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

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

This month's column covers the third and forth analogue output modules, or analogue output modules 1 and 2 for a 0-5V to -5V - +5V signal converter. These provide voltages from -5V to +5V; module 2 requires three DC power supplies (+5V, -12V and +12V) and module 1 two DC power supplies (-12V and +12V).

Output module 1

Figure 1 shows module 1's circuit, with its connections shown in Figure 2. We've assumed that V_{IN} comes from the DAC output of the 5V microcontroller with $0.00V \le V_{IN} \le 5.00V$. When $0.00V \le V_{IN} \le 5.00V$, $V_{OUT} = 2V_{IN} \le 5$. Input voltage range V_{IN} = 0.00-5.00V and therefore the output voltage range V_{OUT} is -5.00V to +5.00V. The relationship between V_{OUT} and V_{IN} is shown in Figure 3.

Jumper S1 (shown as a switch) is used to select either 0-5V operation mode (S1 open) or 0-5V to -5V - +5V mode (S1 closed). The design is used to level-shift the unipolar 0-5V input voltage signal to a bipolar -5V to +5V output voltage signal. When $0.00V \le V_{IN} \le 5.00V$, the operational amplifier LM358P-A, with bipolar supply voltages, acts with the transfer function:

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

By adjusting P1 we obtain R1 + P1 = R2, hence:

$$V_{OUT} = 2V_{IN} - 5$$

The buffer amplifier (a voltage follower) LM358P-B is used on the output of LM358P-A. Two series Schottky barrier diodes D1 and D2 divert any V_{OUT} overcurrent to the positive or negative power supply. A ferrite bead is connected in series with the output path to add isolation and decoupling from high-frequency transients. A TVS (Transient Voltage Suppressor) filters and suppresses any V_{OUT} transients.

This circuit can supply up to 20mA output current.

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

Circuit calibration when S1 is closed: By adjusting P1, ensure that when V_{IN} = 0.00V, V_{OUT} = -5.00V and, also, when V_{IN} = +5.00V, V_{OUT} = +5.00V. When S1 is open there's no need for calibration.

Analogue output module 2

Figure 5 shows the circuit diagram of analogue output module 2 for a 0-5V to -5V - +5V signal converter, with its connections to the 5V microcontroller shown in Figure 6.

As in the previous module, we assume V_{IN} comes from the MCU's DAC, with $0.00V \le V_{IN} \le 5.00V$. When $0.00V \le V_{IN} \le 5.00V$, $V_{OUT} = 2V_{IN} \le 5$. The input voltage range V_{IN} = 0.00V to 5.00V and therefore the output voltage range V_{OUT} = -5.00V to +5.00V; see V_{OUT} and V_{IN}'s relationship in Figure 3.

The bottom part of Figure 5 is identical to that of module 1, whereas the top part produces the +5.00V reference voltage. R3, D3 (a 10V Zener diode) and C3, together with the buffer amplifier LM358P-1A, provide a 10.00V reference voltage from a +12V power supply. This 10.00V reference voltage is then divided by resistors R4 and R5 to obtain a +5.00V reference voltage. Next, 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, capable of sourcing up to 20mA.

Table 1 shows voltages for this module, with its prototype circuit board shown in Figure 7.

For proper operation make sure that R4 = R5.

Circuit calibration with S1 closed: By adjusting P1, ensure that when V_{IN} = 0.00V, V_{OUT} = -5.00V and, also, when V_{IN} = +5.00V, V_{OUT} = +5.00V. When S1 is open, there's no need for calibration. EW

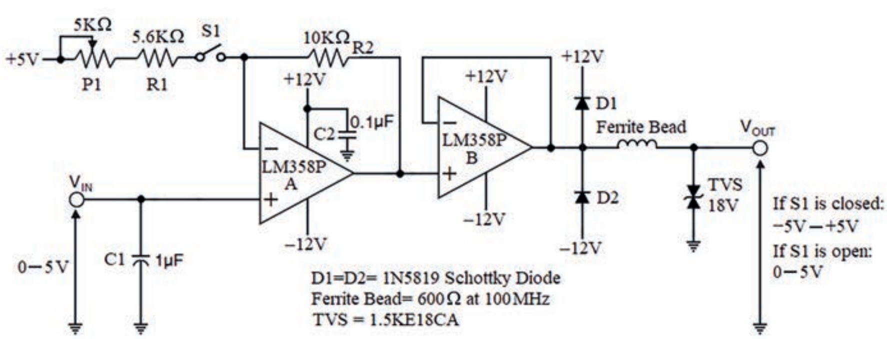

Figure 1: Circuit diagram of the analogue output module 1 for a 0-5V to -5V - +5V signal converter

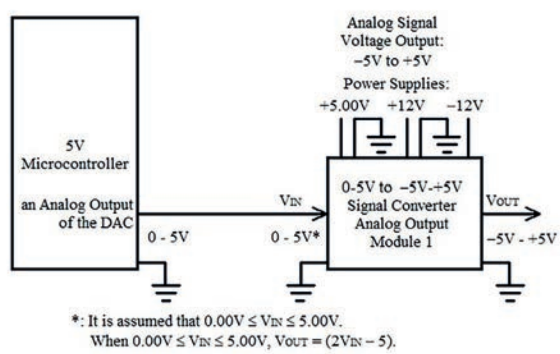

Figure 2: Connections of the analogue output module 1 for a 0-5V to -5V - +5V signal converter

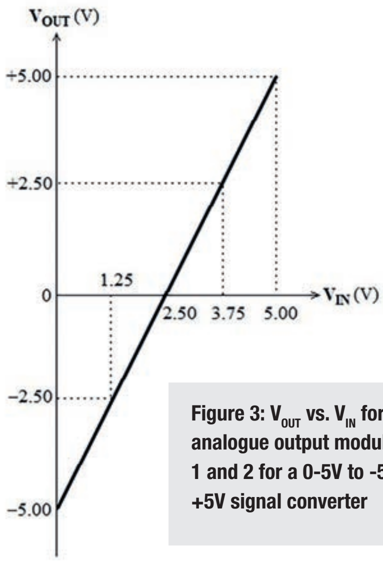

Figure 3: V_{OUT} vs. V_{IN} for analogue output modules 1 and 2 for a 0-5V to -5V - +5V signal converter

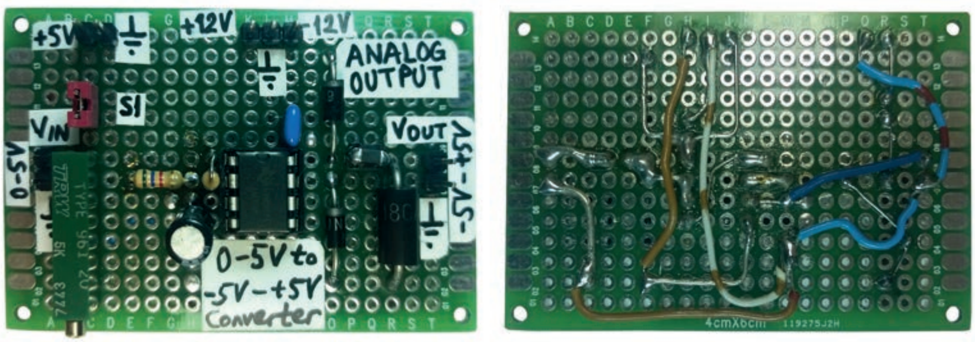

Figure 4: Analogue output module 1 for a 0-5V to -5V - +5V signal converter

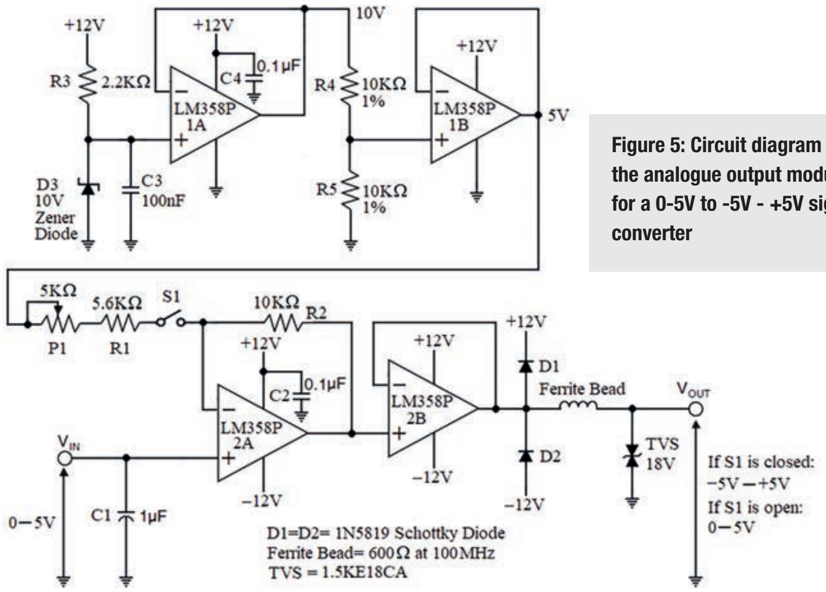

Figure 5: Circuit diagram of the analogue output module 2 for a 0-5V to -5V - +5V signal converter

V_{IN}(V)	V_{OUT}(V)
5.00	+5.00
..	..
4.50	+4.00
..	..
4.00	+3.00
..	..
3.75	+2.50
..	..
3.50	+2.00
..	..
3.00	+1.00
..	..
2.50	0.00
..	..
2.00	-1.00
..	..
1.50	-2.00
..	..
1.25	-2.50
..	..
1.00	-3.00
..	..
0.50	-4.00
..	..
0.00	-5.00

Table 1: Input and output voltages for analogue output modules 1 and 2 for a 0-5V to -5V - +5V signal converter, assuming $0.00V \le V_{IN} \le 5.00V$

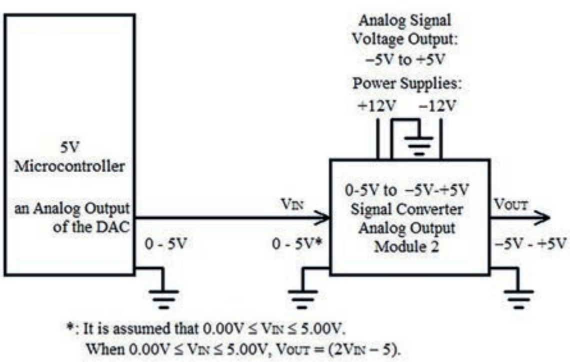

Figure 6: Analogue output module 2's connections to a 5V microcontroller

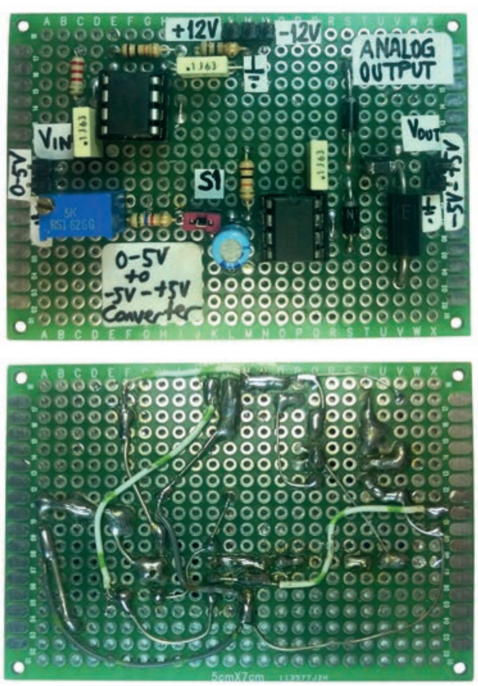

Figure 7: Analogue output module 2's prototype circuit board, top and bottom views