# Positive Feedback Circuit Technique Reduces Line Driver Power Dissipation in ADSL System

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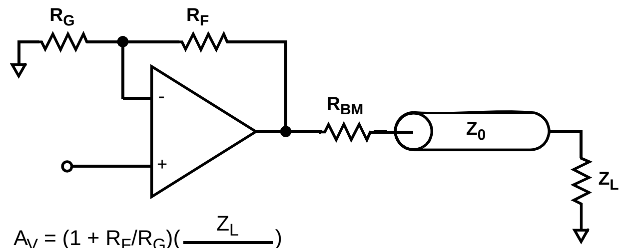
One of the major challenges faced by ADSL CO system designers today is to cramp more CO channels on given board size. ADSL service providers are demanding an upgrade to 72 port cards from 48 port cards. To address this problem, component manufacturers are offering multi-channel DSP and AFE, putting ICs in smaller packages and finding ways to reduce power dissipation. This application note presents a new method of reducing line driver dissipation in ADSL systems by using positive feedback to synthesize large output resistance.

The traditional circuit for a line driver with passive termination is shown in Figure 1. $R_{BM}$ is the backmatch resistance added for proper termination at the source. This backmatch resistance is typically equal to the value of the cable line characteristic impedance and the load impedance. The output impedance of the amplifier is negligible in comparison with the value of the backmatch resistor it appears in series with. The gain equation reflects the output voltage across the load resistance with respect to the input voltage. It includes the equation of a non-inverting amplifier with an additional factor to represent the resistive divider between the backmatch resistor and the load. It is this additional factor that active termination will address.

While functional, this passive termination circuit has some disadvantages. The output impedance of the driver, while small, can be a noticeable quantity. The backmatch resistor is necessary to properly terminate the source end of a transmission line such as a twisted pair, but now the voltage delivered to the load is split between that backmatch resistance and the load resistance. Since there is a required voltage level at the load, the driver must now produce twice the voltage swing. The voltage swing and power dissipation increases. The power burned in the backmatch resistor is lost as heat, which causes the total power dissipation to double. There also is quiescent power used in the op amp.

Positive feedback addresses these issues. With negative feedback already in place to set the gain, positive feedback can be used to adjust the output impedance. Lowering the backmatch resistor without compromising the total source termination impedance relaxes the output and supply voltage requirement for the amplifier and reduces the overall power dissipation. The active termination driver circuit is shown in Figure 2. $R_{P1}$ and $R_{P2}$ are the only additions to the passive circuit and provide the positive feedback for the amplifier. This feedback synthesizes larger output impedance for the amplifier, allowing a reduction of the backmatch resistance. For convenience, a factor **k** is being introduced. It is the ratio between the backmatch resistance and the physical backmatch resistor. The stability of the amplifier and the physical backmatch resistance tolerance




$$A_V = (1 + R_F/R_G)\left(\frac{Z_L}{R_{BM} + Z_L}\right)$$

$$Z_{SOURCE} = R_{BM} + Z_{AMP} \cong R_{BM}$$

**FIGURE 1. PASSIVE TERMINATION**

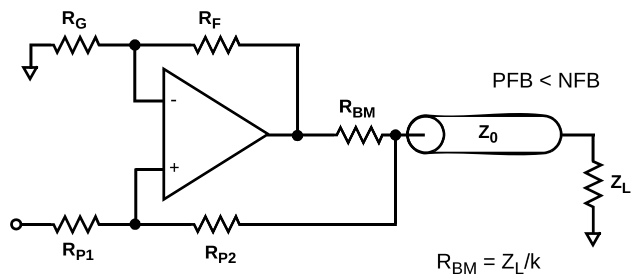



**FIGURE 2. ACTIVE TERMINATION**

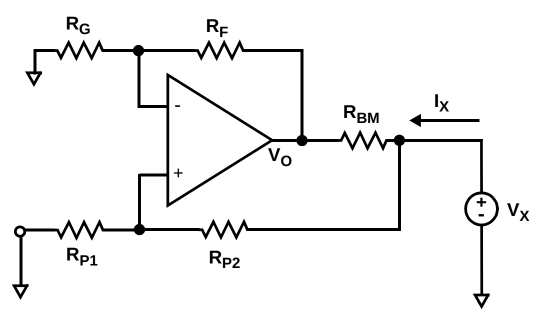



**FIGURE 3. MEASURING OUTPUT IMPEDANCE**

typically limit **k** to around 4 or 5. The output impedance of the amplifier is increased by the positive feedback, allowing the backmatch resistance to decrease, keeping the total source impedance constant. Figure 3 shows a standard method for measuring the output impedance of any circuit. Ohm's law applies, so a test voltage (Vx) applied to a node divided by the test current calculated from that voltage will give the impedance seen at that node. Ideal op amp simplifications (input terminals are at the same voltage and there is no current flowing into the inputs) $R_{P2}$ is assumed much larger the $R_{BM}$ so the current through the positive feedback loop can be neglected. In practice, this is a reasonable assumption. The voltage at the input terminals is given by a resistive divider of the output voltage on either side of the backmatch resistor. These feedback resistors alter the output resistance for the op amp, allowing reduction in the backmatch resistance. The derivations are as follows:

$$V+ = \frac{R_{P1}}{(R_{P1} + R_{P2})} \cdot V_X$$

$$V- = \frac{R_G}{(R_F + R_G)} \cdot V_O$$

$$I_X = \frac{(V_O - V_X)}{R_{BM}}$$

$$Z_{SOURCE} = \frac{V_X}{I_X} = \frac{R_{BM}}{\left(\frac{R_{P1}}{(R_{P1} + R_{P2})} \bullet \frac{(R_F + R_G)}{R_G} - 1\right)} \quad \text{(EQ. 1)}$$

In an ADSL system, the POTS phone line, a twisted pair cable is used for data transmission. As shown in Figure 3, the single ended active terminate line driver is reconfigured to drive differential lines. The gain resistor is shared to allow accurate gain matching between the two amplifiers.

Table 1 is a quick comparison of the reduction in voltage and power requirements for the driver with passive or active termination. The key specification of a ADSL CO driver are as follows: Peak output line power is 20dBm, POTS line impedance is 100Ω and the crest factor for ADSL DMT signal is 14.5dB. This specification translates to 16.76$V_{P-P}$ voltage on the line with 5.3 peak to average ratio PAR and 31.6mA average output current. In the passive termination case where the load and backmatch resistors are the same, the amplifier must provide 33.52$V_{P-P}$ at its outputs. A high voltage line driver typically needs 4V of total headroom. As a result, the total supply voltage required is 37.5V. With the necessary output average current, that translates into 1.185W dissipated in addition to the quiescent power of the amplifier.

**TABLE 1. COMPARISON OF REDUCTION IN VOLTAGE AND POWER REQUIREMENTS FOR DRIVER WITH PASSIVE OR ACTIVE TERMINATION**

| PASSIVE TERMINATION | ACTIVE TERMINATION |
|---|---|
| 16.5$V_{P-P}$ into a 100Ω line | 16.5$V_{P-P}$ into a 100Ω line |
| $V_{OUT\ DRIVER} = V_{RBM} + V_{RLOAD}$ | $V_{OUT\ DRIVER} = V_{RBM} + V_{RLOAD}$ |
| $R_{BM} = R_{LOAD}$ | $R_{BM} = R_{LOAD}/5$ |
| $V_{RBM} = V_{RLOAD}$ | $V_{RBM} = V_{RLOAD}/5$ |
| $V_{OUT\ DRIVER}$ = 33.52V | $V_{OUT\ DRIVER}$ = 20.11V |
| $V_{SUPPLY}$ = 37.52 | $V_{SUPPLY}$ = 24.11 |
| $I_{OUT}$ = 31.6mA | $I_{OUT}$ = 31.6mA |
| $P_{OUT\ DRIVER} = V_{SUPPLY} * I_{OUT}$ = 1.185W (plus quiescent power | $P_{OUT\ DRIVER} = V_{SUPPLY} * I_{OUT}$ = 0.714W (plus quiescent power) |

In the active case, a **k** of 5 is assumed. This reduces the backmatch resistor to 20% of its value in the passive case. The peak-to-peak output voltage provided by the driver is reduced to 20.11V which allows the use of the EL1508, a median voltage line driver. The EL1508 requires 2.5V of headroom. With 2.5V of supply voltage headroom, the power supply required becomes 22.61. With the same output current drive, the power dissipation is reduced by 39.7% to 0.714W. While it is true that additional power is dissipated in the feedback networks, the feedback resistors are typically much larger than the backmatch resistor and their losses are negligible.