

2 Adder / Subtractor Circuit (Task 1a)

2.1 Requirements

A circuit is required with the following characteristics:

- It should have three input voltages: Input A, Input B and Input C
- The value of Input A should be multiplied by 0.1, i.e. divided by 10 (we will call this o/p A)
- The value of Input B should be multiplied by 0.2, i.e. divided by 5 (o/p B)
- The value of Input C should be multiplied by 0.5, i.e. divided by 2 (o/p C)
- There will be one output from the circuit: Output = o/p A + o/p B – o/p C

For an *ideal* op-amp the output voltage is calculated as follows: $V_{out} = -\frac{R_Y}{R_X} * V_{in}$. Therefore, if we know what output to input ratio is required we can calculate the ratio of R_Y to R_X (ignoring the change of sign):

Table 1: Amplification values for each input value

Input A	Input B	Input C
The ratio is 0.1 or $\frac{1}{10}$	The ratio is 0.2 or $\frac{1}{5}$	The ratio is 0.2 or $\frac{1}{2}$
$\frac{V_{out}}{V_{in}} = \frac{R_X}{R_Y}$ $\frac{1}{10} = \frac{R_X}{R_Y}$ $R_Y = R_X * 10$	$\frac{V_{out}}{V_{in}} = \frac{R_X}{R_Y}$ $\frac{1}{5} = \frac{R_X}{R_Y}$ $R_Y = R_X * 5$	$\frac{V_{out}}{V_{in}} = \frac{R_X}{R_Y}$ $\frac{1}{2} = \frac{R_X}{R_Y}$ $R_Y = R_X * 2$
If we chose an arbitrary value for R_X , say 1k Ω , then $R_Y = 1 * 10 = 10 \text{ k}\Omega$	$R_X = 1 \text{ k}\Omega$ $R_Y = 1 * 5 = 5 \text{ k}\Omega$	$R_X = 1 \text{ k}\Omega$ $R_Y = 1 * 2 = 2 \text{ k}\Omega$

To add two numbers (i.e. voltages) together we simply connect the wires together and the op-amp will amplify them according to the resistor ratios used. The output from the op-amp will be negative (i.e. inverted), so we need to pass the result through a second inverting op-amp to invert it again, thus correcting the sign.

Our circuit needs to perform the following arithmetic operation: $Output = (A + B) - C$. If we multiply both sides by -1 we get $-Output = -(A + B) + C$. The output from the first op-amp is $-(A + B)$. So if we add C to that output, and invert the result we are left with the required output result.

3.3 Actual Circuit

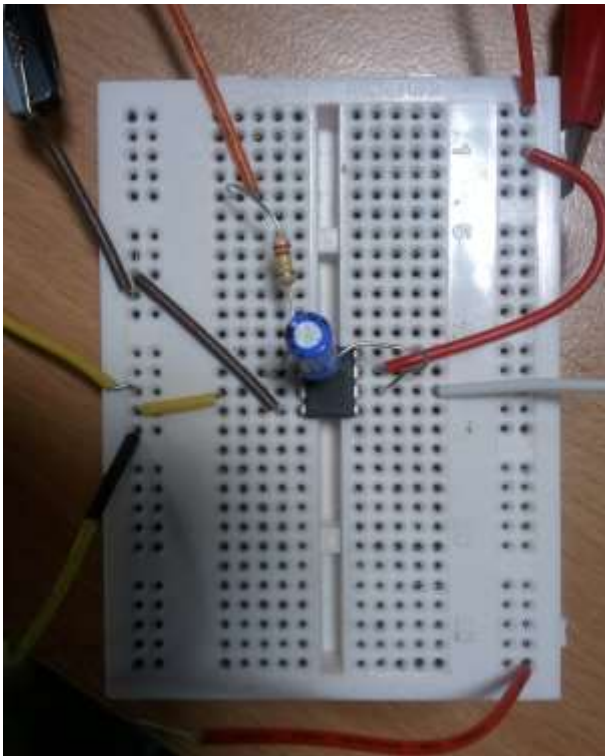


Figure 15: integrator circuit on breadboard



Figure 16: Power supply



Figure 17: Function generator producing the square wave input for the integrator

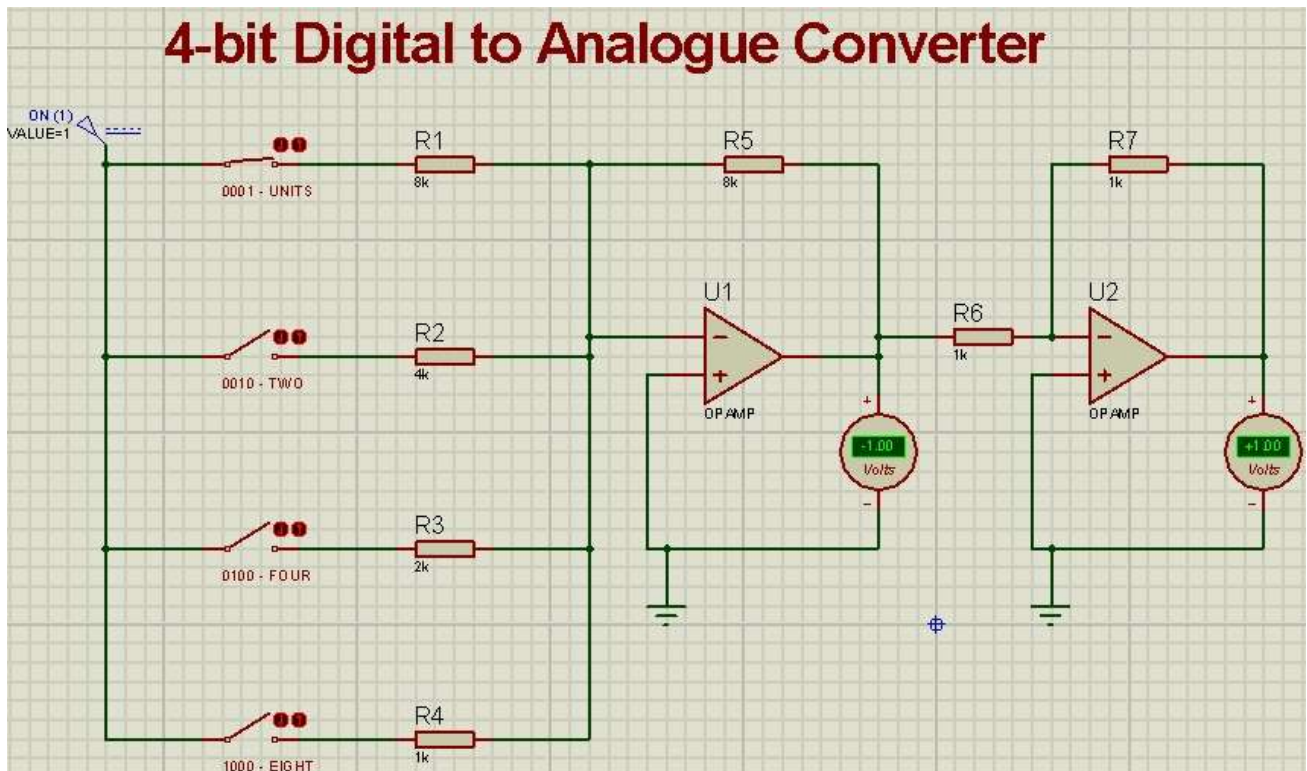


Figure 21: Input 0001, Output 1

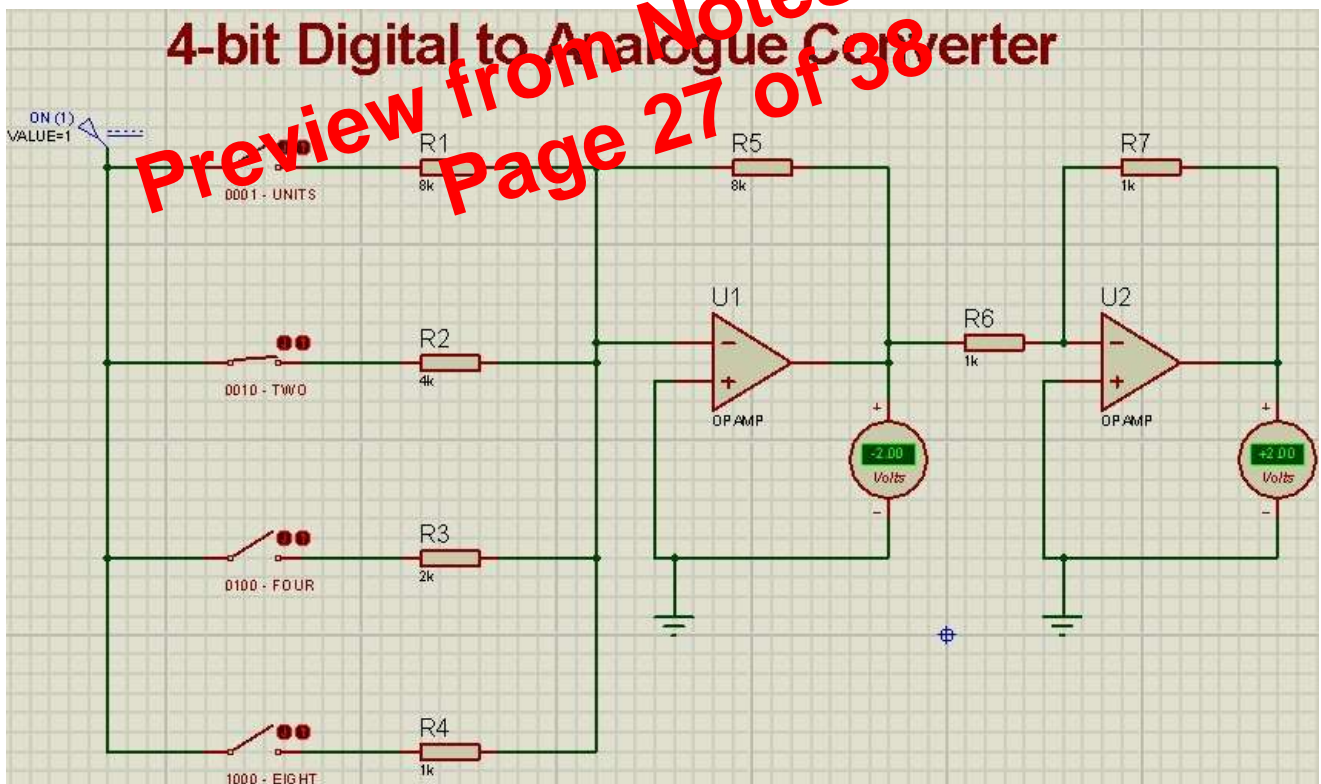


Figure 22: Input 0010, Output 2

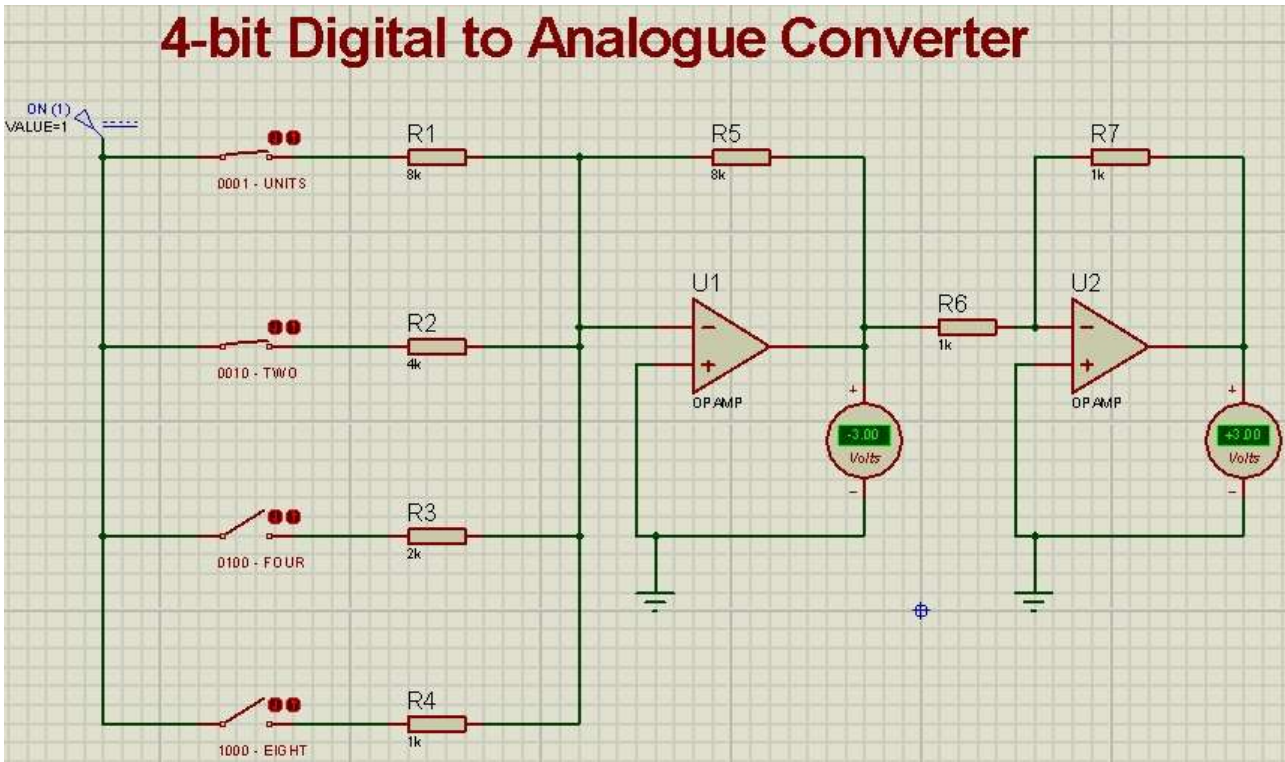


Figure 23: Input 0011, Output 3

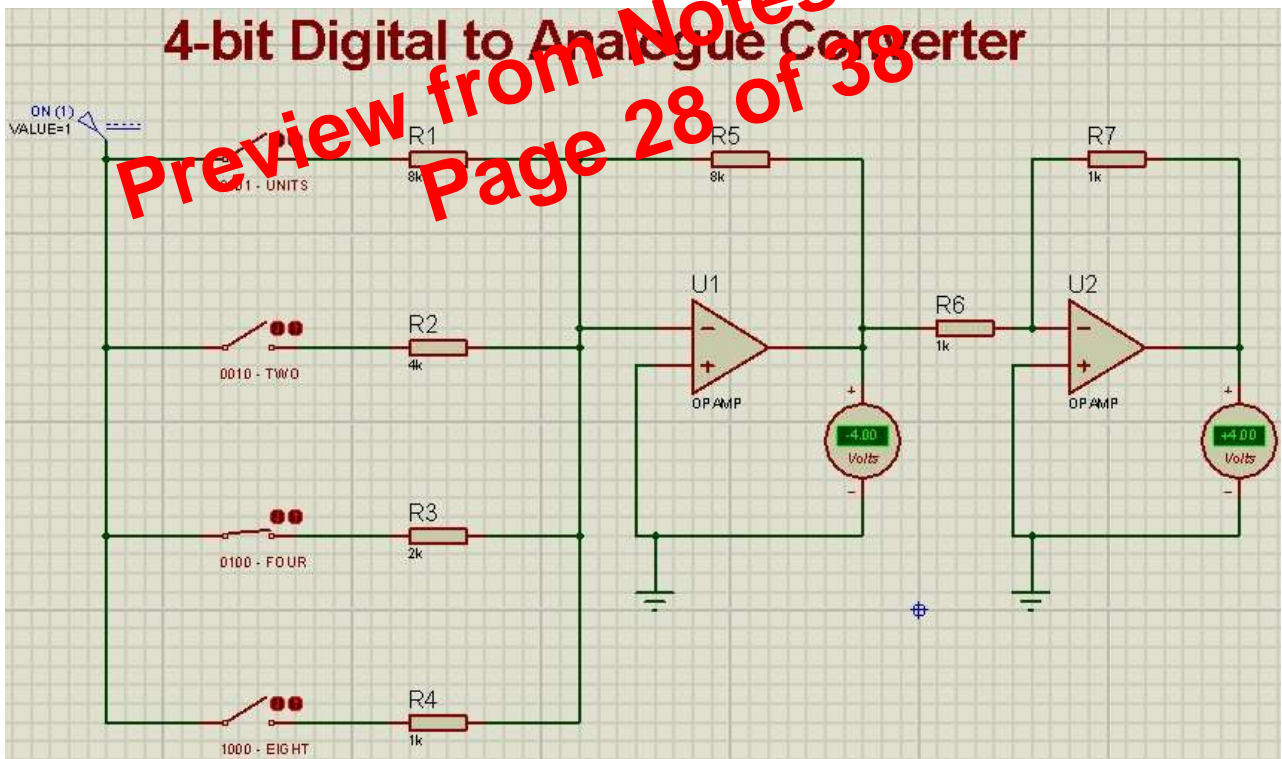


Figure 24: Input 0100, Output 4

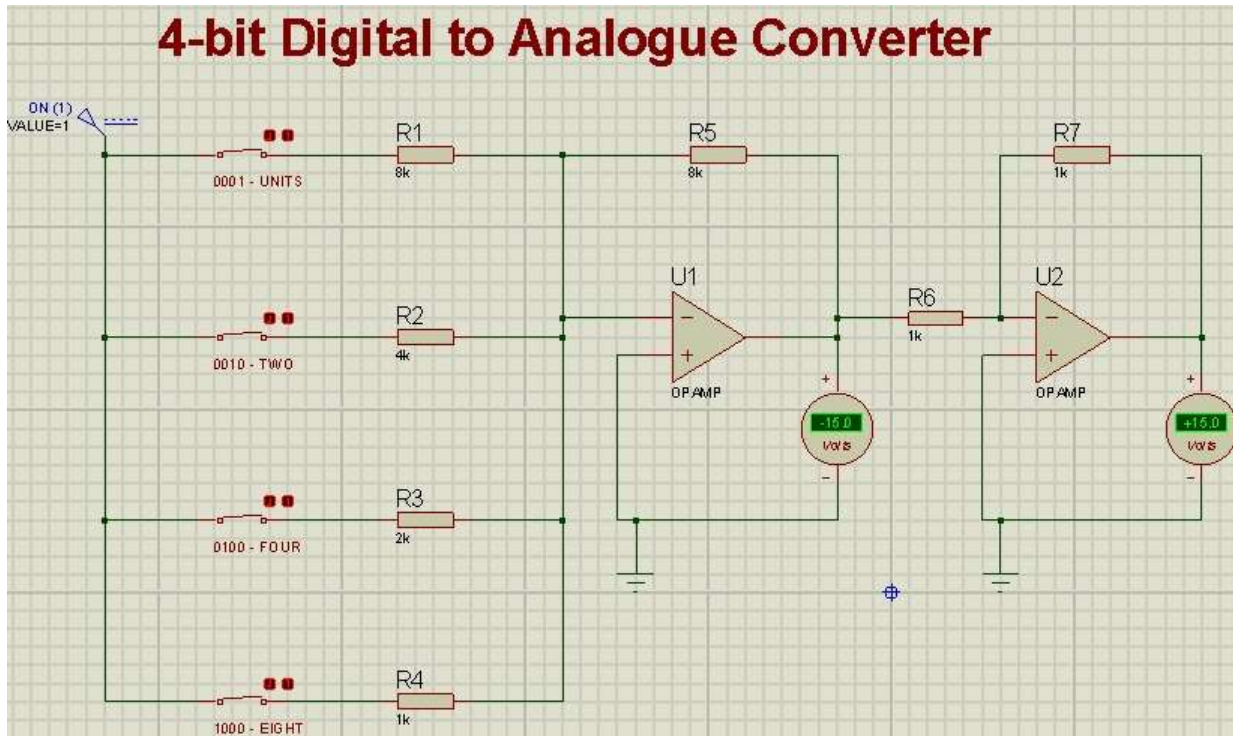


Figure 35: Input 1111, Output 15

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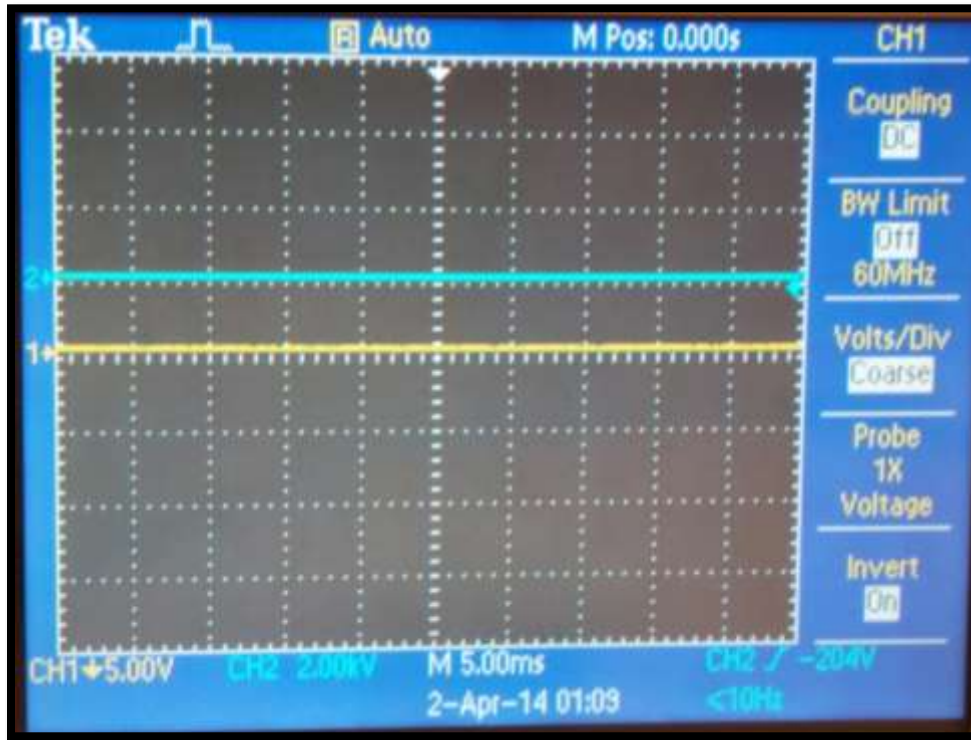


Figure 38: Oscilloscope showing input and output voltages

The values shown in Figure 38 differ from those in the simulator primarily because different input voltages were used. Had the voltage been the same, there would probably still show some slight difference:

- The supply voltage to the Op Amps was not exactly $\pm 12.0\text{V}$. (Actually $+12.0, -12.1\text{V}$.)
- The resistance of the wires may have affected the input ratios slightly.
- The calibration of the PSUs and oscilloscope may be out.