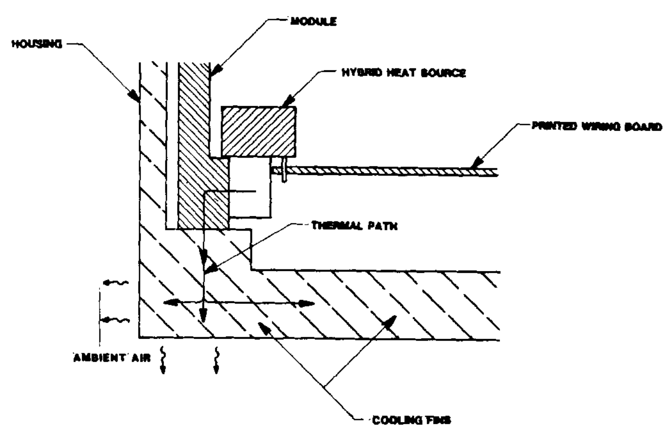

Figure 6

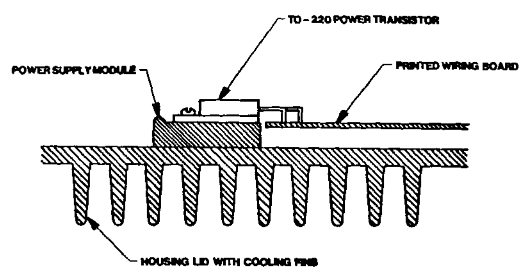

Figure 7A

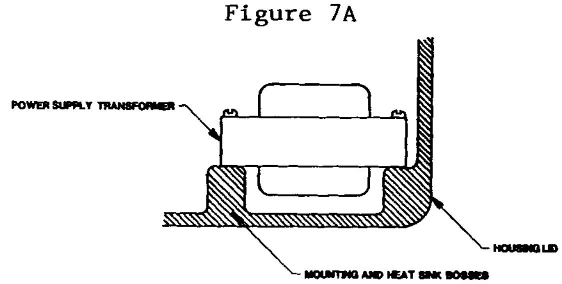

Figure 7B

MODULARITY

The flexibility of this modular configuration has produced an amplifier having two-way high gain capability, optional AGC and optional switching regulated power supply. In addition, the plug-in accessory (diplex filter, interstage filter, trim network, AGC RF) concept used in the RF module accomodates a variety of forward and reverse frequency splits. The appropriate networks need only to replace the jumpers in the basic RF module to produce the desired frequency configuration. Because each of these networks is a stand alone 75 Ohm input/output device, they can be aligned and tested independently to assure each part meets the required performance specifications.

Cost effectiveness is achieved because the individual modules can be optimized for efficiency in manufacturing and testing. This produces high quality modules with optimal performance specifications. System inventory is reduced because the same basic module is used throughout with total interchangeability of parts.

With this modular approach the system can be upgraded at any time. Extended bandwidth becomes a function of hybrid response as all other components have been predesigned to accomodate higher frequencies.

An important benefit of the modular design used is that specialized circuits and new technology can be easily implemented allowing the manufacturer to more effectively meet the needs of the continuously changing CATV industry.

REFERENCE

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