Analogue output modules for a 0-5V to -10V - +10V signal converter

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This series of columns is dedicated to a project involving thirteen analogue input modules and seven analogue output modules for a 5V microcontroller, connecting them to its ADC and DAC channels.

This month we will cover the fifth and sixth analogue output modules, i.e. the 0-5V to −10V - +10V signal converter's analogue output modules 1 and 2. Module 1, and then module 2 respectively, provide voltages from −10V to +10V, requiring three DC power supplies (+5V, −12V, +12V) for module 1, and two (−12V, +12V) for module 2.

Analogue output module 1

Figure 1 shows the 0-5V to −10V module 1 for use with the DAC output of a 5V microcontroller, with Figure 2 showing its connections. It is assumed that V_{IN} is taken from the DAC output of the 5V microcontroller with $0.00V \le V_{IN} \le 5.00V$. In this condition, $V_{OUT} = 4V_{IN} - 10$. Input voltage range V_{IN} is 0.00V to 5.00V and, therefore, the output voltage range V_{OUT} is −10.00V to +10.00V. This relationship is shown in Figure 3.

Jumper S1 (shown here as a switch) is used to select either 0-5V to 0-10V operation mode when S1 is open, or 0-5V to −10V operation mode when S1 is closed. With S1 open, the circuit works like the analogue output module for the 0-5V to 0-10V signal converter, so we will only discuss the 0-5V to −10V operation mode, i.e. when S1 is closed.

This design is used to level-shift a unipolar 0V to 5V input voltage signal to a bipolar −10V to +10V output voltage signal. When $0.00V \le V_{IN} \le 5.00V$, the two operational amplifiers LM358P-A and LM358P-B, with their bipolar supply voltages, provide the following transfer function:

$$V_{OUT} = \left(1 + \frac{R3 + P2}{R4}\right)\left(\left(1 + \frac{R1 + P1}{R2}\right)V_{IN} - 5\right)$$

After adjusting P1, we obtain R1 + P1 = R2; and, after adjusting P2, we obtain R3 + P2 = R4, hence:

$$V_{OUT} = 2(2V_{IN} - 5) = 4V_{IN} - 10$$

Series Schottky barrier diodes D1 and D2 divert any V_{OUT} overcurrent to the positive or the negative power supply. A ferrite bead in series with the output path adds isolation and decoupling from high-frequency transient noises. A TVS (transient voltage suppressor) is used to filter and suppress any output transients.

Table 1 shows some input and output voltages for module 1, assuming $0.00V \le V_{IN} \le 5.00V$. The module's prototype circuit board is shown in Figure 4.

Circuit calibration

With S1 open, adjust P2 to ensure that when V_{IN} = +5.00V, V_{OUT} = +10.00V.

With S1 closed:

1. Set V_{IN} to +5.00V and, then, by adjusting P2, ensure V_{OUT} = +10.00V.
2. Set V_{IN} to 0.00V and, then, by adjusting P1, ensure V_{OUT} = −10.00V.

Analogue output module 2

Figure 5 shows the analogue output module 2 for the 0-5V to −10V - +10V signal converter, for use with a 5V MCU's DAC output; Figure 6 shows its connections.

In this design, as in the previous module, it is assumed that V_{IN} is taken from the DAC output of the MCU with $0.00V \le V_{IN} \le 5.00V$. When it is, $V_{OUT} = 4V_{IN} - 10$. Input voltage range V_{IN} is 0.00V to 5.00V, so the output voltage range V_{OUT} is −10.00V to +10.00V. This relationship is shown in Figure 3.

The lower part of the diagram is the same as that of the analogue output module 1 of a 0-5V to −10V - +10V signal converter, with the upper part being dedicated to obtaining the +5.00V reference voltage. R5, D3 (a 10V Zener diode) and C3, together with the buffer amplifier LM358P-1A, provide a 10.00V reference voltage from a +12V supply. Then, this voltage is divided with resistors R6 and R7 to obtain a +5.00V reference voltage. Next,

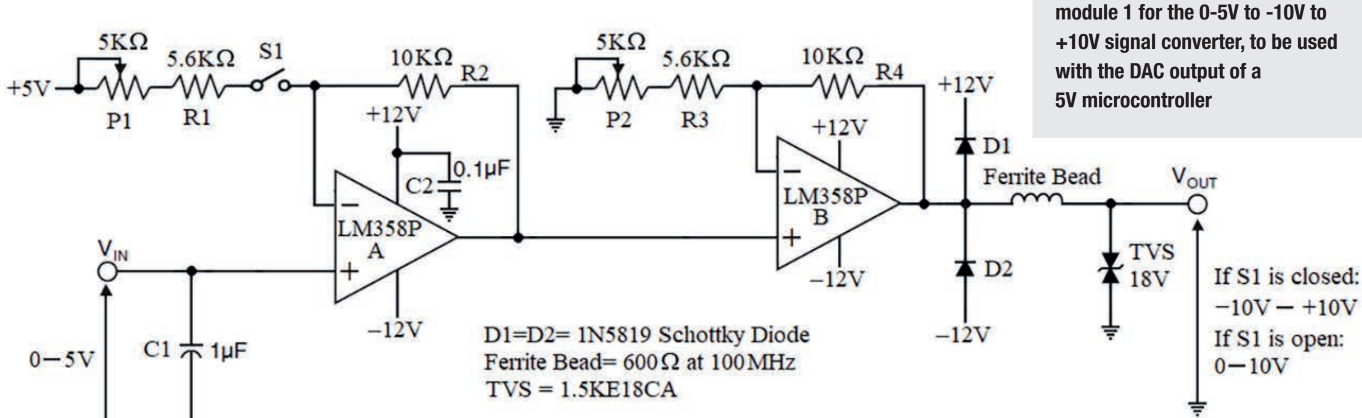


Figure 1: Analogue output module 1 for the 0-5V to -10V to +10V signal converter, to be used with the DAC output of a 5V microcontroller

Figure 2: Connections of the analogue output module 1 for the 0-5V to -10V - +10V signal converter

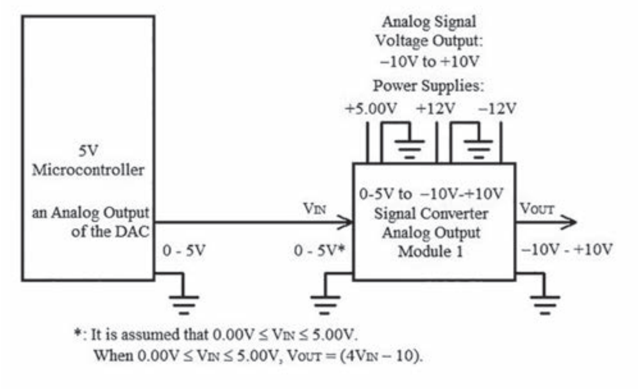
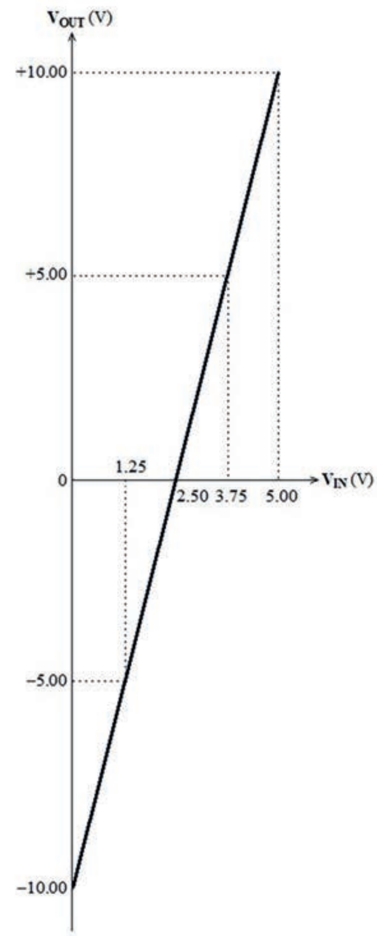


Figure 3: V_{OUT} vs V_{IN} for the analogue output modules 1 and 2 for the 0-5V to -10V - +10V signal converter



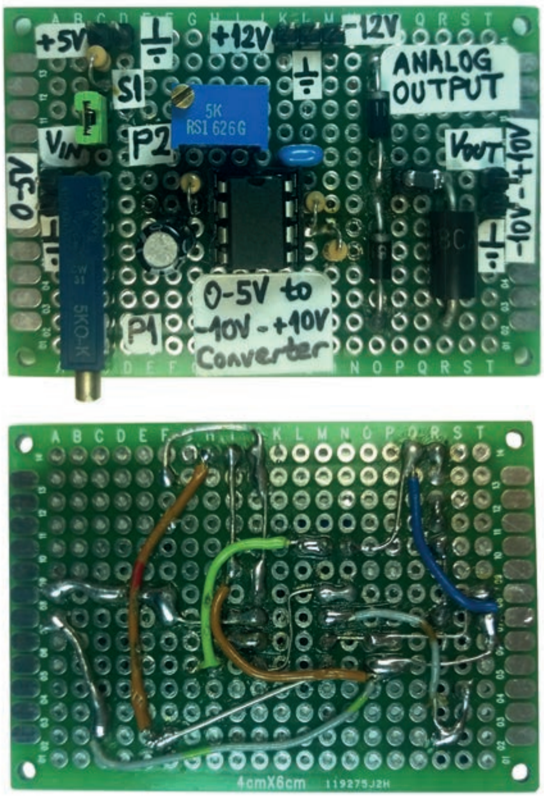


Figure 4: Prototype circuit board of the analogue output module 1 for the 0-5V to -10V - +10V signal converter

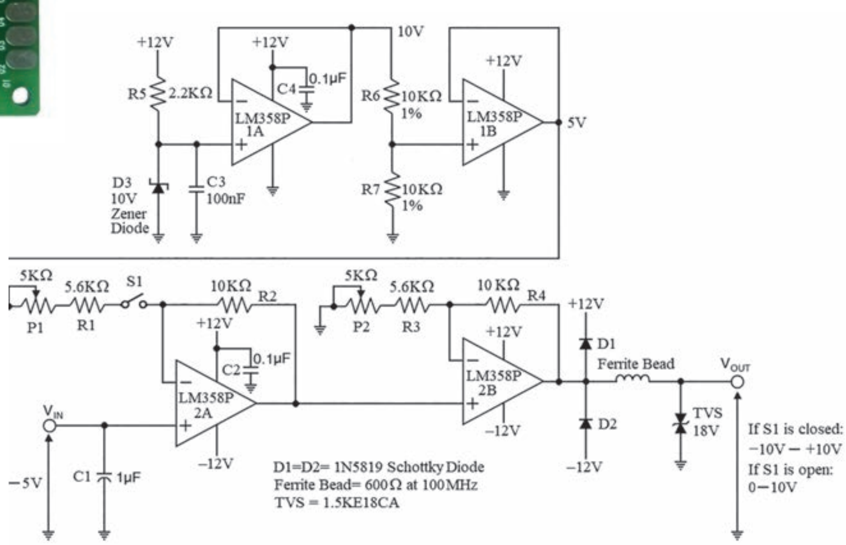


Figure 5: Analogue output module 2 for the 0-5V to -10V to +10V signal converter, for use with the DAC output of a 5V microcontroller

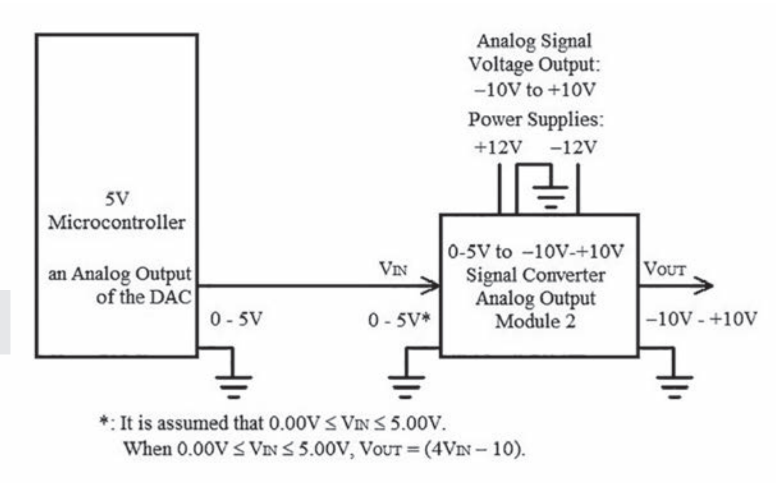


Figure 6: Connecting module 2

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

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

the +5.00V reference voltage is connected to the non-inverting input of the buffer amplifier LM358P-1B, whose output is fixed as a +5.00V reference voltage, capable of sourcing up to 20mA.

Table 1 shows input and output voltages for module 2, assuming 0.00V ≤ V_{IN} ≤ 5.00V. This module's prototype circuit board is shown in Figure 7.

For this circuit's proper operation, R6 and R7 must be equal.

Circuit calibration

With S1 open, adjust P2 to ensure that when V_{IN} = +5.00V, V_{OUT} = +10.00V.

With S1 closed:

1. Set V_{IN} to +5.00V and, then, adjust P2 to ensure V_{OUT} = +10.00V.
2. Set V_{IN} to 0.00V and, by adjusting P1, ensure V_{OUT} = −10.00V. EW

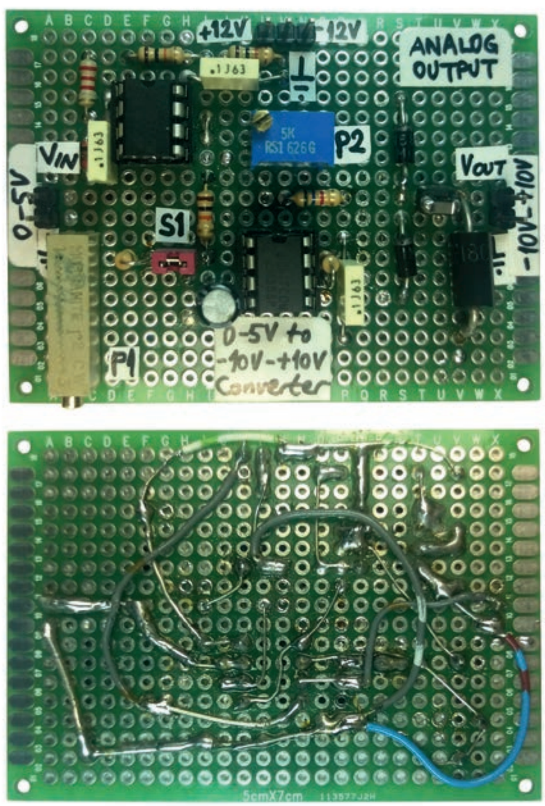


Figure 7: Module 2's prototype circuit board