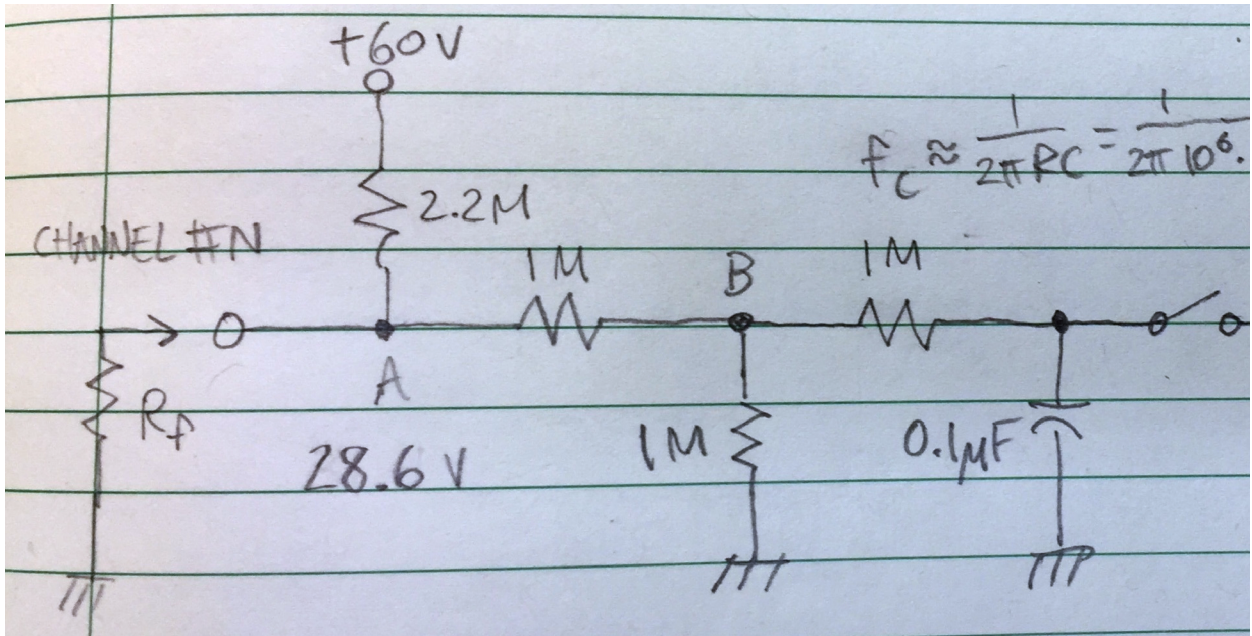


Ventana Ground Fault Board Analysis

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The DTEC Ground Fault Monitor and Water Alarm Circuit board has an input resistor network that produces an output voltage V_f at point B in the circuit proportional to ground-fault resistance R_f . See McGill's "general lab notebook" for equation derivation. Note that V_f is not the output of the circuit board—just the output of the input resistor network.



First find the voltage at point A in the input resistor network. This isn't part of our calculation of V_f , but tells us what voltage is being applied to the circuits being monitored.

$$V_a = 60 \frac{1 + 1}{2.2 + 1 + 1}$$

$$28.5714$$

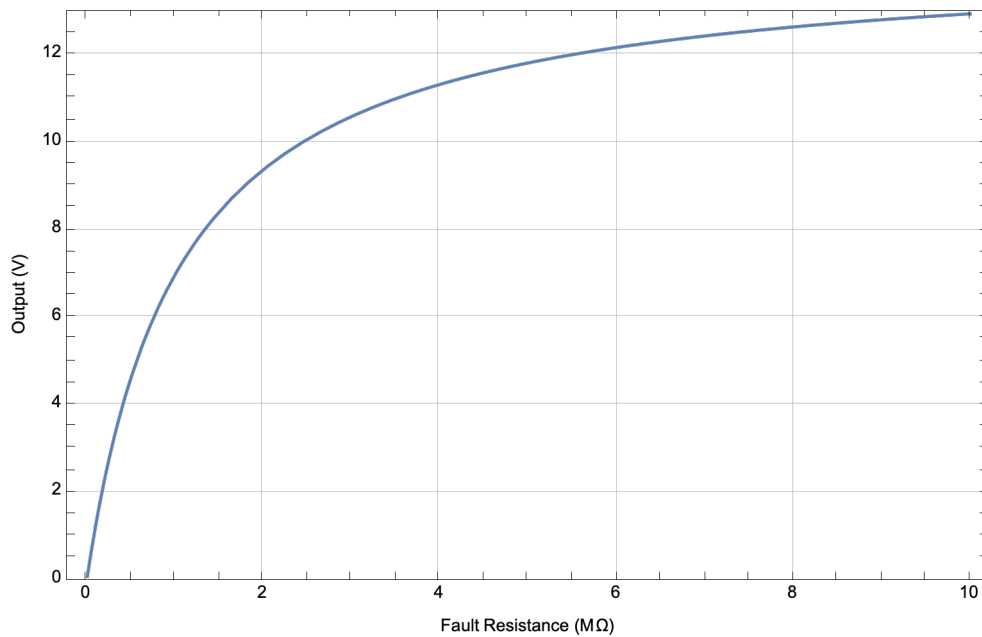
Note that the DTEC data sheet incorrectly lists this voltage as both 26.5 V and 25.6 V, but not 28.6 V.

Now find V_f as a function of the fault resistance R_f .

$$V_f = \frac{60}{2} \frac{\frac{R_f}{R_f + 2}}{2.2 + \frac{R_f}{R_f + 2}}$$

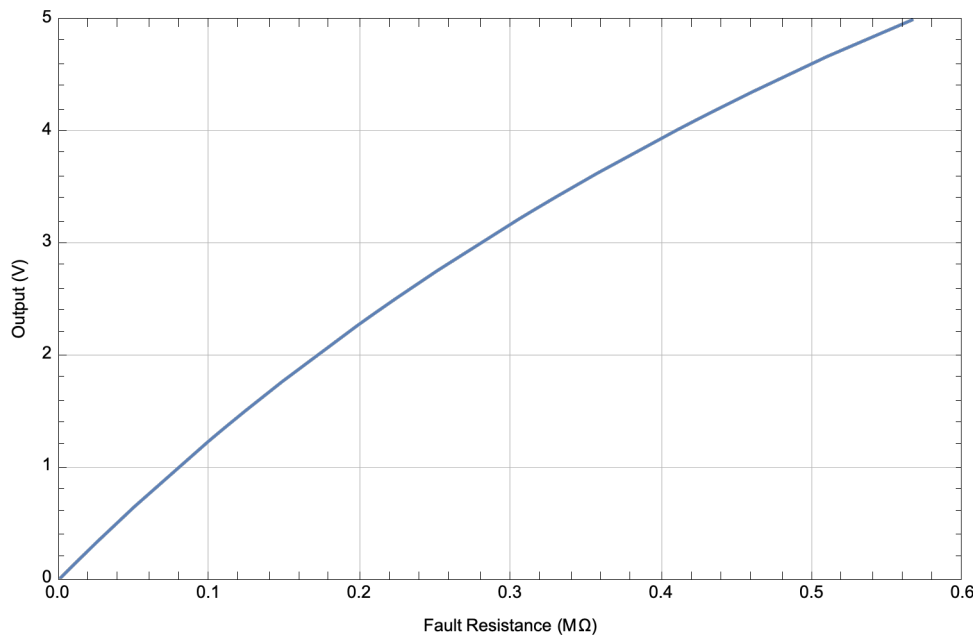
$$\frac{60 R_f}{(2 + R_f) \left(2.2 + \frac{2 R_f}{2 + R_f} \right)}$$

```
Plot[Vf, {Rf, 0.001, 10}, GridLines → Automatic, PlotRange → {Automatic, {0, 13}},
Frame → True, FrameLabel → {"Fault Resistance (MΩ)", "Output (V)"}]
```



Above is the output of the resistor network before the voltage goes through the buffer and isolation amps. The AD202K isolation amp input range is ± 5 V, so it will limit the max output voltage to 5 V and we'll be operating at the lowest end of the curve.

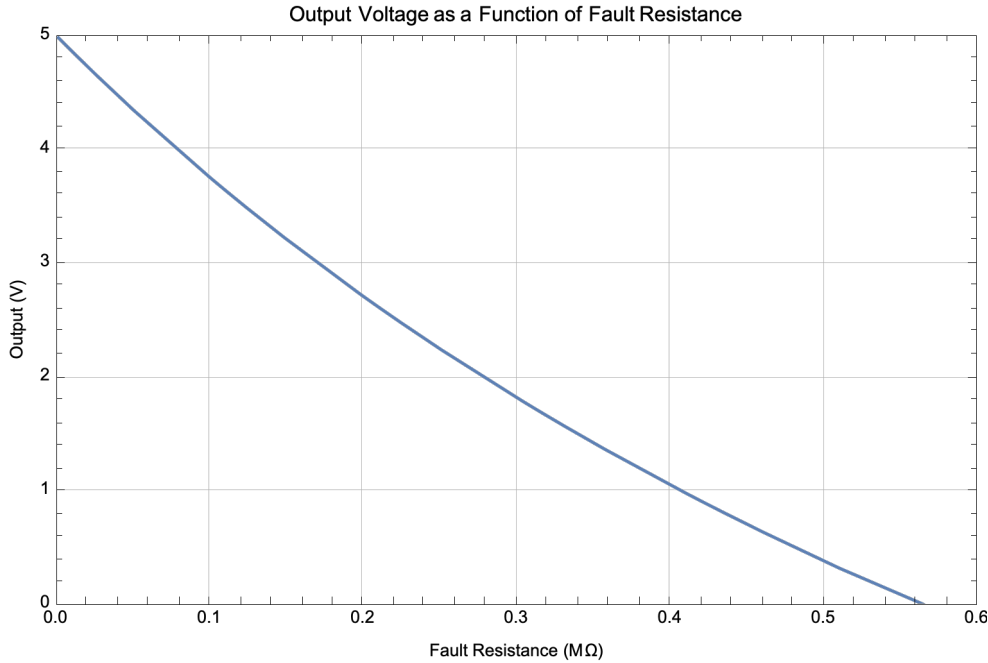
```
Plot[Vf, {Rf, 0.001, 10}, PlotRange → {{0, 0.6}, {0, 5}}, GridLines → Automatic,
Frame → True, FrameLabel → {"Fault Resistance (MΩ)", "Output (V)"}]
```



The AD202K isolation amp is set up as an inverting amplifier, so the output voltage actually drops as the fault resistance increases. It is only by adjusting the offset potentiometer P1 to produce a positive

offset of, say, +5 V that the board output can remain positive.

```
Plot[-Vf + 5, {Rf, 0.001, 10}, PlotRange -> {{0, 0.6}, {0, 5}}, GridLines -> Automatic,
  Frame -> True, FrameLabel -> {"Fault Resistance (MΩ)", "Output (V)"},
  PlotLabel -> "Output Voltage as a Function of Fault Resistance"]
```



According to the board setup procedure from DTEC, the board should produce 5.00 V with a 600 kΩ fault (offset adjustment P1), and 0.62 V with a 5 MΩ fault (gain adjustment P2). From these numbers we can find the required offset and gain.

To get a sense of what's going on, find the output of the input resistor network when the fault is 600 kΩ (0.6 MΩ), and 5 MΩ.

$$V_{0p6} = \frac{60}{2} \frac{\frac{0.6 \times 2}{0.6 + 2}}{2.2 + \frac{0.6 \times 2}{0.6 + 2}}$$

$$5.20231$$

$$V_5 = \frac{60}{2} \frac{\frac{5 \times 2}{5 + 2}}{2.2 + \frac{5 \times 2}{5 + 2}}$$

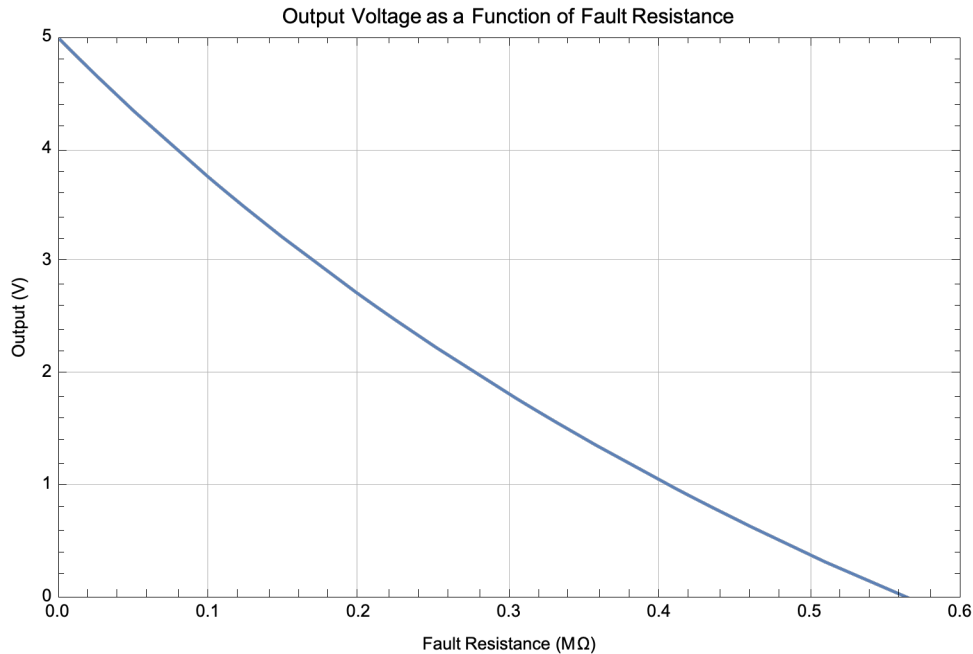
$$11.811$$

Define a new function that defines the board output voltage in terms of the offset voltage V_{off} , the gain G , and the fault resistance R_f .

$$V_{out}[V_{off}_-, G_-, R_f_-] := V_{off} + G \frac{\frac{R_f}{2}}{2.2 + \frac{R_f}{2}}$$

We should be able to reproduce the third plot on this page if we set $V_{off} = 5$ and $G = -1$.

```
Plot[Vout[5, -1, Rf], {Rf, 0.001, 10},
  PlotRange -> {{0, 0.6}, {0, 5}}, GridLines -> Automatic, Frame -> True,
  FrameLabel -> {"Fault Resistance (MΩ)", "Output (V)"},
  PlotLabel -> "Output Voltage as a Function of Fault Resistance"]
```



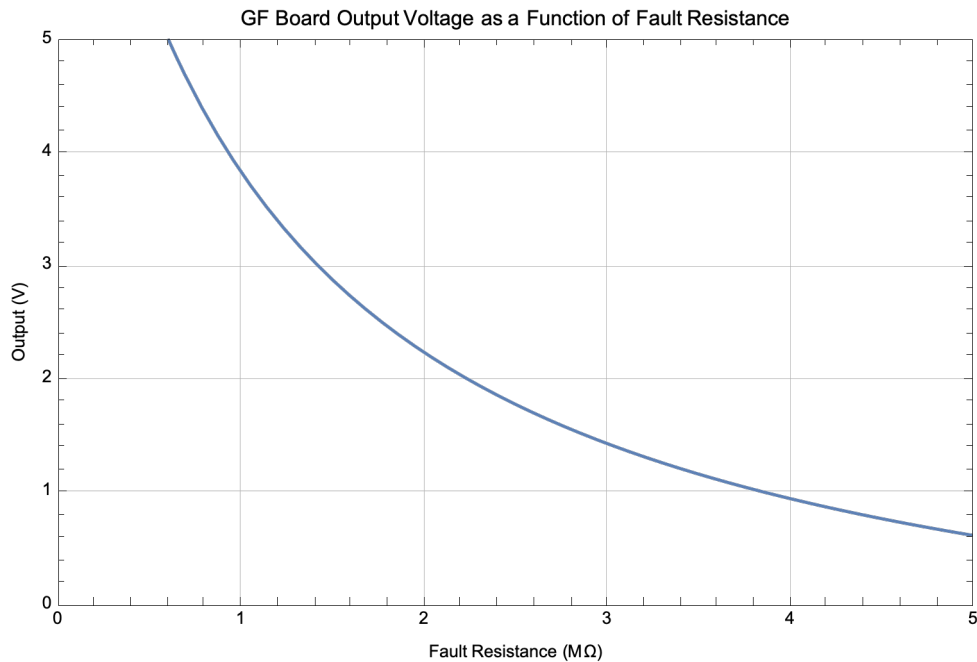
Find the offset and gain that produces the calibration values.

```
soln = NSolve[{Vout[Voff, G, 0.6] == 5, Vout[Voff, G, 5] == 0.62}, {Voff, G}]
{{Voff -> 8.44789, G -> -0.662762}}
```

Note that the offset is more than 5 V and the gain is less than -1, so the graphs above don't represent what the board actually outputs. To correct this, we can define a new output function that incorporates the calculated offset and gain values.

$$Vout[Rf_] := Voff + G \frac{60}{2} \frac{\frac{Rf}{2}}{2.2 + \frac{Rf}{2}} /. First@soln$$

```
plt = Plot[Vout[Rf], {Rf, 0.6, 5}, PlotRange → {{0, 5}, {0, 5}}, GridLines → Automatic,
  Frame → True, FrameLabel → {"Fault Resistance (MΩ)", "Output (V)"},
  PlotLabel → "GF Board Output Voltage as a Function of Fault Resistance"]
```



Input the measured voltages produced by test resistances connected to a properly adjusted board (data provided by Duane Thompson).

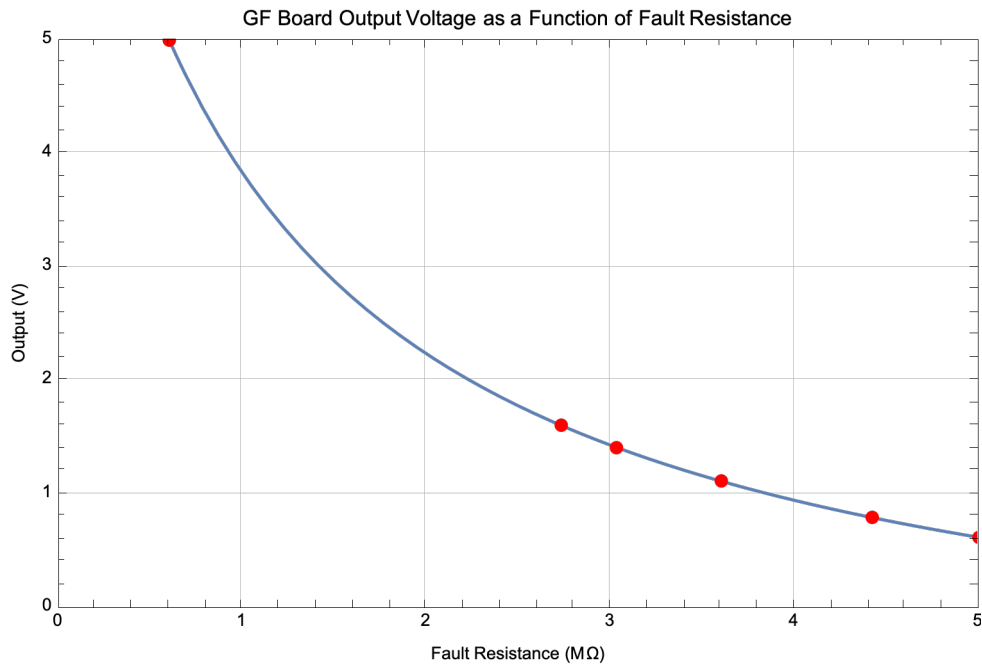
```
drtDat = {{0.6, 5.000}, {2.73, 1.608},
  {3.03, 1.410}, {3.6, 1.117}, {4.42, 0.796}, {5, 0.620}};
```

```
Grid[drtDat, Frame → All]
```

0.6	5.
2.73	1.608
3.03	1.41
3.6	1.117
4.42	0.796
5	0.62

Plot the measured data on top of the calculated output curve.

```
Show[{{plt, Graphics[{{Red, PointSize[Large], Point[drtDat]}]}]}
```



Find the test fault resistor that will produce a 2.5 V output (50% fault).

```
NSolve[Vout[Rf] == 2.5, Rf] // First
```

```
{Rf -> 1.77014}
```

This is 1.77 MΩ.

Find the inverse function that outputs resistance given the voltage and make a table that tells you what resistance produced the fault percentage shown on the *Ventana* GUI.

```
soln
```

```
{{Voff -> 8.44789, G -> -0.662762}}
```

```
soln2 = NSolve[Vout == 8.44789 + -0.662762 *  $\frac{60}{2} \frac{\frac{Rf^2}{Rf+2}}{2.2 + \frac{Rf^2}{Rf+2}}$ , Rf] // First
```

```
{Rf -> -  $\frac{7.33333 (-844789. + 100000. Vout)}{714097. + 700000. Vout}$ }
```

```

table = Grid[Prepend[
  Table[{NumberForm[Vout, {2, 1}], Round[20 Vout], NumberForm[soln2[[1, 2]], {3, 2}]}],
  {Vout, 0, 5, 0.5}], {"Vout (V)", "% FS", "Fault (M $\Omega$ )"}], Frame  $\rightarrow$  All]

```

Vout (V)	% FS	Fault (M Ω)
0.0	0	8.68
0.5	10	5.48
1.0	20	3.86
1.5	30	2.89
2.0	40	2.24
2.5	50	1.77
3.0	60	1.42
3.5	70	1.15
4.0	80	0.93
4.5	90	0.75
5.0	100	0.60

```

csv = First@table

```

```

{{Vout (V), % FS, Fault (M $\Omega$ )}, {0.0, 0, 8.68}, {0.5, 10, 5.48}, {1.0, 20, 3.86},
 {1.5, 30, 2.89}, {2.0, 40, 2.24}, {2.5, 50, 1.77}, {3.0, 60, 1.42},
 {3.5, 70, 1.15}, {4.0, 80, 0.93}, {4.5, 90, 0.75}, {5.0, 100, 0.60}}

```

```

Export["VentanaGFTable.csv", csv]

```

VentanaGFTable.csv