INSTRUCTION MANUAL

VIBRATING WIRE SURFACE STRAIN GAGE

Model SM-5A

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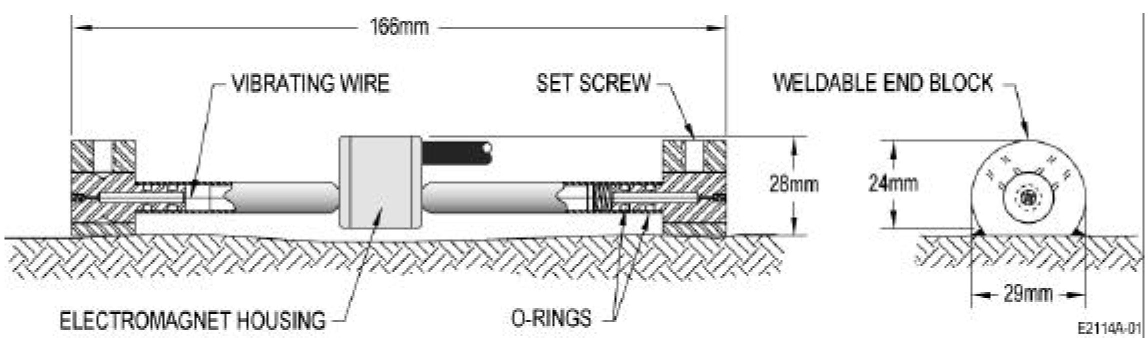
1 DESCRIPTION

The SM-5A strain gage is intended primarily for long-term strain change measurements on steel structures such as bridges, piles, arches, joists and prefabricated tunnel linings. It can also be used to monitor strain changes on concrete or rock surfaces using mounting blocks grouted or embedded in the surface.

The SM-5A consists of a length of high strength wire clamped at its extremities into two ends blocks. The wire is enclosed within a stainless steel tube sealed to the end blocks at both ends by double O rings. The gages are equipped with a spring that pre-tensions the wire. This enables the gage to be read without pulling on the wire manually. A removable electromagnet assembly fits on a construction at the center of the stainless steel tube. A thermistor is incorporated in the electromagnet assembly. In use, the end blocks are secured into two mounting blocks attached to the structure under study. Changes in length between the two mounting blocks modify the tension in the wire and consequently the resonant frequency. The digital readouts generate voltage pulses at various frequencies in the electromagnet, forcing the wire to oscillate. The oscillations generate AC voltages in the coil. The readout selects the frequency corresponding to the peak voltage generated, that being the resonant frequency of the wire. The readout will then display either the period or the linearized value in microstrains.

The relevant dimensions of the SM-5A vibrating wire surface strain gage attached to its mounting blocks are shown below.



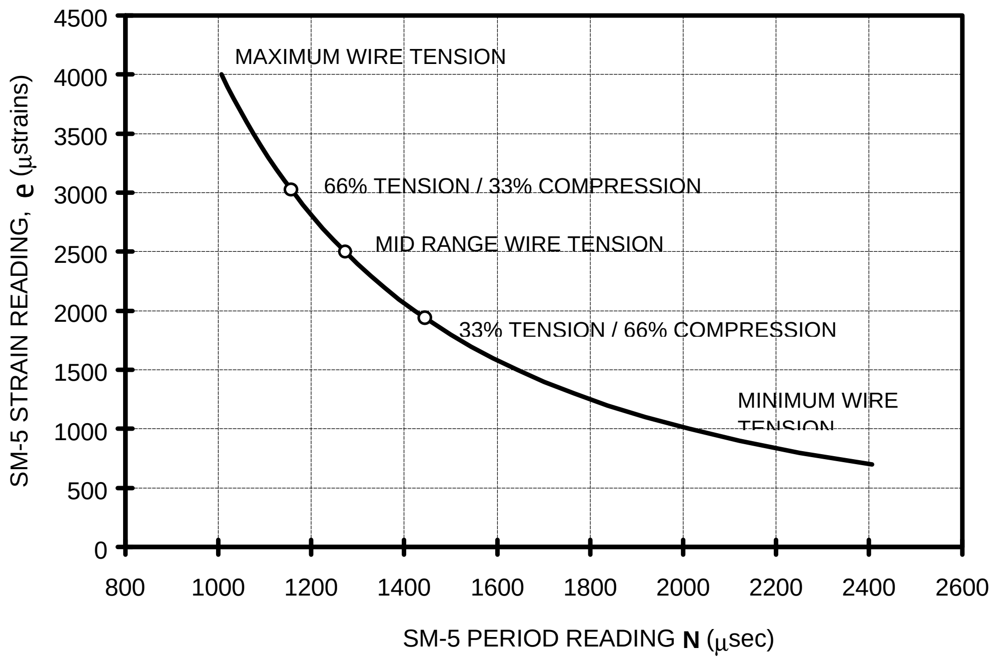
SM-5A pretensioned vibrating wire strain gage description and dimensions

To mount the gage on steel structures, the mounting blocks are set onto a spacer bar (described below) to provide the required spacing before they are welded to the structure. After welding, the spacer bar is then removed and replaced by an actual gage with a separate electromagnet assembly mounted over the gage to excite the gage and measure the response. If necessary, changes in the wire tension are carried out by pulling slightly on the tube. At the required tension, the end blocks are firmly clamped into the mounting blocks. The mounting blocks can also be bolted to the steel structure or, in the case of rock or concrete structures, grouted into shallow holes.

1.1 STRAIN RANGE

The nominal strain range of the SM-5A strain gage is 3 000 microstrains.

Figure below is a plot showing a typical strain range of the SM-5A gage with the NORMAL reading in µsecs shown plotted against the LINEAR reading in µstrains.



SM-5A strain range vs period

1.2 READOUTS

Several types of vibrating wire gage readouts can be utilized to read the SM-5A, including models SENSLOG, MB-6T, MB-6TL, and PALMETO VW.

2 INSTALLATION PROCEDURE

SM-5A gages are supplied fully sealed with the electromagnet assembly separate and the wire pretensioned. The SM-5A coil/magnet assembly also contains a thermistor which is read using the MB-6T readout.

It is suggested that a preliminary check of both the vibrating wire and the thermistor be carried out to verify the gage lead cable and readout.

Connect the wire leads to the readout box as follows:

IRC-41A	MB-6T Leads
Red	Wire HI
Black	Wire LO
Green	Thermistor HI
White	Thermistor LO
Shield	Shield

A complete description of the readout procedure is contained in the MB-6T or MB-6TL instruction manuals.

In all cases the gage should not be operated or checked at values lying outside the range shown in graphic above.

The initial uninstalled ***N*** reading of the pretensioned gages should lie within 1,200 to 1,300 microseconds which corresponds approximately to the mid-range of the gage. At the time of installation, the initial setting can be changed to suit the magnitude and direction of the expected change in strain.

The correct resistance readings between the conductors in the lead cable are:

<table>
<tr><th>Leads</th><th>Resistance</th></tr>
<tr><td>Black</td><td rowspan="2">140 ±10 ohms</td></tr>
<tr><td>Red</td></tr>
<tr><td>Green</td><td rowspan="2">3000 ohms at 25°C (77°F)
(varies with temperature)</td></tr>
<tr><td>White</td></tr>
</table>

If the correct resistance is not obtained, check for faulty connections or possible damage to the cable. If required, consult ROCTEST TELEMAC for repair or replacement.

2.1 ATTACHMENT OF MOUNTING BLOCKS

The SM-5A gage is attached to mounting blocks which can be fastened to the surface to be studied by a variety of methods. For steelworks, welding is recommended.

2.1.1 WELDING ONTO METAL SURFACES

Welding is the standard technique for mounting the SM-5A strain gages. To weld mounting blocks directly to steelworks, mount the blocks onto a spacer bar to ensure correct placement.

The two mounting blocks are placed over the ends of a spacer bar. An aluminum spacing block is then used to provide the correct spacing and orientation of the end blocks while the set screws in the anchor blocks are tightened, as illustrated in Figure below. Set screws should be tightened only moderately to avoid deforming the spacer bar.

When the set screws are tight, the mounting blocks are held firmly against the surface to which they are to be welded. First, lightly tack weld all four outside edges, avoiding excessive heat, and then firmly weld in place in the sequence shown in Figure below. Do not weld the outside ends of the mounting block

Allow the end blocks and spacer bar to cool. Loosen the set screws and slide the spacer bar out. Tap the blocks slightly before installing the gage.

2.1.2 BOLTING TO STEELWORKS

Special mounting blocks can be bolted to structural steelworks by single bolts welded onto the mounting blocks and tightened from the underside of the steelworks. Special jigs are supplied to ensure correct hole spacing.

2.1.3 FASTENING TO ROCK OR CONCRETE SURFACES

It is best to place the mounting blocks in the concrete before it sets. Mounting blocks for placement in concrete are equipped with short lengths of reinforcing steel bar.

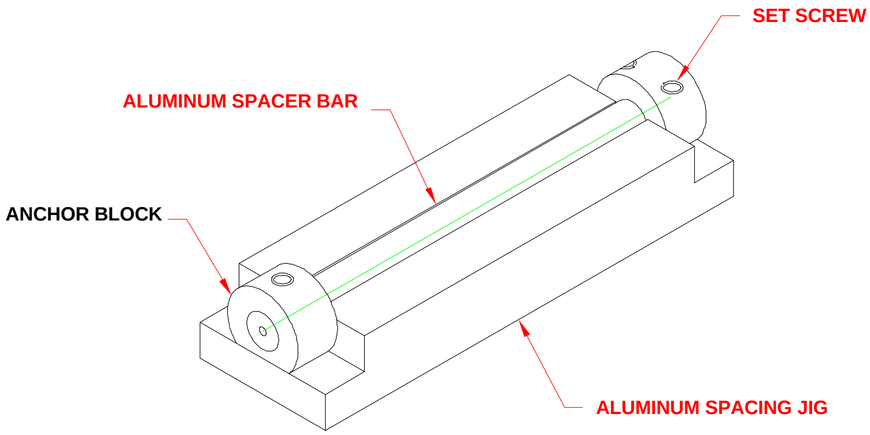
Where this is not possible, such as in rock, shallow holes can be drilled into the rock and the rebar mounting blocks, grouted in the holes using cement or cold setting epoxy resin.

To ensure correct spacing, the same jig as described for the welding sequence is used to set the anchors on the spacer bar.

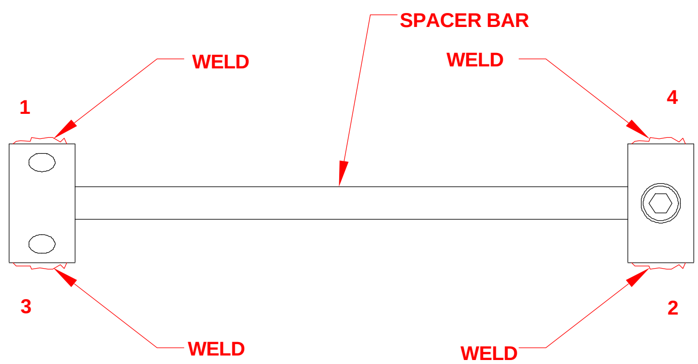
2.1.4 EPOXY BONDING

Under certain circumstances, it may not be feasible to use any of the techniques mentioned above to attach the mounting blocks, in which case bonding may be considered. The gage places a maximum 3.2 kgf on the anchors, so bonding using cold setting epoxy resins is a practical technique.

Weldable mounting blocks may be epoxied to any types of surfaces (metallic, concrete, rock, etc.) using the positioning jigs described above to set the mounting blocks correctly. The surface must be prepared in accordance with the epoxy instructions. A good bond will only be attained if the surfaces are clean, dry and sound (free from flakes). The mounting blocks must be degreased using acetone (or an equivalent) and sanded to remove the cadmium plating on the lower surface. Weights or clamps may be used to hold the blocks in place until the epoxy has set.



Anchor block being positioned on the spacer bar



Welding sequence for the anchor blocks

2.2 GAGE INSTALLATION

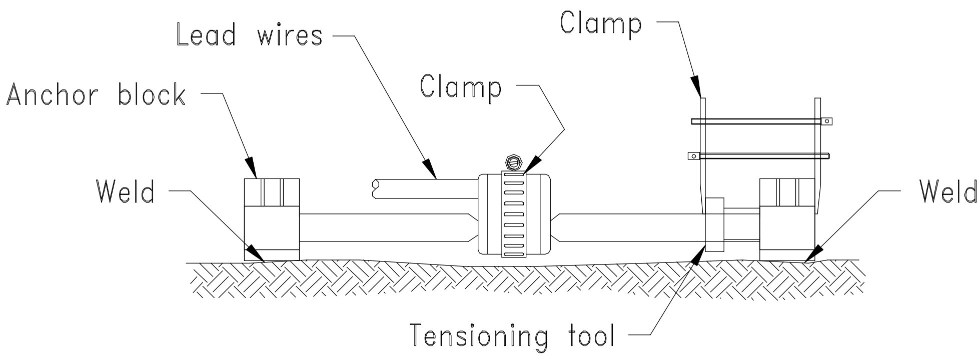
After the mounting blocks have been set in place, the strain gage is slid in from one end. One gage end block has a V-groove. This end must be located in the anchor block with the single set screw. The single set screw has a conical point which fits in the end block groove. The coil/magnet assembly is supplied in two halves that snap in place about the crimped section of the gage body. The thinner section goes on the underside of the gage body up against the structure. The thin section must be set under the gage body before the gage is slid into final position in the second end block.

1. Slide the gage, plain end block forward into the singe set screw mounting block. Stop half way and place the thin half of the coil/magnet assembly housing under the gage body. Continue to advance the gage until the groove on the end block is located under the set screw. Tighten down the screw hard.

2. Place the single piece electromagnet assembly or the remaining half of the two part assembly over the gage and fasten it in position with the hose clamp. Connect the cable to the readout unit.

3. If the tensioning tool is used, place the tool over the gage as illustrated below. The SM-5A is already adjusted at mid-range and, to change the setting, a light squeezing pressure applied at the end of the tool will lower the reading when read in 'NORMAL' mode and, similarly, relaxing the pressure will increase the reading. The initial reading will depend upon whether or not tensile or compressive strains are expected. If in doubt, set the initial reading to mid-range.

4. Once a reading has been selected, tighten down the set screws on the remaining mounting block. The reading may shift ± 50 units during tightening. Re-adjust if necessary.



SM-5A installation procedure

2.3 GAGE AND LEAD WIRE PROTECTION

The amount of protection depends on the type of installation and the environmental conditions. ROCTEST TELEMAC supplies a variety of accessories for this purpose. Please consult a factory representative to discuss particular applications.

Gages can be protected by cover plates that bolt over the top of the gage. Studs may be tapped directly into the work surface, or they may be glued, grouted or welded to the surface. The studs pass through holes in the cover plate which is then held in place by nuts. Studs should not be positioned within 15 cm of the strain gage, nor should cover plates be tightened down hard as this may induce non-uniform strains.

It is usual to run the leads from different gages to a central measurement station, such as the SENSLOG Data Acquisition System, and to connect them to terminal boxes for easy reading. Where required, a conduit should be provided to protect the lead wires, particularly if shotcreting is to be used.

3 MB-6T READINGS

The vibrating wire strain gage is set to an initial tension during installation. This initial value must be subtracted from subsequent readings to determine the strain change in the surface under study. To read the SM-5A gage, follow the instructions given in the MB-6T or MB-6TL instruction manuals.

The readout units display two readings: the **NORMAL** mode reading (N value) and the **LINEAR** mode reading (L value).

3.1 NORMAL READINGS (N)

The change in strain in the surface under study on which the SM-5A is mounted is given by the following formula:

$$\Delta\varepsilon \quad = \quad \varepsilon_1 - \varepsilon_0 \quad = \quad K \times 10^9 \left[\frac{1}{N_1^2} - \frac{1}{N_0^2} \right]$$

where:	*De*	=	Strain change in µstrains in the surface under study
	K	=	Gage Constant = 4.0624
	N_0	=	Initial reading in the **NORMAL** mode (in µsec)
	N_1	=	Current reading in the **NORMAL** mode (in µsec)
	e_1	=	Current strain corresponding to N_1
	e_0	=	Current strain corresponding to N_0 .

3.2 LINEAR READINGS (L)

To determine the strain change in the instrumented structure from **LINEAR** readings, the following equation is applied:

$$\Delta\varepsilon \quad = \quad (L_1 - L_0)$$

where:	*De*	=	Strain change in µstrains in the structure
	L_0	=	Initial reading in **LINEAR** units
	L_1	=	Current reading in **LINEAR** units.

Decreasing ***L*** values correspond to a negative *De* and are equivalent to a contraction of the structure.

4 SPECIFICATIONS

STRAIN RANGE:	3000 μstrains
RESOLUTION:	- Wire: 0,01 μsec (MB-6T(L) 0.1 μstrain (MB-6T(L) 0.1 Hz (PALMETO WW) - Temperature: 0.1°C
OPERATING TEMPERATURE RANGE	-50°C to +60°C
GAGE FACTOR:	4.0624
THERMISTOR:	- Type: 3 kΩ (2kΩ optional) - Accuracy: ±0.5% F.S.
ELECTRICAL CABLE:	- IRC-41A (standard): 2 twisted shielded pairs 22 AWG, 6.2 mm O.D., PVC jacket - IRC-41AP (optional): identical to IRC-41A except that jacket is polyethylene
ACCESSORIES	• Portable readout units (MB-6T(L), PALMETO VW) • Data acquisition system (SENSLOG) • Setting tools • Terminal and junction boxes • Lightning protection box • Protective cover • Splicing kit

5 MISCELLANEOUS

5.1 CONVERSION FACTORS

	To Convert From	To	Multiply By
LENGTH	Microns Millimeters Meters	Inches Inches Feet	3.94E-05 0.0394 3.2808
AREA	Square millimeters Square meters	Square inches Square feet	0.0016 10.7643
VOLUME	Cubic centimeters Cubic meters Liters Liters	Cubic inches Cubic feet U.S. gallon Can–Br gallon	0.06101 35.3357 0.26420 0.21997
MASS	Kilograms Kilograms Kilograms	Pounds Short tons Long tons	2.20459 0.00110 0.00098
FORCE	Newtons Newtons Newtons	Pounds-force Kilograms-force Kips	0.22482 0.10197 0.00023
PRESSURE AND STRESS	Kilopascals Bars Inches head of water* Inches head of Hg Pascal Kilopascals Kilopascals Kilopascals	Psi Psi Psi PsI Newton / square meter Atmospheres Bars Meters head of water*	0.14503 14.4928 0.03606 0.49116 1 0.00987 0.01 0.10199
TEMPERATURE	Temp. in °F = (1.8 x Temp. in °C) + 32 Temp. in °C = (Temp. in °F – 32) / 1.8		

* at 4 °C

E6TabConv-990505

Conversion Factors

5.2 THERMISTOR: TEMPERATURE READING

Temp. °C	Reading in Ohms			Temp. °C	Reading in Ohms		
	With a 2K Thermistor	With a 3K Thermistor	With a 10K Thermistor		With a 2K Thermistor	With a 3K Thermistor	With a 10K Thermistor
-50		201100	670500	1	6208	9310	31030
-49		187300	670500	2	5900	8851	29500
-48		174500	624300	3	5612	8417	28060
-47		162700	581700	4	5336	8006	26690
-46		151700	542200	5	5080	7618	25400
-45		141600	440800	6	4836	7252	24170
-44		132200	472000	7	4604	6905	23020
-43		123500	411700	8	4384	6576	21920
-42		115400	384800	9	4176	6265	20880
-41		107900	359800	10	3980	5971	19900
-40	67320	101000	336500	11	3794	5692	18970
-39	63000	94480	315000	12	3618	5427	18090
-38	59000	88460	294900	13	3452	5177	17260
-37	55280	82870	276200	14	3292	4939	16470
-36	51800	77660	258900	15	3142	4714	15710
-35	48560	72810	242700	16	3000	4500	15000
-34	45560	68300	227700	17	2864	4297	14330
-33	42760	64090	213600	18	2736	4105	13680
-32	40120	60170	200600	19	2614	3922	13070
-31	37680	56510	188400	20	2498	3748	12500
-30	35400	53100	177000	21	2388	3583	11940
-29	33280	49910	166400	22	2284	3426	11420
-28	31300	46940	156500	23	2184	3277	10920
-27	29440	44160	147200	24	2090	3135	10450
-26	27700	41560	138500	25	2000	3000	10000
-25	26080	39130	130500	26	1915	2872	9574
-24	24580	36860	122900	27	1833	2750	9165
-23	23160	34730	115800	28	1756	2633	8779
-22	21820	32740	109100	29	1682	2523	8410
-21	20580	30870	102900	30	1612	2417	8060
-20	19424	29130	97110	31	1544	2317	7722
-19	18332	27490	91650	32	1481	2221	7402
-18	17308	25950	86500	33	1420	2130	7100
-17	16344	24510	81710	34	1362	2042	6807
-16	15444	23160	77220	35	1306	1959	6532
-15	14596	21890	72960	36	1254	1880	6270
-14	13800	20700	69010	37	1203	1805	6017
-13	13052	19580	65280	38	1155	1733	5777
-12	12352	18520	61770	39	1109	1664	5546
-11	11692	17530	58440	40	1065	1598	5329
-10	11068	16600	55330	41	1024	1535	5116
-9	10484	15720	52440	42	984	1475	4916
-8	9932	14900	49690	43	945	1418	4725
-7	9416	14120	47070	44	909	1363	4543
-6	8928	13390	44630	45	874	1310	4369
-5	8468	12700	42340	46	840	1260	4202
-4	8032	12050	40170	47	808	1212	4042
-3	7624	11440	38130	48	778	1167	3889
-2	7240	10860	36190	49	748	1123	3743
-1	6876	10310	34370	50	720	1081	3603
0	6532	9796	32660	51	694	1040	3469

Conversion Table (Continued)

Temp. °C	Reading in Ohms			Temp. °C	Reading in Ohms		
	With a 2K Thermistor	With a 3K Thermistor	With a 10K Thermistor		With a 2K Thermistor	With a 3K Thermistor	With a 10K Thermistor
52	668	1002	3340	102	128	192.2	640.3
53	643	965.0	3217	103	125	186.8	622.1
54	620	929.6	3099	104	121	181.5	604.4
55	597	895.8	2986	105	118	176.4	587.5
56	576	863.3	2878	106	114	171.4	571.0
57	555	832.2	2774	107	111	166.7	555.1
58	535	802.3	2675	108	108	162.0	540.0
59	516	773.7	2580	109	105	157.6	524.9
60	498	746.3	2488	110	102	153.2	510.7
61	480	719.9	2400	111	99	149.0	496.4
62	463	694.7	2316	112	97	145.0	483.1
63	447	670.4	2235	113	94	141.1	469.8
64	432	647.1	2157	114	91	137.2	457.4
65	416	624.7	2083	115	89	133.6	444.9
66	402	603.3	2011	116	87	130.0	433.4
67	388	582.6	1942	117	84	126.5	421.8
68	375	562.8	1876	118	82	123.2	410.7
69	363	543.7	1813	119	80	119.9	399.6
70	350	525.4	1752	120	78	116.8	389.4
71	339	507.8	1693	121	76	113.8	379.2
72	327	490.9	1636	122	74	110.8	369.4
73	316	474.7	1582	123	72	107.9	360.1
74	306	459.0	1530	124	70	105.2	350.8
75	296	444.0	1479	125	68	102.5	341.9
76	286	429.5	1431	126	67	99.9	333.0
77	277	415.6	1385	127	65	97.3	324.6
78	268	402.2	1340	128	63	94.9	316.6
79	260	389.3	1297	129	62	92.5	308.6
80	251	376.9	1255	130	60	90.2	301.1
81	243	364.9	1215	131	59	87.9	293.5
82	236	353.4	1177	132	57	85.7	286.0
83	228	342.2	1140	133	56	83.6	279.3
84	221	331.5	1104	134	54	81.6	272.2
85	214	321.2	1070	135	53	79.6	265.5
86	208	311.3	1036	136	52	77.6	259.3
87	201	301.7	1004	137	51	75.8	253.1
88	195	292.4	973.8	138	49	73.9	246.9
89	189	283.5	944.1	139	48	72.2	241.1
90	183	274.9	915.2	140	47	70.4	235.3
91	178	266.6	887.7	141	46	68.8	229.6
92	172	258.6	861.0	142	45	67.1	224.2
93	167	250.9	835.3	143	44	65.5	218.9
94	162	243.4	810.4	144	43	64.0	214.0
95	157	236.2	786.4	145	42	62.5	208.7
96	153	229.3	763.3	146	41	61.1	203.8
97	148	222.6	741.1	147	40	59.6	199.4
98	144	216.1	719.4	148	39	58.3	194.5
99	140	209.8	698.5	149	38	56.8	190.1
100	136	203.8	678.5	150	37	55.6	185.9
101	132	197.9	659.0				

Thermistor temperature derivation