Short guide through the Wheatstone Bridge soft;
partially translated from "Redals", Rocket Data Acquisition Software available at LK pages, written by Libor Ulcak.

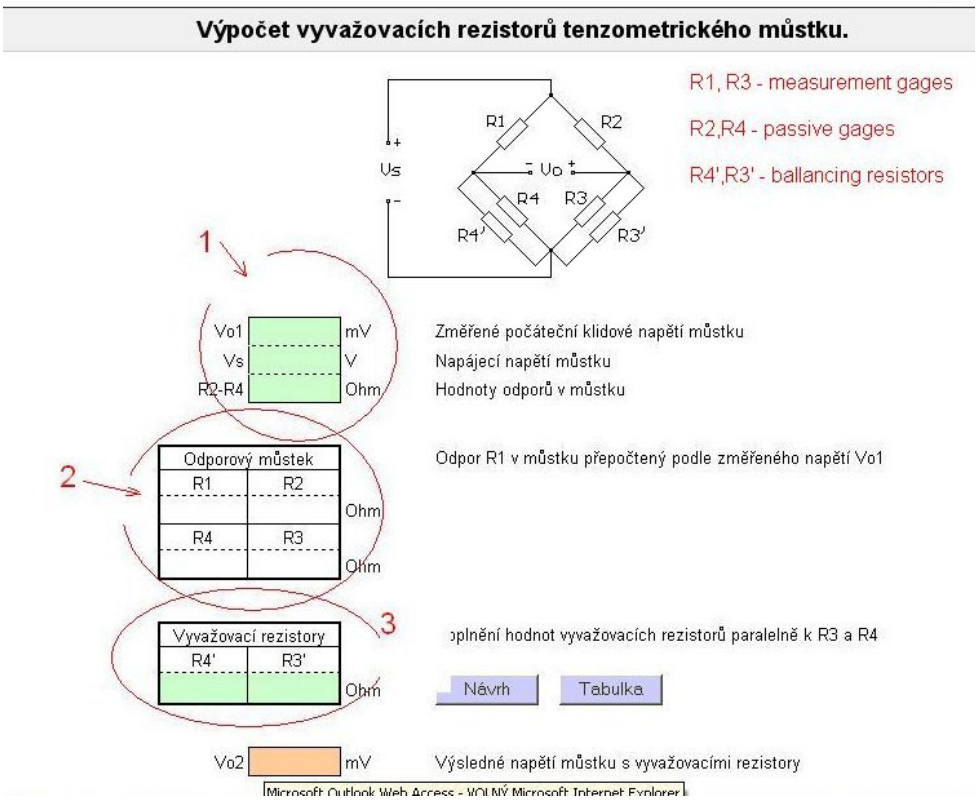
- First. Try please English version of the "Wheatstone B.". I rewrote that yesterday. Simply put into the one folder, click on the "vyvazeni mustku". You have to allow pop-up windows and JavaScript. On my computer it works. The spreadsheet is simple; all cells are described. R1 & R3 are stressed gages; R2 & R4 are passive ones. R3' & R4' are balancing resistors connected in parallel to R3 & R4; they balancing the bridge. If this JavaScript works, jump over the description of the Czech version straightly to section describing practice of connection.

- If this doesn't work for any reason, you have to go through the LK website; its in Czech, but need just input values into three cells and push two buttons; that's it.

  In this case, you follow the link:

  { HYPERLINK "http://raketky.ebox.cz/redals/kompm/index.htm" }

  The title is "Calculation of the balancing resistors". On the picture is standard Wheatstone bridge; important note is, that measurement resistors [gages] are the R1 & R3; the R2 & R4 ale the passive stems of the bridge. R3' & R4' are connected in parallel to the R3 & R4 as shown on the picture [you can anyway print the English version even if it doesn't work an use it like a master; all cells and rows are on the same place on page]:



Do not mess them together as I already did; it was helpful for me to make a small sketch which one is which one on the load cell. Other variables are [in green three cells], marked as **#1**:

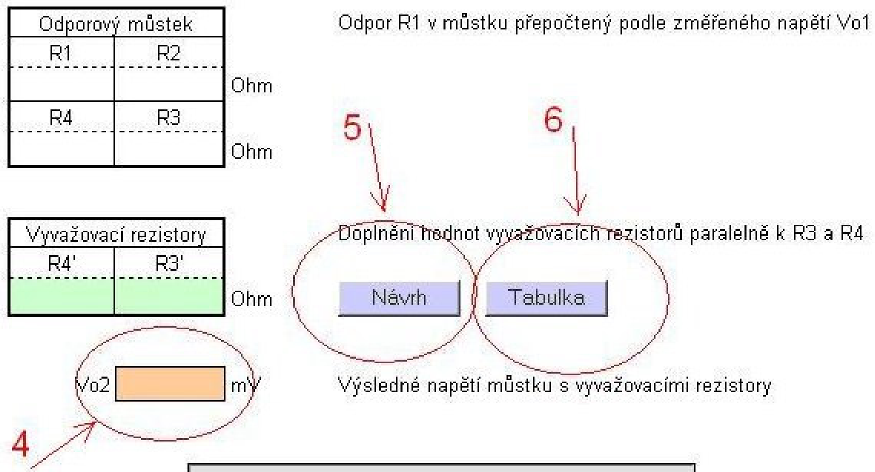
V01 [mV] ....output voltage of the bridge without ANY load simultaneously powered by main voltage "Vs".
Vs [V]............. main supply, stabilized
R2-R4 ....are values of the resistors in the bridge; in our case 350

- So, link the load cell up>
- Check the main supply voltage [at least 3 valid digits] >
- Without touching the sensor measure the output voltage of the bridge [at least 3 valid digits, usually 5-15mV. A usual electronic multimeter on the range of 200mV is accurate enough. Remark both values. Perform few times subsequently. The values shouldn't change at all>
- Enter measured values into the 3 green cells in following order: output voltage of the bridge [mV]; main supply voltage [V]; resistivity of the gage - 350. Note: do not mess the polarity of the output signal [mV]. I may become negative; it this case you have simply write -12.6 [for instance]. It switches values of balancing resistors between themselves. Correct polarity is shown on the picture of the bridge.

Example>>>>>>>>>

Main supply voltage of the bridge [in my case] is 5.00V. My load cell consists from (4) 350-ohm strain gages. Output voltage of the bridge without any load is -12.6mV [compare to the polarity as shown on picture of the bridge, important]. For measurement a usual multimeter has been used. I'm entering (3) values into the (3) green cells in following order: -12>5>350. I do not need press any enter; script automatically writes into the white table 350 ohm into white (3) cells [the table in the middle, marked by **#2**]; the left upper writes 346.4897; it is recalculated value of the last one resistor for balanced condition; you don't need that. However, you need following table described "Vyvažovací rezistory" {Balancing resistors}, described as our old know ones R4' & R3'. To get their values, press button "Návrh" {proposal} **#5** on the following picture. Under the R4'value appears 33000ohm [33kOhm] and on the R3' 750000 ohms [750kOhm], marked on the picture as **#3**. The calculated remanent voltage in balanced stage is in the orange box, marked as Vo2 [mV], in our example 0.00446mV, marked by **#4**.

End of example>>>>>>>>



Tabulka vyráběných hodnot rezistorů v řadě E24			
1.0	1.8	3.3	5.6
1.1	2.0	3.6	6.2
1.2	2.2	3.9	6.8
1.3	2.4	4.3	7.5
1.5	2.7	4.7	8.2
1.6	3.0	5.1	9.1

- OK. Now, you need to get these exact values; they are picked out from the E24 resistor value line; not every shop has them all. To get some approximate other values, press button "Tabulka" {Table}, marked by **#6** ; It appears table with combination of several values from the E24 line; each combination shows a residual voltage on the bridge also. Try getting the combination with the smallest output voltage.

“Solid phase” approach

- Now, you going to buy them. Prior that, you need to take some decision here; first; you may buy SMD resistors from any size-line [there are several of them, at least 5 as far as I know, maybe more], usually E24 is carried on just in 204 or 102 line [the largest components, relatively easy to handle. Each resistor is marked by his value].

- IMPORTANT - you need resistors of 1% of tolerance; usually 5% is not accurate enough.

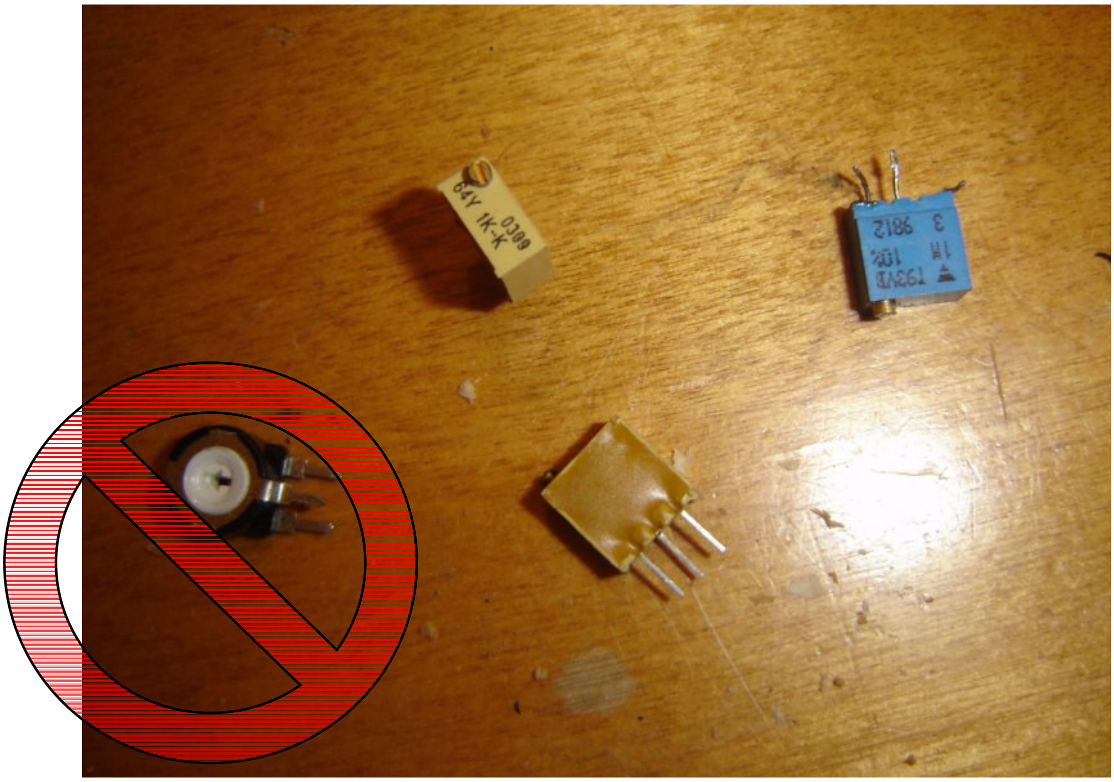
- If you can get them, you won. Now, you have to just solder them directly on connecting pads; the bridge now should work. Unfortunately, in my case it never did for a simple reason: Any touching of leading wires [leading to the gages] even the lightest one, any change of their position; even encapsulating by liquid silicon adhesive - it changes balancing of the bridge. I have never seen anything so sensitive before...Just kidding around. If you had already enough patience to read this thing even here, you can finish it. So, for this reason, if you want to use this technique,

- I STRONGLY RECCOMEND ENCAPSULATE THE SENSOR FIRST!!!

- . Leave free connection pads and let adhesive fully cure [I’m using acid-based silicon sealant]. You don't need touch the sensors anyway. After, you may check the output voltage again [Ouuuugh - it is different again...]. So, in this method, you have to encapsulate the sensor first, leaving freely accessible just all (4) wires of the bridge. The measurement of the output voltage is follows, buying required values of the SMD-resistors and soldering directly on connection pad on the sensor. After new checking of the voltage [still is the chance change anything] encapsulate them too. Sensor is finished. It is very compact, perfect thermal match, already balanced [almost...] etc. Great.

The "adjustable" approach

- Now, if you prefer to get a chance balance the bridge anytime you want, even subcontracts the weight of the engine exactly on zero, you need adjustable balancers [exactly spoken just one]. Procedure is the same, with few exceptions. You are going to get same values of the resistors; but the smaller one [in our case 33kOhms] has to be replaced by solid resistor for instance 31kOhm [or whatsoever is in the line];



connected in series with ACCURATE adjustable resistor [see picture],

- in my case about 5 kOhm. Both of them makes now original 33kOhms together [general rule> the variable part of the resistivity = value of the adjustable resistor = suppose to be somewhere about 10% of total resistance required in this stem of the bridge]

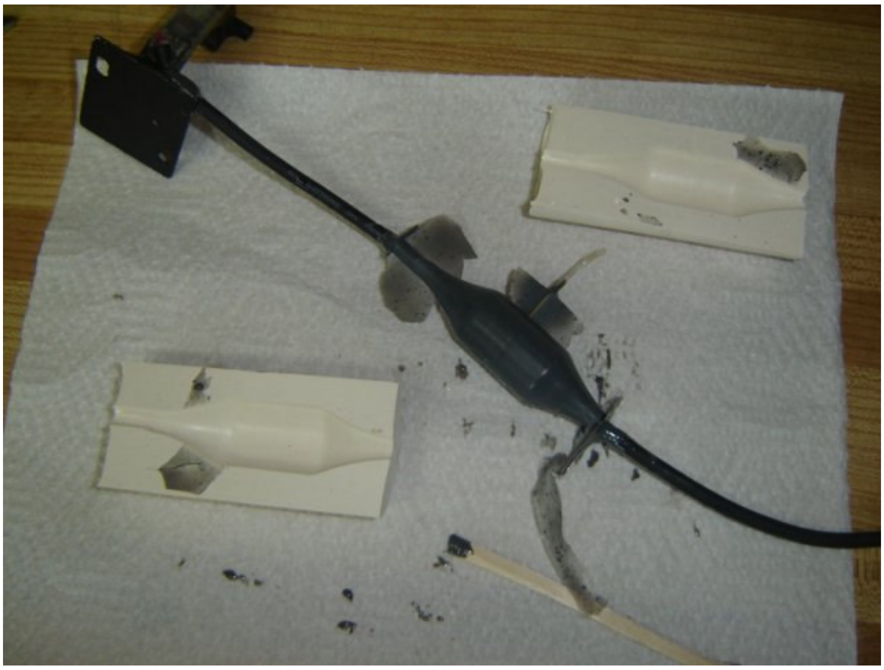
- DO NOT TRY USE REGULAR 270 deg. type, it can't work; it is too sensitive; even light touch changes everything. On picture is marked by red circle.

- As you can realize, the optimum value of the summary resistivity is somewhere around the middle of value of the adjustable resistor; it means bridge suppose to be balanced somewhere in the middle of the resistor run [important; you have some backup on both sides] It is usually 10-run adjustable precise plastic encapsulated adjustable resistor - I do not know exact translation - I'm sure you do. See picture for the appearance]. Shortly; you need good-quality component here [price could be about 1-2 bucks/pc]. In my particular case, from maximum 4096 input values [10 bit resolution, I can read it in RECON application, microcomputer design; it has something like oscilloscope screen; you may see the load in the real time. The same way will work Dataq.] I'm capable to setup zero from -300 to +300 approximately; the sensor has sensitivity 20lbs at 4096 [at full range]; therefore I'm capable setup the zero load from approx -1,5 to +1,5 lbs, which is just enough to eliminate weight of the engine. Ingenious.

- However, this kind of "resistor sparrow nest" you cannot apply directly on the sensor [it needs at least relatively big trim, approx 1x1x0.5 cm; you need setup it by tiny screwdriver which is dangerous around the sensors, etc]. Ones you going to move the balancing resistors out from the sensor, there is no need to make them so small; so a usually metal-oxide resistor can be used. There is valid the same rule as before - as exact values as you can; however instead of tiny SMD's which are usually carried on just in few main values and in special shops only, usual 1/4Watt or 1/8W metal oxides in 1% tolerance [important, NO CARBON RESISTORS, they have different thermal coefficient]. Metal oxides using the same materials as the SMD's, they are just larger] you can buy everywhere. If not, you can file them down on the exact value you need [an old technique of sanding of the resistive layer; you need to buy the nearest LOWER value; by slow and painful sanding - watch your fingers - you may get required value almost exactly. Few attempts will be necessary.] They are larger in size; easier to handle; therefore is better and safer to move them out from the sensor; the easiest place for them is the cable.

- I'm attaching few pictures how does it look after encapsulating; inside are just two main resistors calculated by this spreadsheet [and I have to be honest, checked and replaced against by slightly different values about 10-times]. Finally, inside is the trim also; the moving shaft has been insulated against the encapsulating material [epoxy, see picture] by short piece of shrink tube of small diameter; it has to be tight around the cover of the trim.

- Picture shows, how the resistors are encapsulated inside the silicon mould; instead of the mould I'll send you fiberglass casings for covers. You just have to put the resistors inside, seal by adhesive tape and along one cable inject adhesive inside. To make sure, the cables cannot be pulled out, I'm securing them by tightly twisted tie-straps, secured by crazy-glue against surface of the cable. Few threads of thick twisted cotton yard secured crazy glue would work too.



- Light greasing will help release and pullout the shrink tube [marked by red arrow on the picture] down from the shaft after the adhesive is fully cured. What remains, is completely encapsulated set of balancers, accessible by tiny hole leading just to the shaft of trim.

- Great solution with one exception - these trims are not watertight; so you have to be careful in rain, etc. But to this time, it is the best think here I have ever seen; and you bet I'm crazy perfectionist [and as I would say you too...]....

Good Luck.....

Roman Lev

Written for Richard Nakka, with using of original Recon/Redals calculating spreadsheet originally from LK & Libor Ulcak.

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