APPLICATION NOTE

AN105
Digital attenuator

1988 Dec

Philips
Semiconductors

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Digital attenuator **AN105**

Figure 1 shows a DC-coupled Digital Attenuator or Programmable Gain Amplifier

Pin 14 of the DAC is a Virtual Ground. Current must always flow into Pin 14, so the current through R4 must be greater than that through R1 when the input signal is at its most negative usable value. If the input signal value goes low enough to cause the current through R1 to be greater than that through R4, output clipping will occur.

To extend the operating frequency range, the compensation cap, C_C, needs to be minimized, which implies that the resistance at Pin 14 (R1 and R4) must be minimized. If the voltage to which R4 and R5 are returned has any noise on it at all, R4 and RS should be formed of two series resistors with the junction of them bypassed with 0.1μF to ground. Pin 15 could be grounded with a small sacrifice in accuracy and temperature drift. R6 and R7 compensate for reference amplifier input off set.

R1 and R4 should be chosen such that, when the input is at peak usable signal, the total current into Pin 14 does not exceed 4mA. When the input is most negative, R1 current must be less than R4 current (remember, Pin 14 is always at 0V). Also, when the input is at its absolute positive peak value, current into Pin 14 should not exceed 5mA. Minimum compensation capacitor, (C_C), in pF is 15 times the parallel combination of R1 and R4 in kΩ.

With a single DAC, there is a DC offset at the circuit output that varies with the digital word input. To eliminate this, we use a second DAC to subtract this offset at the sum node of the op amp.

Example 1: Input signal is to be 20Vp p, centered at 0V. Maximum input frequency is to be 15kHz. Power supplies available are ±15V, both regulated. Determine values of all resistors for maximum gain of unity.

Solution 1: At minimum input (-10V), reference current, I_{REF} is

$$I_{REF} = \frac{15V}{R4} + \frac{(-10V)}{R1}$$

If minimum I_{REF} = 0, then

$$\frac{15V}{R4} = \frac{10V}{R1}$$

and R4 = (1.5)(R1)

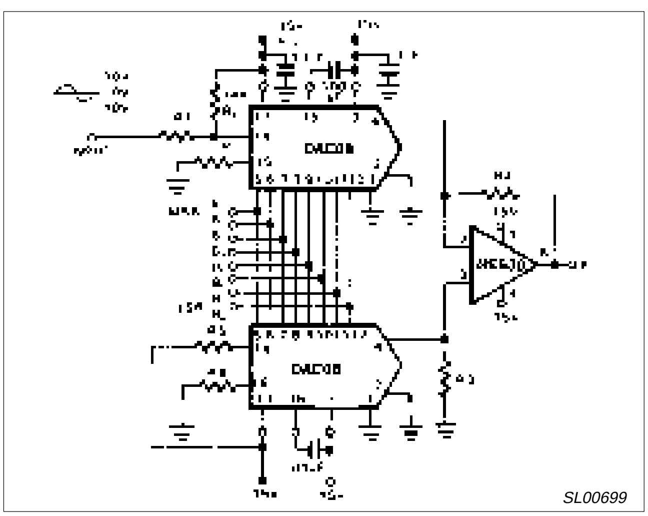

Figure 1.

Therefore, 60% of I_{REF} comes through R4. If we let I_{REF} go to about 3.9mA (4mA is max. recommended), R4 current is found to be I_{R4} = (0.6) (3.9mA) = 2.34mA and R4 = 6.4k.

The balance of the reference current I_{R1} is found to be

$$I_{R1} = 3.9mA - I_{R4}$$

or

$$I_{R1} = 3.9mA - 234mA = 1.56mA$$

and

$$R1 = 6.4k$$

Using commonly available values, and remembering that R4 current must exceed R 1 current, we set

R1 = 6.8k

and R4 = 6.2k.

Maximum reference current is now

$$I_{REF}(max) = \frac{15V}{6.2k} + \frac{10V}{6.8k} = 3.9mA$$

The parallel combination of R1 and R4 is found to be 3.24k, so minimum compensation capacitor value is

C_C(min) = (3.24)(15)pF = 48.6pF

If we use 50pF, from the graph we find f_{MAX} to be 370kHz. For unity gain,

R2 = R1 = 6.8k

R3 = R2 = 6.8k

RS = R1 = 6.8k

$$R6 = R7 = \frac{(R1)(R4)}{R1 + R4} = 3.24k$$

Example 2: Usable input signal is $12V_{P-P}$, centered at 0V, with occasional excursion to twice this amplitude, which we do not care about. Maximum input frequency is to be 500kHz. Available power supplies are +5V logic supply, +15V, –15V, all regulated. Determine values of all resistors and C_C for maximum gain of 2.

Solution 2: To extend the frequency response, we want minimum compensation capacitor value; therefore, we need minimum R1 and R4 values, so we want to return R4 to as low a regulated supply as is possible; we will use the 5V logic supply.

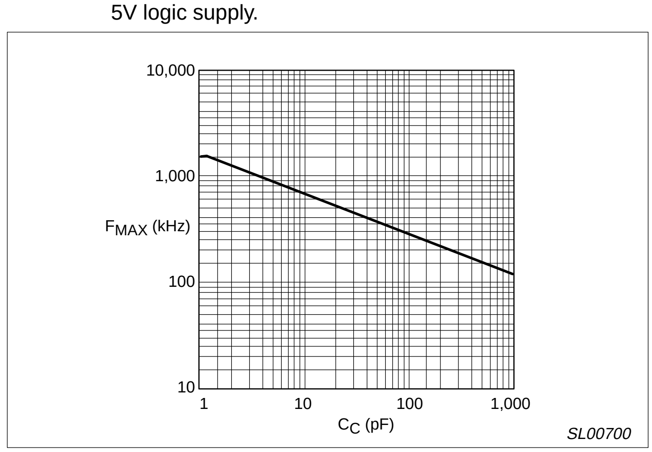

Figure 2.

At minimum usable input,

$$I_{REF} = \frac{5V}{R4} + \frac{6V}{R1}$$

or, for

$$I_{REF} = 0, \frac{5V}{R4} = \frac{6V}{R1}$$

therefore, 55% of I_{REF} comes through R4, and

R4 = (5/6)R1.

Because peak input goes to +12V, this condition should not cause I_{REF} to exceed 5mA, and

$$\frac{12V}{R1} + \frac{5V}{R4} = 5mA$$

Recall that R4 = (5/6)R1.

$$\frac{12V}{R1} = \frac{6V}{R1} = 5mA$$

R1 = 3.6k

and R4 = (5/6)R1 = 3.0k.

Because the reference source will be the 5V logic supply, which will be noisy, we will split R4 into two resistors and bypass their junction with 0.1µF to ground. Furthermore, to be sure that R4 current exceeds R1 current, we will increase R1 to 4.3k. The absolute maximum reference current is now

$$I_{REF}(max) = \frac{12V}{4.3k} + \frac{5V}{3k} = 4.46mA.$$

The parallel combination of R1 and R4 is 1.77k, so minimum compensation capacitor is

$C_C(min) = (15)(1.77) = 26.5pF.$

If we use 27pF, the graph tells us the maximum frequency is about 470kHz, which is 6% lower than desired. If we wanted to further extend this frequency range, we find that we can reduce R4 to two resistors of 1.1k and 1.2k, bringing the absolute maximum reference current to

$$I_{REF}(max) = \frac{12V}{4.3k} + \frac{5V}{2.3k} = 4.96mA.$$

and the maximum usable reference current becomes

$$I_{REF}(max) = \frac{6V}{4.3k} + \frac{5V}{2.3k} = 3.57mA.$$

below the 5mA and 4mA respective desired maximum values. Now the resistance at Pin 14 is the parallel combination of R1 and R4, or 1.5k, and the minimum compensation capacitor becomes

$C_C(min) = (15)(1.5)pF = 22pF.$

The graph tells us we can just go to 500kHz.