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Oscilloscopes and High Resolution: No Longer a Contradiction

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Optically-isolated analogue output modules for a 0-5V to –10V - +10V signal converter

By Professor Murat Uzam, Department of Electrical and Electronics Engineering, Yozgat Bozok University, Turkey

This month we will discuss two more optically-isolated output modules, this time for a 0-5V to –10V - +10V signal converter. Modules 1 and 2 provide voltages from –10V to +10V, requiring four DC power supplies (+5.00V, –12V, +12V and isolated +12V) for Module 1, and three DC power supplies (–12V, +12V, and isolated +12V) for Module 2.

Module 1

Figures 1 and 2 show the 0-5V to –10V - +10V signal converter that connects to the DAC output of a 5V microcontroller. The circuit contains the Positive Unipolar Photovoltaic Isolation Amplifier 3 (PUPIA3 – explained before), with an HCNR201 high-linearity analogue optocoupler for photovoltaic isolation. The circuit's input, to the left of HCNR201, is isolated from its output, at the right.

Becuase of its limited current drive capability, the buffer amplifier LM358P-1A (a voltage follower) is used on the DAC output. LM358P-1A's output is connected to PUPIA3's input.

Here, PUPIA3 consists of:

1. Input: R1, R2, LM358P-1B;
2. HCNR201;
3. Output: P1, R3, C3, LM358P-2A.

Provided the input voltage of PUPIA3 is limited to between 0.00V and 5.00V, its output will also be between 0.00V and 5.00V.

PUPIA3's output is connected to the non-inverting input of LM358P-3A. Jumper S1 (shown here as a switch for clarity) is used to select between 0-5V to 0-10V signal converter mode (S1 open), or 0-5V to –10V - +10V signal converter mode, when S1 is closed.

Here, S1 is closed, a setting used to level shift the unipolar 0-5V input signal to a bipolar –10V to +10V output. When $0.00V \le V_{IN} \le 5.00V$, the two operational amplifiers LM358P-3A and LM358P-3B, with bipolar supply voltages, provide this transfer function:

$$V_{OUT} = \left(1 + \frac{R6 + P3}{R7}\right)\left(\left(1 + \frac{R4 + P2}{R5}\right)V_{IN} - 5\right)$$

After adjusting the value of P2, we obtain R4 + P2 = R5, and after adjusting the value of P3, we obtain R6 + P3 = R7:

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

Dual series Schottky barrier diodes D1 and D2 divert any overcurrent coming from V_{OUT} to the positive or negative power supply rail. A ferrite bead is connected in series with the output path to add isolation and decoupling from high-frequency

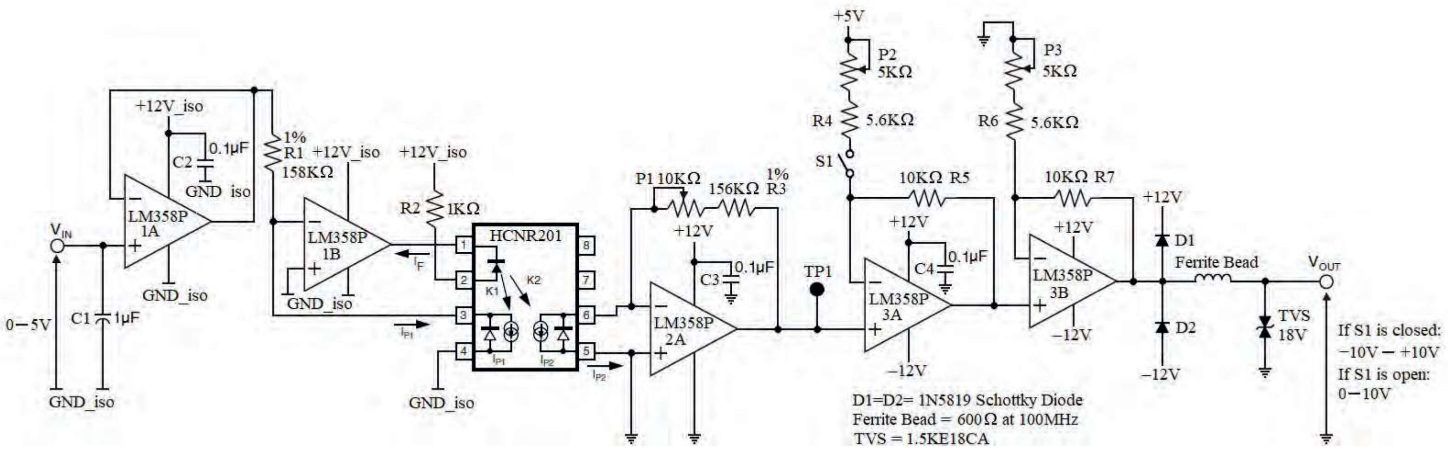


Figure 1: Module 1 circuit diagram

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
..	..

Table 1: Modules 1 and 2 example voltages, assuming $0.00V \le V_{IN} \le 5.00V$

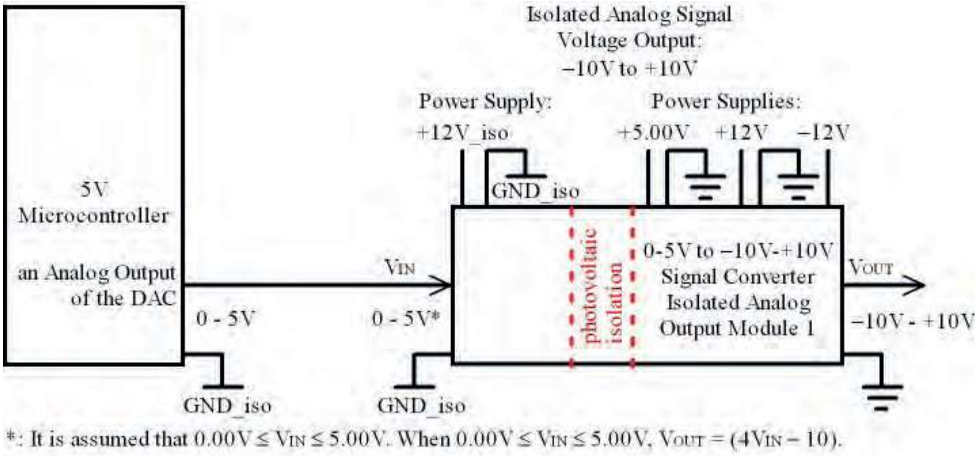


Figure 2: Module 1's connections

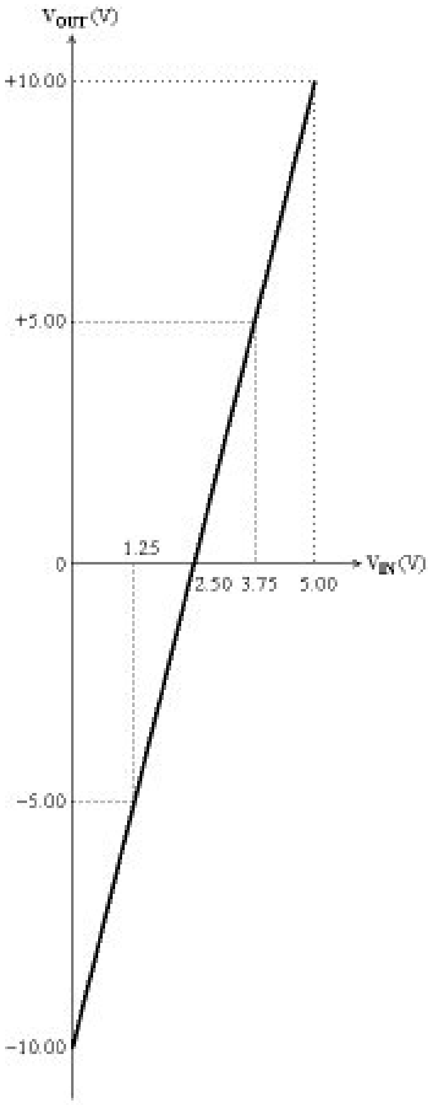
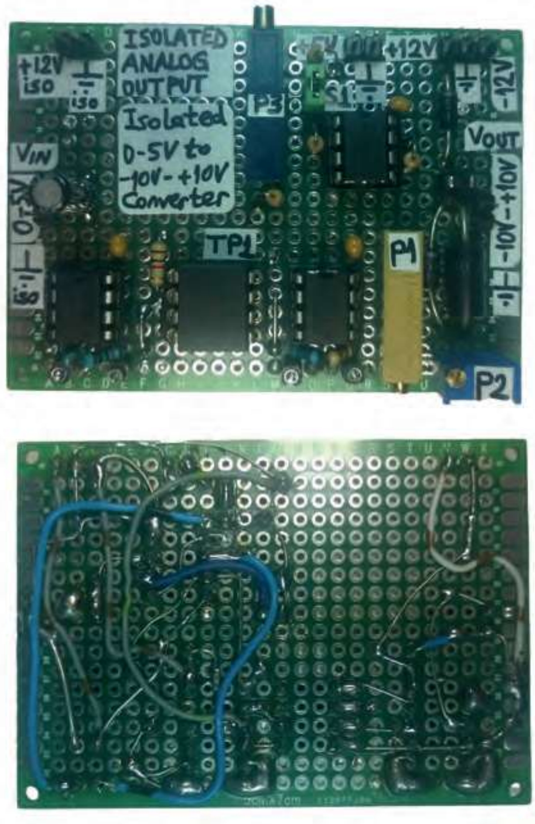


Figure 3: V_{OUT} vs. V_{IN} for Modules 1 and 2

Figure 4: Module 1's prototype board



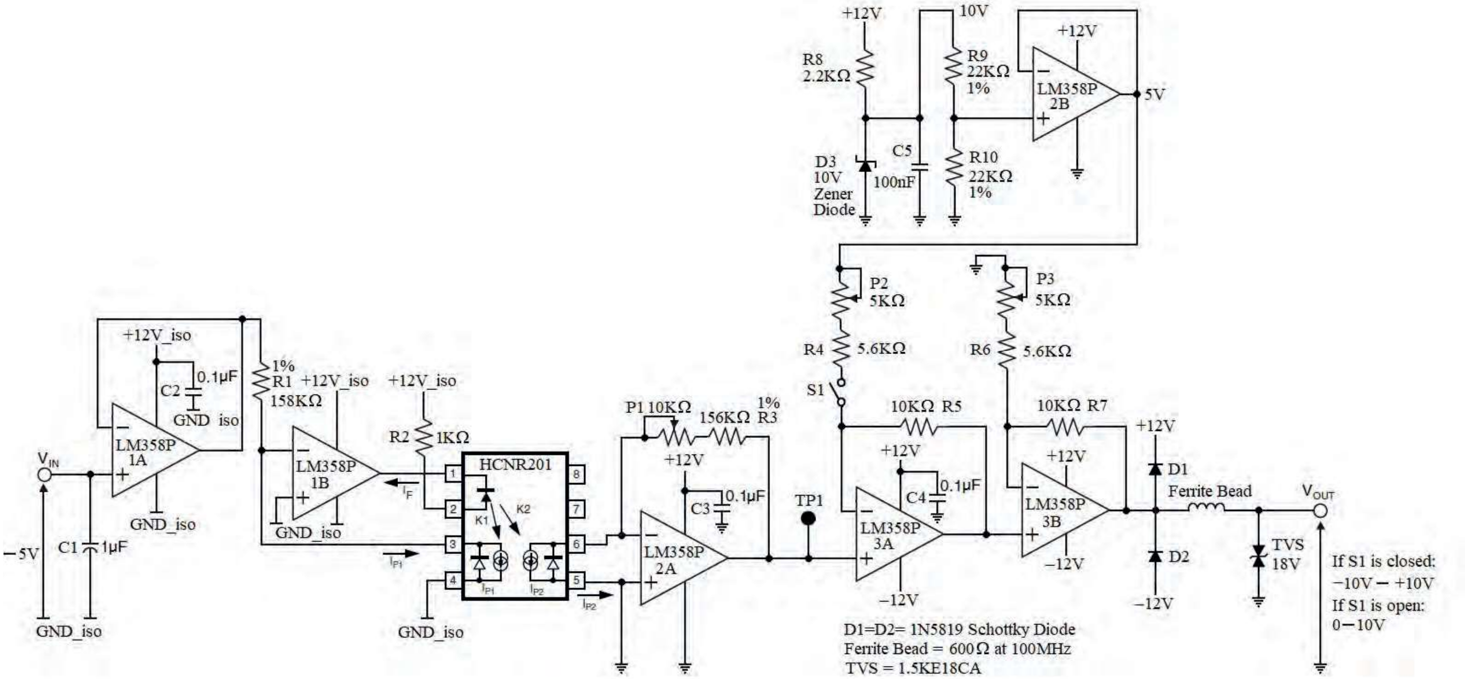
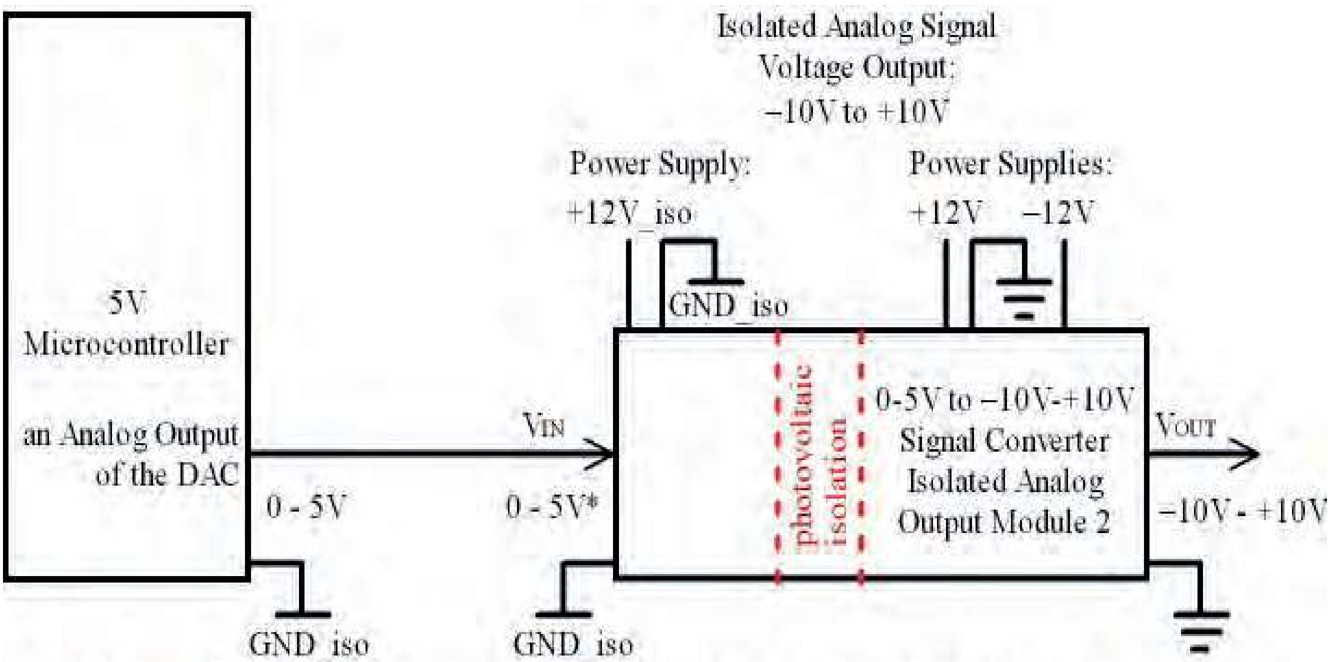


Figure 5: Module 2 circuit diagram



*: It is assumed that 0.00V ≤ VIN ≤ 5.00V. When 0.00V ≤ VIN ≤ 5.00V, VOUT = (4VIN − 10).

Figure 6: Module 2's connections

transient noises. A TVS (transient voltage suppressor) is used to filter out any transients coming from V_{OUT}.

This circuit is capable of supplying up to 20mA. Its input is powered by +12V, whereas its output by +5.00V, +12V and −12V isolated from its input.

When $0.00V \le V_{IN} \le 5.00V$, $V_{OUT} = 4V_{IN} - 10$. V_{IN} = 0-5V, therefore V_{OUT} = −10.00V to +10.00V; see Figure 3.

Table 1 provides some example voltages for this signal converter, with the circuit's prototype board shown in Figure 4.

To calibrate this circuit with S1 open:

1. Set V_{IN} to +5.00V and, then, by adjusting the value of P1, make V_{TP1} = +5.00V.
2. Set V_{IN} to +5.00V and then by adjusting P3 make V_{OUT} = +10.00V.

To calibrate the circuit with S1 closed:

1. Set V_{IN} to +5.00V and, by adjusting P1, make V_{TP1} = +5.00V.
2. Set V_{IN} to +5.00V and, by adjusting P3, make V_{OUT} = +10.00V.
3. Set V_{IN} to 0.00V and, by adjusting P2, make V_{OUT} = −10.00V.

Module 2

Figures 5, 6 and 7 show Module 2, with its connections to the DAC output of a 5V microcontroller. As with Module 1, this circuit is also PUPIA3 based, with a high-linearity analogue optocoupler (HCNR201) providing photovoltaic isolation.

Module 2 operates exactly the same way as Module 1, so it has all the same components, but with the addition of R8, D3 (10V Zener diode) and C5 to provide a 10.00V reference voltage from a +12V supply. This 10.00V reference voltage is then divided by resistors R9 and R10 to obtain a +5.00V reference voltage. This +5.00V is connected to the non-inverting input of buffer amplifier LM358P-2B, whose output is fixed at +5.00V and capable of sourcing up to 20mA.

Unlike Module 1, in Module 2 the circuit's output is powered with only +12V and −12V, isolated from the circuit's +12V input. For its proper operation, make R9 = R10.

To calibrate the module with S1 open:

1. Set V_{IN} to +5.00V and, by adjusting P1, make V_{TP1} = +5.00V.
2. Set V_{IN} to +5.00V and, by adjusting P3, make V_{OUT} = +10.00V.

To calibrate the circuit with S1 closed:

1. Set V_{IN} to +5.00V and, by adjusting P1, make V_{TP1} = +5.00V.
2. Set V_{IN} to +5.00V and, by adjusting P3, make V_{OUT} = +10.00V.
3. Set V_{IN} to 0.00V and, by adjusting P2, make V_{OUT} = −10.00V. EW

A ferrite bead is connected in series with the output path to add isolation and decoupling from high-frequency transient noises. A TVS (transient voltage suppressor) is used to filter out any transients coming from V_{OUT}

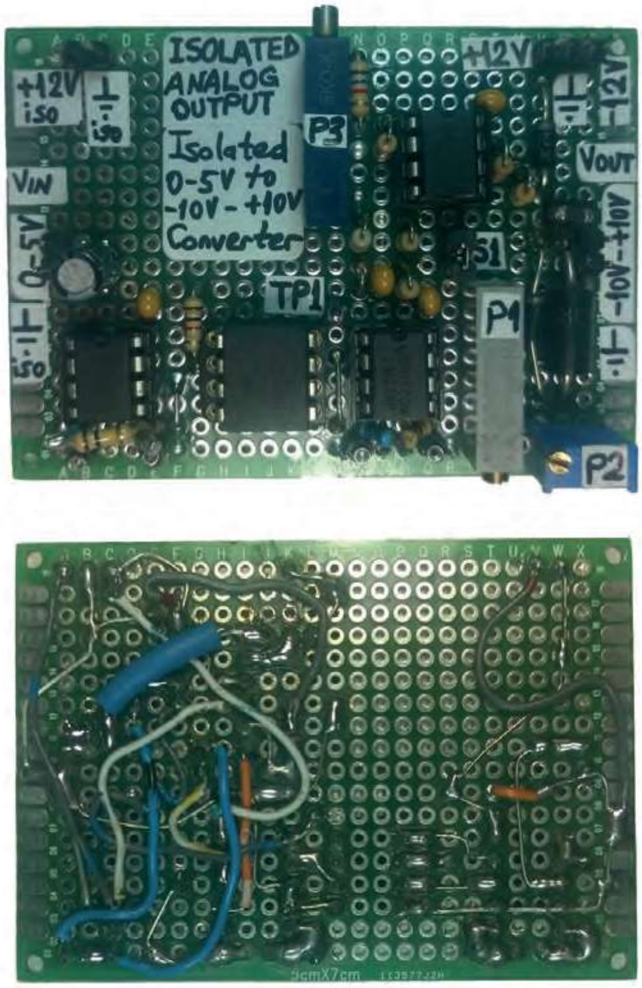


Figure 7: Module 2's prototype board