Analogue input modules for a -5V to +5V to 0-5V signal converter

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This series is about a project involving thirteen analogue input modules and seven analogue output modules for use with a 5V microcontroller via its ADC and DAC channels. In columns two to four, we discussed the 0-5V analogue input modules 1 to 5, which accept DC input voltages from 0V to +6.26V, +12V, +24V and require a different DC power supplies.

In column five we considered the 0-10V to 0-5V signal converter and its analogue input modules 1 and 2. These modules handle DC input voltages from 0V to +24V, and operate from +6.26V and +12V for module 1, and +12V DC for module 2, respectively.

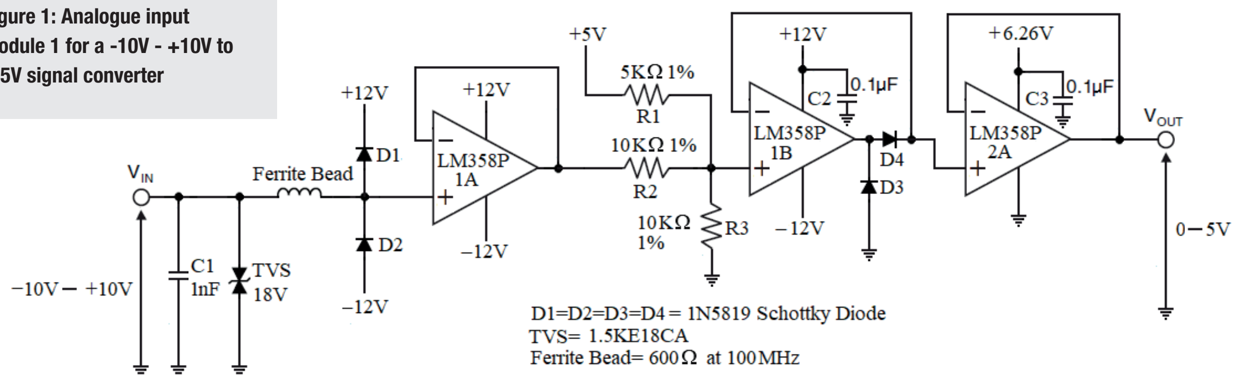
In column six we covered analogue input modules 1 and 2 of the -5V - +5V to 0-5V signal converter, which accepts DC input voltages from -12V to +12V. Analogue input module 1 requires four DC power supplies (+5V, +6.26V, -12V, +12V), whereas module 2 needs two (-12V, +12V).

In this month's column, we'll focus on the tenth and eleventh analogue input modules, which are analogue input modules 1 and 2 of a -10V - +10V to 0-5V signal converter. The first module can accept DC input voltages from -12V to +12V and requires four DC power supplies: +5V, +6.26V, -12V, +12V; see Figures 1 and 2. Respectively, module 2 needs only two DC power supplies: -12V, +12V; see Figures 5 and 6.

Analogue Input Module 1

In this design it is assumed that the input voltage range V_{IN} = -12V to +12V. When -12.00V ≤ V_{IN} < -10.00V, V_{OUT} = 0.00V; when

Figure 1: Analogue input module 1 for a -10V - +10V to 0-5V signal converter



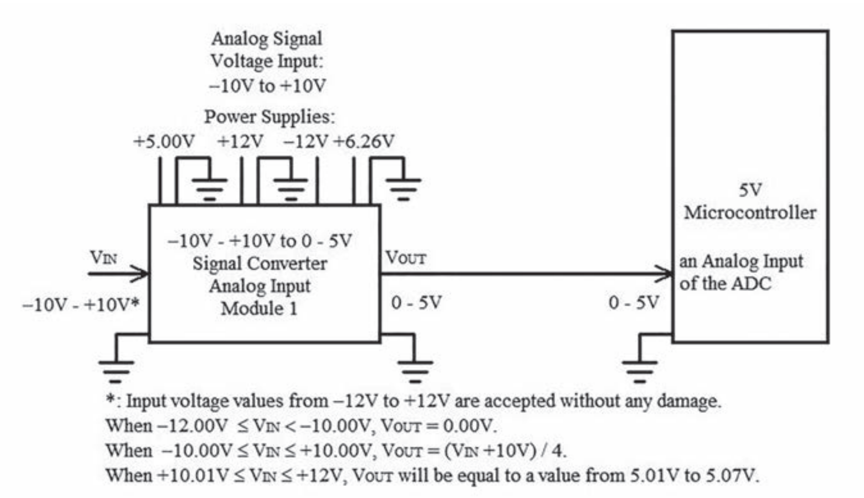


Figure 2: Connecting analogue input module 1 for a -10V - +10V to 0-5V signal converter to the analogue input of a 5V microcontroller

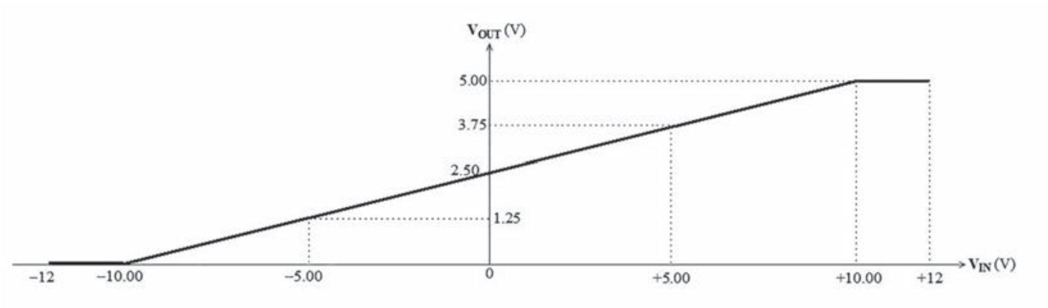


Figure 3: V_{OUT} vs. V_{IN} for analogue input modules 1 and 2 of the 10V - +10V to 0-5V signal converter

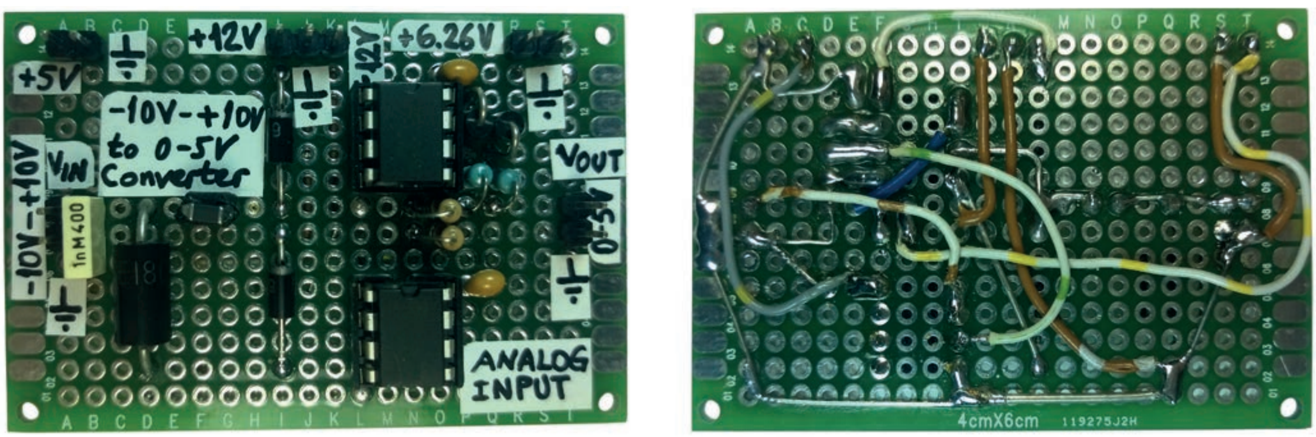


Figure 4: Top and bottom view of the prototype of analogue input module 1 of a -10V - +10V to 0-5V signal converter

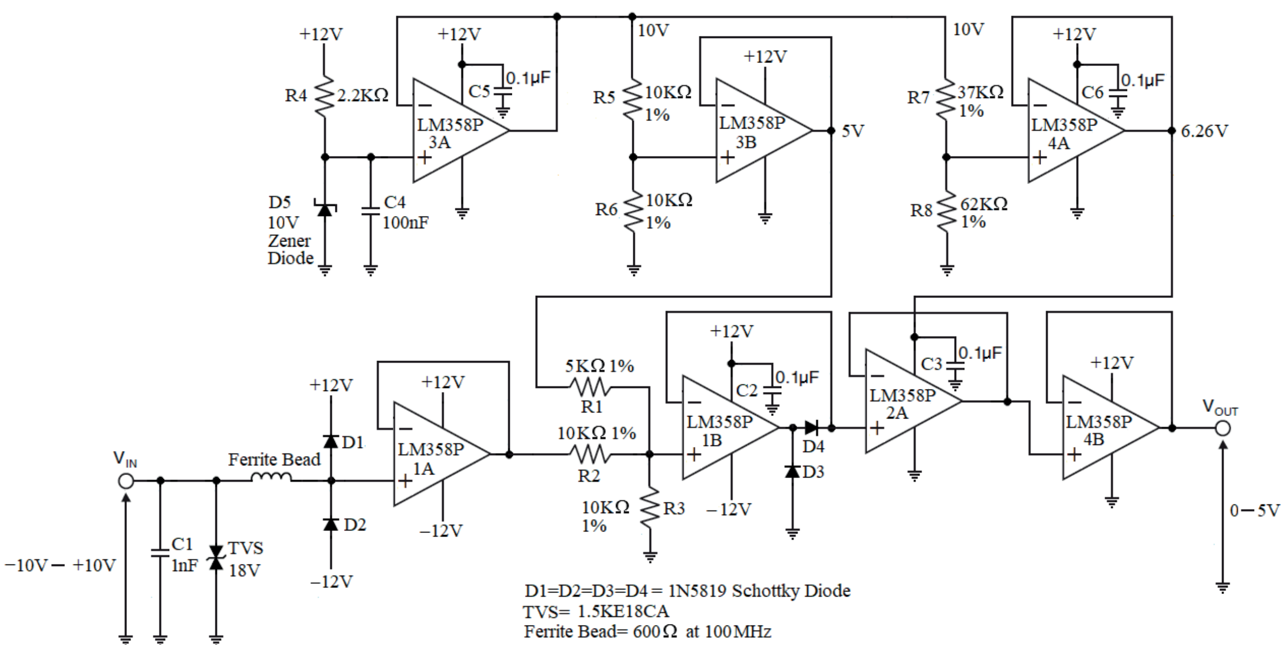


Figure 5: Schematic diagram of analogue input module 2 of a -10V - +10V to 0-5V signal converter

V_{IN}(V)	V_{OUT}(V)
+12.00	5.0X
..	5.0X
+10.00	5.00
..	..
+9.00	4.75
..	..
+8.00	4.50
..	..
+7.00	4.25
..	..
+6.00	4.00
..	..
+5.00	3.75
..	..
+4.00	3.50
..	..
+2.00	3.00
..	..
0.00	2.50
..	..
-1.00	2.25
..	..
-3.00	1.75
..	..
-4.00	1.50
..	..
-5.00	1.25
..	..
-6.00	1.00
..	..
-7.00	0.75
..	..
-8.00	0.50
..	..
-9.00	0.25
..	..
-10.00	0.00
..	..
-12.00	0.00

Table 1: Example input and output voltages for analogue input modules 1 and 2 of the -10V - +10V to 0-5V signal converter

(5.0X: a value from 5.01V to 5.07V, due to the electrical characteristics of the LM358P-2A used)

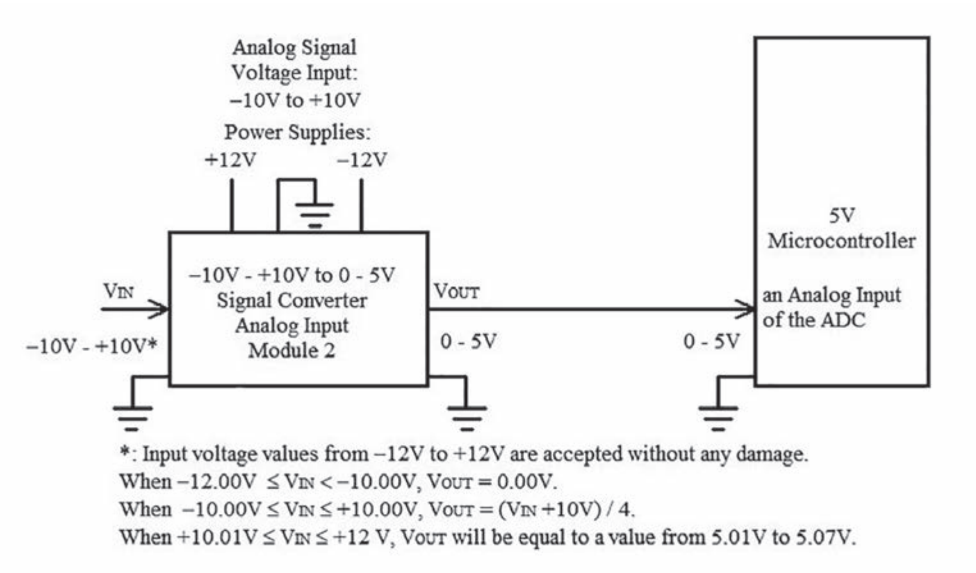


Figure 6: Connecting the analogue input module 2 of the -10V - +10V to 0-5V signal converter to an analogue input of a 5V microcontroller

-10.00V ≥ V_{IN} ≥ +10.00V, V_{OUT} = (V_{IN} +10V)/4. When +10.01V ≥ V_{IN} ≥ +12V, V_{OUT} will be between 5.01V and 5.07V, due to the electrical characteristics of the LM358P-2A used.

The relationship between V_{OUT} and V_{IN} is shown in Figure 3. It can be seen that input voltages up to +12V are accepted without damage to the circuit, outputting 5.01V to 5.07V.

This design is used to level-shift a bipolar -10V - +10V analogue voltage signal to provide a unipolar 0-5V analogue input signal. The transfer function is obtained from the superposition principle:

$$V_{OUT} = \left(\frac{\frac{R1.R3}{R1+R3}}{R2+\frac{R1.R3}{R1+R3}}\right)V_{IN} + \left(\frac{\frac{R2.R3}{R2+R3}}{R1+\frac{R2.R3}{R2+R3}}\right)5$$

Since R2 = R3, R1 = ½ R2:

$$V_{OUT} = \left(\frac{1}{4}\right)V_{IN} + \left(\frac{1}{2}\right)5 = \frac{V_{IN}+10}{4}$$

The analogue input V_{IN} can be subjected to electric surge or electrostatic discharge on the external terminal connections; TVS (transient voltage suppressor) shown in the circuit provides highly effective protection against such discharges. A ferrite bead is connected in series with the input path to add isolation and to decouple from high-frequency transient noises. External Schottky diodes generally protect the operational amplifier. Even when internal ESD protection diodes are provided, the use of external diodes lowers and offset errors.

The dual series Schottky barrier diodes D1 and D2 divert any overcurrent to the positive or negative power supply. The operational amplifier LM358P-1A, with bipolar supply voltages, provides a high input impedance and is connected as a buffer amplifier (voltage follower). Diodes D3 and D4 ensure that when -12.00V ≤ V_{IN} < -10.00V, V_{OUT} = 0.00V. The operational amplifier LM358P-2A, with its +6.26V supply voltage, acts as a voltage limiter and is connected as a buffer amplifier. V_{OUT} is obtained from the output of the LM358P-2A.

Table 1 shows some example input and output voltage values for the analogue input module 1 of a -10V - +10V to 0-5V signal converter. Its prototype circuit board is shown in Figure 4.

It's worth noting that for proper operation you should make R2 = R3, R1 = ½R2 and +5V = +5.00V.

Analogue Input Module 2

In designing analogue input module 2 of a -10V - +10V to 0-5V signal converter, as with the previous module, we've assumed that the input voltage range V_{IN} = -12V to +12V. When -12.00V ≤ V_{IN} < -10.00V, V_{OUT} = 0.00V. When -10.00V ≤ V_{IN} ≤ +10.00V, V_{OUT} = (V_{IN} +10V)/4. When +10.01V ≤ V_{IN} ≤ +12V, V_{OUT} will be equal to a value from 5.01V to 5.07V, due to the electrical characteristics of the LM358P-2A used.

Except for the buffer amplifier LM358P-4B where the output voltage V_{OUT} is obtained, the lower part of Figure 5 is identical to that of the first module (Figure 1).

The top part of Figure 5 is dedicated to producing two reference voltages: +5.00V and +6.26V. The components R4, D5 (10V zener diode) and C4 with the buffer amplifier LM358P-3A provide a 10.00V reference voltage from a +12V power supply. This 10.00V reference voltage is then divided by using resistors R5 and R6 to obtain the +5.00V reference voltage.

Next, the +5.00V reference voltage is connected to the non-inverting input of the buffer amplifier LM358P-3B, whose output is fixed as a +5.00V reference voltage, capable of sourcing up to 20mA.

Likewise, the voltage is also divided by R7 and R8 to obtain a +6.26V reference voltage, which is connected to the non-inverting input of the buffer amplifier LM358P-4A.

For proper operation, make sure that R2 = R3, R1 = ½ R2, R5 = R6, and R8/(R7+R8) = 62.62%.

Example input and output voltage values for the analogue input module are shown in Table 1. EW

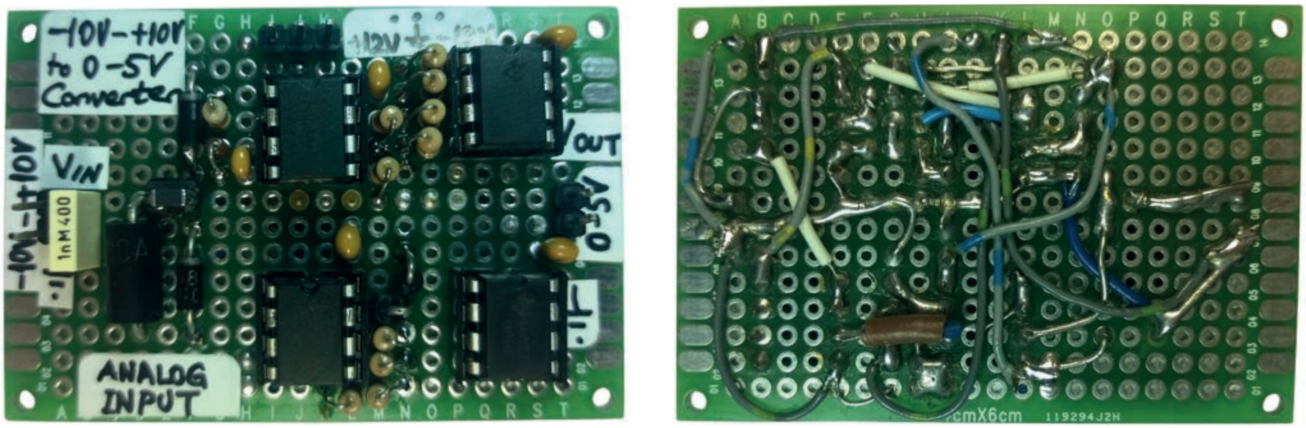


Figure 7: Top and bottom views of the prototype of analogue input module 2 of a -10V - +10V to 0-5V signal converter