Design of Differential Amp. on MCM card

Aniruddha Adoni
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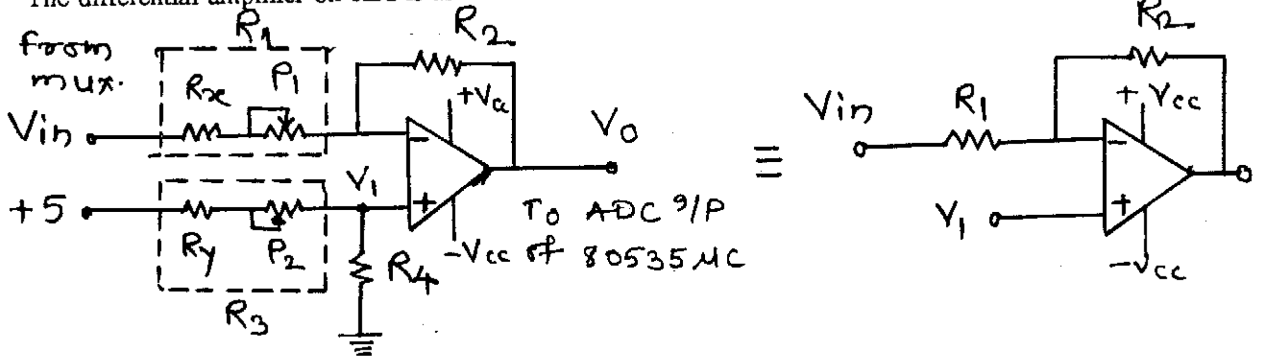
The purpose of differential amplifier between multiplexer output and ADC input is to get 0 to 5 Volts as ADC input for any specified analog range. The known analog input ranges for MCM card are as follows : (a) 0 to 5V, (b) -5 to +5V, (c) -2.5 to +2.5 and (d) 0 to +2.5V

The differential amplifier on card is as shown below :



The equation for the output voltage is :

$$V_0 = \frac{R_1 + R_2}{R_1} \left[V_1 - V_{in} \frac{R_2}{R_1 + R_2}\right] \qquad \text{(A)}$$

The resistors should be selected such that for any known range , we should be able to fulfill following conditions :

a) For maximum analog input, ADC input should be 0V and (1)

b) For minimum analog input, ADC input should be 5V. (2)

Thus, for various ranges to find unique R_1 and R_2 for following conditions

For V_{in} *as* V_{min}, V_0 *should be 5V* (i)

V_{in} *as* V_{max}, V_0 *should be 0V* (ii)

(i) For first condition, the equation (A) becomes

$$5 = \frac{R_1 + R_2}{R_1} V_1 - \frac{R_2}{R_1} V_{min}$$

$$5 = (1 + \frac{R_2}{R_1}) V_1 - \frac{R_2}{R_1} V_{min}$$

$$= V_1 + \frac{R_2}{R_1} (V_1 - V_{min})$$

$$5 - V_1 = \frac{R_2}{R_1} (V_1 - V_{min})$$

$$\frac{R_1}{R_2} = \frac{V_1 - V_{min}}{5 - V_1} \qquad (3)$$

(ii) For second condition, substituting in equation (A), we get

$$0 = \frac{R_1 + R_2}{R_1} V_1 - \frac{R_2}{R_1} V_{max}$$

$$V_1 + \frac{R_2}{R_1} V_1 - V_{max} \frac{R_2}{R_1} = 0$$

$$\frac{R_2}{R_1} (V_1 - V_{max}) = - V_1 \frac{R_2}{R_1}$$

$$= - \frac{V_1}{(V_1 - V_{max})}$$

$$= \frac{V_1}{V_{max} - V_1}$$

$$\frac{R_1}{R_2} = \frac{V_{max} - V_1}{V_1} \qquad (4)$$

From equations (3) and (4), we can write

$$V_1 - \frac{V_{min}}{5 - V_1} = \frac{V_{max} - V_1}{V_1}$$

By cross multiplying, we get equation for V_1 as,

$$V_1 = \frac{5 \, V_{max}}{5 + V_{max} - V_{min}} \qquad (5)$$

Now, by substituting the values for V_{min} and V_{max}, we will get the value of V_1 to be adjusted for the selected range.

Next, substituting this voltage V_1 in any of the equations of R_1 by R_2 (i.e. equation (3) or (4)), we will get the gain adjustement value.

Thus, for the given range, one has to set V_1 and $\frac{R_1}{R_2}$ by pots P_1 and P_2 respectively.

For the four ranges the values of V_1 and $\frac{R_1}{R_2}$ are calculated and given in the following table :

Voltage Range	V1	R1 by R2
0V to +5V	2.5V	1
-5V to +5V	1.66V	2.01
-2.5V to +2.5V	1.25V	1
0 to +2.5V	1.66V	0.506

Thus, for the specified ranges , the resistor ratio should vary between 0.5 to 2.5 and voltage at inverting terminal of OPAMP should vary between 1.0 to 3.0 volts.

To satisfy the $\frac{R_1}{R_2}$ ratio and V_1 for all ranges the components should be chosen as follows :

$R_x = R_y = 2k2$ $\qquad$ $R_2 = R_4 = 4k7$
$P_1 = 10k$ $\qquad$ $P_2 = 20k$

If one is sure that first 3 ranges are the only ranges, then R_x, R_y and R_2, R_4 can be decreased or increased. But one condition is always there : $R_x < R_2$ and $R_y < R_4$.

So, for first 3 ranges, another combination can be :

$R_x = R_y = 4k7$ $\qquad$ $R_2 = R_4 = 5k6$
$P_1 = 10k$ $\qquad$ $P_2 = 20k$

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