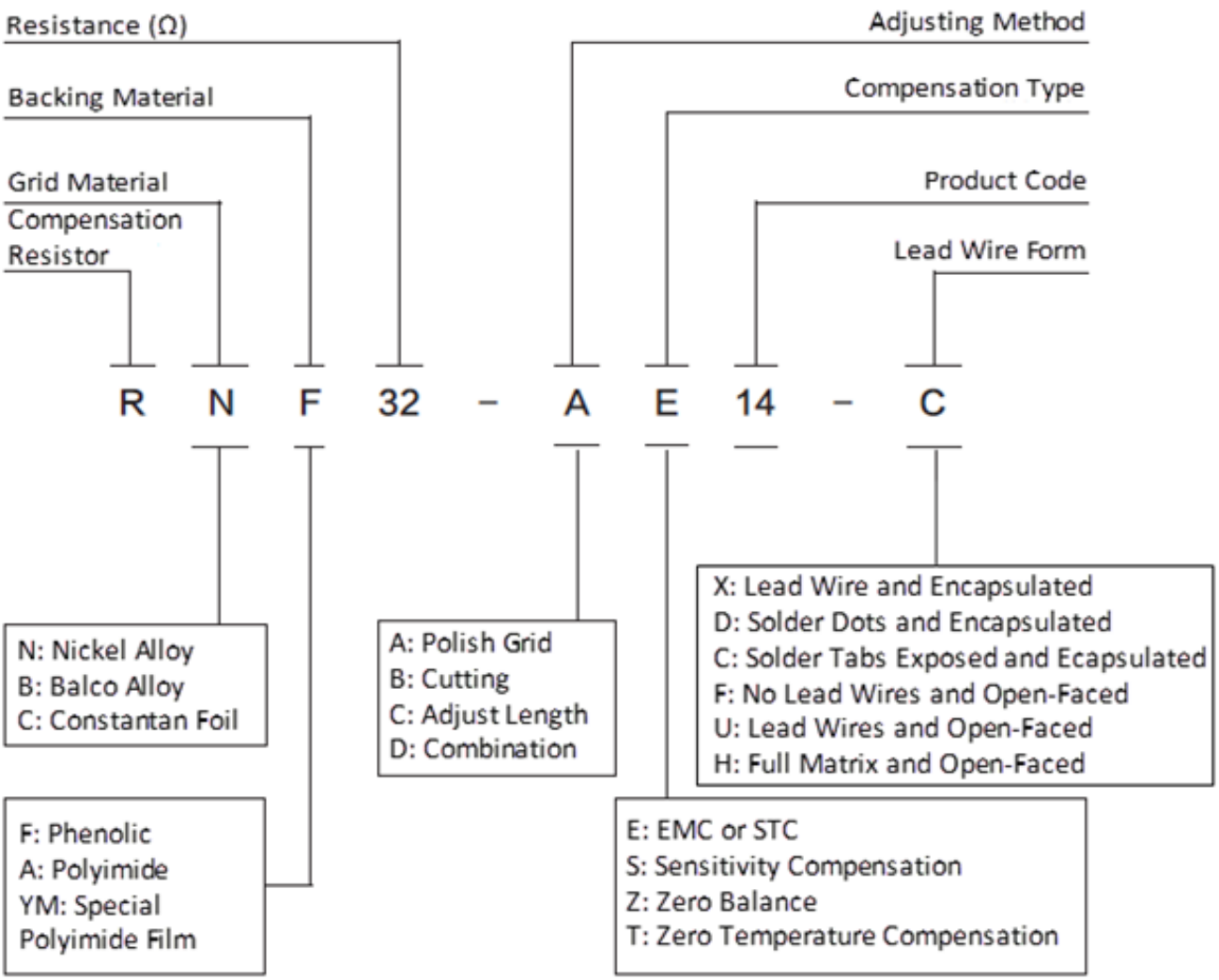
Compensation resistor designation and selection method

High accuracy transducers not only need high accuracy strain gauges to achieve their specifications but also need series compensation and adjustment resistors. ZEMICs R series compensation resistors is a kind of bondable adjustable compensation resistor. The resistors can be used to improve a transducers specifications like output sensitivity, temperature effect on sensitivity, zero output, zero output drift due to temperature and other technical specifications. In addition it has several other advantages; the resistors can be easily installed by easy bonding, they are easy to adjust, the temperature change is the same as the temperature change of the spring elements material due to the Self–temperature compensation and can reach very high compensation accuracy.



Choice in compensation resistors

During the production of high accuracy transducers, a series of compensations should be done in order to improve the specifications of transducers. This is done mainly to compensate the temperature effect on sensitivity , the overall sensitivity, zero balance and the temperature effect on zero balance. Following is an introduction to the possible compensation methods and a guide to choose the correct compensation resistor:

1. Temperature effect on sensitivity compensation (i.e. Elastic Modulus Compensation) usually adopts RNF or RBF series compensation resistors. When the transducers environmental temperature changes, the elastic modulus of the spring element and the strain gauges gauge factor will also change accordingly. This causes an error in measurements. This is the reason that for high accuracy transducers, this has to be compensated. The method is as follows: To connect the compensation resistor in a serial connection with the input excitation circuit. The compensation resistor will change with the same temperature effect characteristics as the transducer will but in opposite direction which will therefore compensate the change back to a minimum.
To know what compensation resistance value is necessary, this should be calculated with the following formula:

$$R_m \approx [(S_1-S_2) \cdot R_{in}]/\{[1+\alpha_c (T_1-T_2)] \cdot S_1- S_2\}$$

Wherein R_m refers to the resistance value of the compensation resistor, S_1 and S_2 refer to the transducers sensitivity at temperature values $T_1$and T_2 respectively. R_{in} refers to the input resistance of the bridge when the temperature value is T_1. α_c refers to the temperature resistance coefficient of the compensation resistor. These coefficients are as follows: For the RNF resistors: 5.5×10^{-3}/℃ and for the RBF resistors: 4.3×10^{-3}/℃ . Further, S (transducer sensitivity) is calculated as follows: $S=E_0/V$ in which E_0 is the bridge output voltage and V is the supply excitation voltage.
Generally spoken, steel transducers usually use a RNF series 20 Ω compensation resistor. For aluminium transducers a RNF series 32 Ω compensation resistor is usually chosen. The specific compensation resistance value however, should be confirmed by testing and adjusting the compensation resistor according to the transducers' accuracy.

2. Sensitivity compensation usually adopt RCF series compensation resistors or thin wires with a lower resistance temperature coefficient than the transducers. Because the spring elements material differences, process variation and gauge factor dispersion combined together (which is usually lower than 1%), the dispersion between transducers sensitivity would occur and therefore make it harder to interchange transducers. During the production of transducers, the sensitivity of transducers is generally a little bit higher than intended. So that at the end of the process it can be adjusted to the correct value according to test results. The specific method is as follows: The compensation resistor with smaller resistance temperature coefficient into the excitation circuit with the intention to lower the real excitation voltage of the transducer will be connected into the input circuit. This way the sensitivity of the transducer is decreased. The compensation resistance value can be calculated with the following formula:

$$R_C \approx ((S_1-S_2))/(S_1 \cdot R)$$

R_C refers to the resistance value of the compensation resistor. S_1 and S_2 refer to the sensitivity before adjustment and the sensitivity after adjustment. R refers to the input resistance of the bridge.

Compensation resistor

3. Zero balance compensation usually adopts RCF compensation resistors or varnished wrapped wires with lower resistance temperature coefficient. They will be applied into one of the arms of the bridge to make sure the transducers strain gauge bridge output is as close to zero as possible without any load applied. In this way measuring errors can be prevented and zero adjustments by indicators are easy to perform. Usually, polishable, cutable and length adjustable compensation resistors are used. This way, the bridge zero can be easily and neatly adjusted. Resistance value of polisable compensation resistors can be adjusted by carefully polishing the grid with an abrasive. Cutable compensation resistors can be adjusted by carefully cutting the grid on designated places. The resistance value of length adjustable compensation resistors can be adjusted by changing the length of the resistor.

A small example of how this works is shown below:

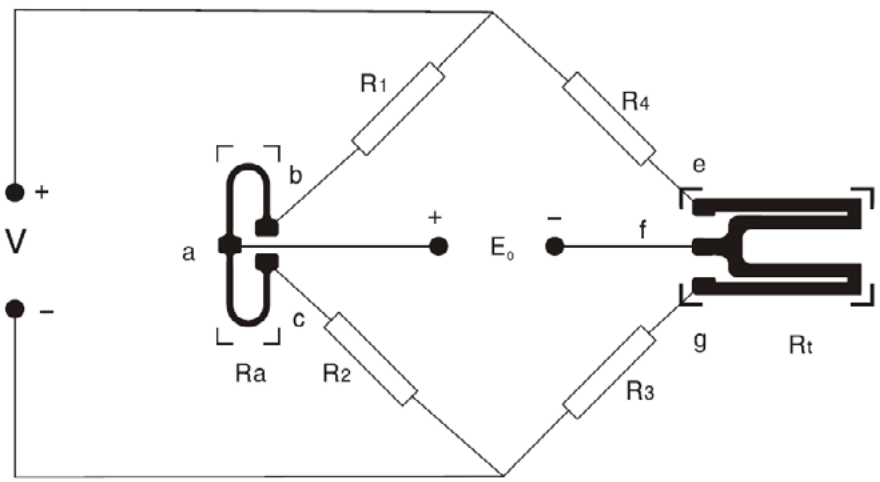


Figure 4: Zero balance compensation

When strain gauge R_1 and R_3 receive compressive strain and R_2 and R_4 receive tensile strain and the zero output is positive, terminal A–B should be having an increased resistance. For polishable compensation strain resistors this means the grid should be polished, for cutable compensation resistors, the grid should be cut to increase the resistance and for a length adjustable compensation resistor the length should be increased. Meanwhile it is important to keep an eye on the bridge output. The intention is to get the bridge output to zero. When too much is polished, cut or the length too long, another adjustment has to be made. To return the value back to zero the same procedure should be executed on terminal A–C. This will compensate the other way until the zero balance reaches zero again. Please not that this adjustment method can't be performed unlimited times. Eventually the resistance will break or no cutting can be done or the length adjustable resistor will be too long.

4. Zero temperature compensation usually adopts an RNF or varnished wrapped pure copper wire or a varnished wrapped nickel wire with larger temperature resistance coefficient. It will be applied into one of the arms of the bridge. With no load applied the output of the transducer should be close to zero. When a transducers' surrounding temperature and therefore the temperature of the

Compensation resistor

transducer itself changes, the spring element, bonding adhesive and strain gauge itself will change and therefore the resistance will change. All those factors will affect the transducers zero output, even self–temperature compensating and full bridge setups can't prevent the signal to shift. This is because of a certain small dispersion between the strain gauges. This will affect the zero output and has to be compensated. The usual method to do this is as follows:
The first thing to do is to test the transducer temperature performance, this means to see what the temperature coefficient is and what values the transducer has at certain temperature levels. After this is determined, a compensation resistor can be applied into one of the arms. The value of compensation resistor can be calculated with the formula below:

$$R_t = | R (U_2 - U_1) | / (| 250 \cdot \alpha_c \cdot U_{in} (T_2 - T_1) |)$$

In this formula, R_t refers to the resistance value of the compensation resistor which should be used. R refers to the bridge resistance and U_{in} to the excitation voltage; α_c refers to the temperature coefficient of the compensation resistor. U_1 and U_2 refer to the transducers zero output voltage at temperature values $T_1$and T_2 respectively. Usually, polishable, cutable and length adjustable compensation resistors are used. The theory of zero temperature compensation is very similar to the zero balance compensation, however, the zero temperature must be adjusted during different temperature changes.

A small example of how this works is shown below:

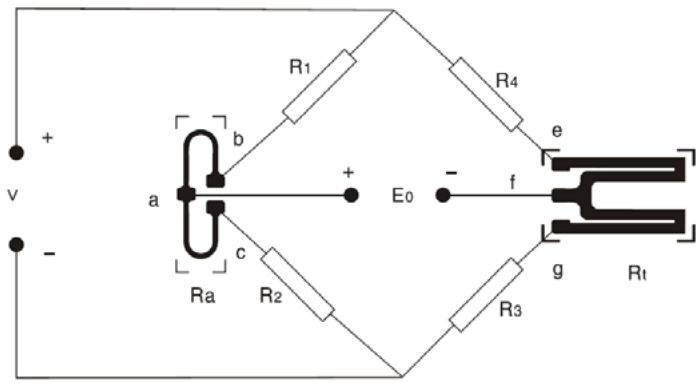
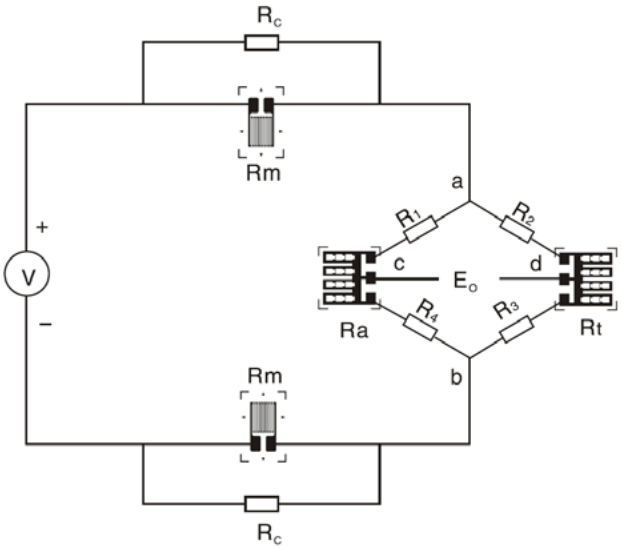


Figure 5: Zero temperature compensation

When strain gauge R_1 and R_3 receive compressive strain and R_2 and R_4 receive tensile strain and the zero temperature output is positive (The positive output is the difference between the zero output at normal temperature and at higher temperature), terminal F–G should be having an increased resistance. For polishable compensation strain resistors this means the grid should be polished, for cutable compensation resistors, the grid should be cut to increase the resistance and for a length adjustable compensation resistor the length should be increased. Meanwhile it is important to keep an eye on the bridge output. The intention is to get the bridge output to zero. When too much is polished, cut or the length too long, another adjustment has to be made. To return the value back to zero the same procedure should be executed on terminal E–F. This will compensate the other way until the zero balance reaches zero again. Please not that this adjustment method can't be performed unlimited times. Eventually the resistance will break or no cutting can be done or the length adjustable resistor will be too long.

Basic drawing of transducers wiring compensation



R_1 ~R_4 ------ Strain Gauges

R_t ------ Zero Temperature compensation resistor

R_a ------ Adjustable Zero output resistor

R_m ------ Temperature sensitivity compensation resistor (or elastic modulus resistor)

R_c ------ Linearity compensation resistor

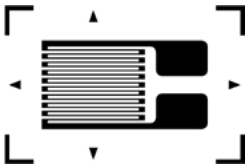
V ------ Excitation voltage

E_0 ------ Bridge output (or measuring output)

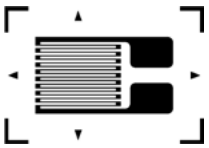
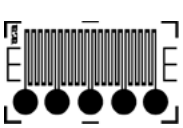
Compensation resistor specification

Specification	RNF Series	RBF Series	RCF Series
Resistance tolerance to average resistance (23 ℃)	⩽ ±0.5%		
Resistance temperature coefficient	5.5×10^{-3}/℃	4.3×10^{-3}/℃	
Temperature range (℃)	−30~+60		
Adhesive	H−610、H−600、X−602		
Wiring	X (may be omitted), C, D, F, H, U		

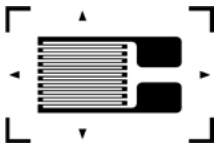
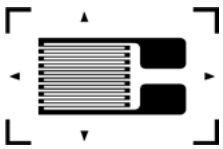
RBF/RNF/RCF/RNA/RNYM

Product geometry	Product code	Nominal resistance (Ω)	Backing size: Length (L) x Width (W) (mm)
	RBF15–AE95	15.0	5.5 × 3.6
	RBF15–AE56	15.0	3.0 × 2.0
	RBF20–AE26	20.0	6.2 × 3.6
	RBF25–AE05	25.0	6.2 × 3.9
	RBF30–AE45	30.0	6.2 × 4.0
	RBF35–AE45	35.0	6.2 × 4.0
	RBF50–AE06	50.0	5.8 × 3.8
	RBF60–AE07	60.0	5.9 × 3.8
	RBF65–AE66	65.0	5.9 × 3.8
	RBF70–AE08	70.0	6.0 × 3.8
	RBF81–AE14	81.0	6.8 × 4.4
	RBF90–AE14	90.0	6.8 × 4.4
	RBF96–AE10	96.0	6.5 × 4.2
	RBF100–AE11	100.0	6.8 × 4.0
	RBF110–AE11	100.0	6.8 × 4.0
	RBF130–AE22	130.0	7.1 × 4.2
	RBF150–AE23	150.0	7.1 × 4.6
	RBF180–AE25	180.0	7.1 × 4.6
	RBF200–AE58	200.0	6.9 × 4.0
	RBF200–AE13	200.0	7.6 × 4.8
	RBF234–AE13	234.0	7.6 × 4.8
	RBF330–AE74	330.0	12.0 × 6.0
	RNF5–AE12	5	5.7 × 4.4
	RNF5.5–AE12	5.5	5.7 × 4.4
	RNF9–AE05	9	6.2 × 3.9
	RNF10–AE05	10	6.2 × 3.9
	RNF12–AE45	12	6.2 × 4.0
	RNF13–AE45	13	6.2 × 4.0
	RNF13.5–AE97	13.5	8.0 × 5.0
	RNF15–AE16	15	5.6 × 3.8
	RNF16–AE57	16	7.6 × 4.3
	RNF16–AE16	16	5.6 × 3.8
	RNF18–AE06	18	5.8 × 3.8
	RNF18–AE73	18	5.8 × 3.8
	RNF18–AE57	18	7.6 × 4.3
	RNF20–AE07	20	5.9 × 3.8
	RNF19.5–AE07	20	5.9 × 3.8
	RNF22–AE07	22	5.9 × 3.8
	RNF23.5–AE66	23.5	5.9 × 3.8
	RNF24–AE66	24	5.9 × 3.8
	RNF26–AE08	26	6.0 × 3.8
	RNF26.5–AE08	26.5	6.0 × 3.8
	RNF28–AE09	28	6.1 × 4.0
	RNF30–AE09	30	6.1 × 4.0
	RNF32–AE14	32	6.8 × 4.4
	RNF35.5–AE10	35.5	6.5 × 4.2
	RNF40–AE11	40	6.8 × 4.0

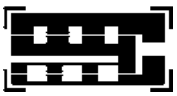
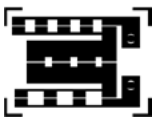
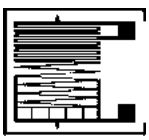
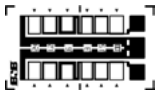
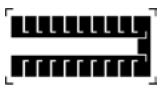
Compensation resistor

Product geometry	Product code	Nominal resistance (Ω)	Backing size: Length (L) x Width (W) (mm)
	RNF42–AE11	42	6.8 × 4.0
	RNF50–AE22	50	7.1 × 4.2
	RNF53.5–AE60	53.5	5.2 × 4.8
	RNF54–AE28	54	7.1 × 4.4
	RNF55–AE62	55	7.2 × 3.0
	RNF60–AE23	60	7.1 × 4.6
	RNF64–AE31	64	7.1 × 4.6
	RNF65.4–AE25	65.4	7.1 × 4.6
	RNF70–AE25	70	7.1 × 4.6
	RNF73–AE25	73	7.1 × 4.6
	RNF76–AE13	76	7.6 × 4.8
	RNF81–AE13	81	7.6 × 4.8
	RNF90–AE13	90	7.6 × 4.8
	RNF112–AE59	112	8.0 × 8.0
	RNF120–AE61	120	6.5 × 3.9
	RNF300–AE64	300	8.6 × 5.3
	RNA4.5–AE12	4.5	5.7 × 4.4
	RNA12–AE45	12.0	6.2 × 4.0
	RNA15–AE16	15.0	5.6 × 3.8
	RNA19–AE06	19.0	5.8 × 3.8
	RNA20–AE07	20.0	5.9 × 3.8
	RNA20–AE15	20.0	10.4 × 6.0
	RNA25–AE66	25.0	5.9 × 3.8
	RNA30–AE09	30.0	6.1 × 4.0
	RNF20–AE15	20.0	10.4 × 6.0

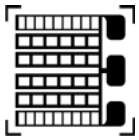
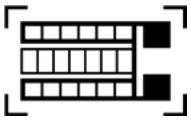
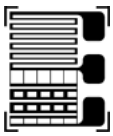
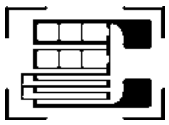
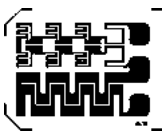
Compensation resistor

Product geometry	Product code	Nominal resistance (Ω)	Backing size: Length (L) x Width (W) (mm)
	RBF4–AT69	3.4	10.0 × 6.5
	RNF035–AT03	0.65	10.6 × 5.5
	RNF1–AT02	0.9	8.5 × 5.4
	RCF2–AZ01	2.0	
	RNF3–AT03	3.0	11.5 × 5.0
	RCF5–AZ04	5.0	
	RCF1–AZ63	1.0	4.8 × 1.6
	RCF2–AS55	2.6	11.2 × 5.2
	RNA4.5–AE12	4.5	5.7 × 4.4
	RNA12–AE45	12.0	6.2 × 4.0
	RNA15–AE16	15.0	5.6 × 3.8
	RNA19–AE06	19.0	5.8 × 3.8
	RNA19.5–AE07	19.5	5.9 × 3.8
	RNA20–AE07	20.0	5.9 × 3.8
	RNA20–AE15	20.0	10.4 × 6.0
	RNA25–AE66	25.0	5.9 × 3.8
	RNA30–AE09	30.0	6.1 × 4.0
	RNA32–AE14	32.0	6.8 × 4.4
	RNA40–AE11	40.0	6.8 × 4.0
	RNA50–AE22	50.0	7.1 × 4.2
	RNA76–AE13	76.0	7.6 × 4.8
	RNYM19–AE06	19.0	5.8 × 3.8
	RNYM25–AE66	25.0	5.9 × 3.8
	RNYM50–AE22	50.0	7.1 × 4.2

Compensation resistor

Product geometry	Product code	Nominal resistance (Ω)		Backing size: Length (L) x Width (W) (mm)
		Initial resistance	Adjustable up to	
	RNF02–BT18	0.2	1.6	6.4 × 6.4
	RCF05–BE17	1.3	10.0	
	RNF02–CT44	0.45	0.07	15.0 × 9.0
	RNF1–CT41	1.0	0.04	7.6 × 3.8
	RNF5–BE75	6.8	14.0	8.0 × 5.5
	RNF5–CT41	2.0	0.05	8.1 × 5.9
	RNF9–BE37	9.5	33.0	7.9 × 7.8
	RNF15–BE32	15.0	25.5	8.2 × 7.3
	RNF10–CT41	13.0	2.0	6.4 × 3.2
	RCF70–CS41	75.0	6.3	
	RCF01–BZ62	17.5	29.0	14.3 × 7.8
	RCF02–CS46	5.3	1.0	20.0 × 10.0

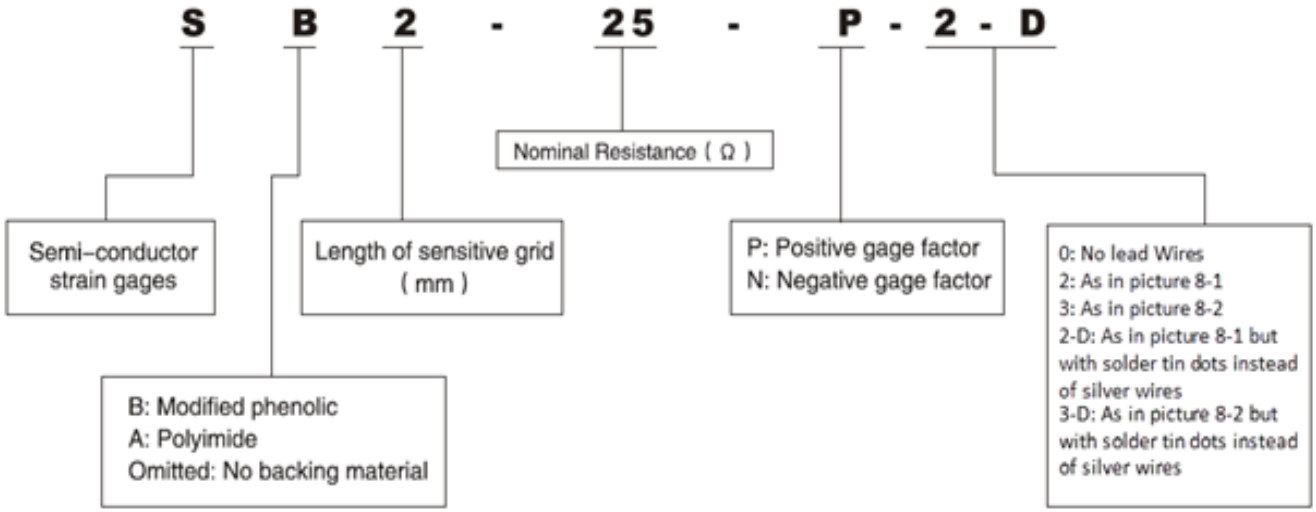
Compensation resistor

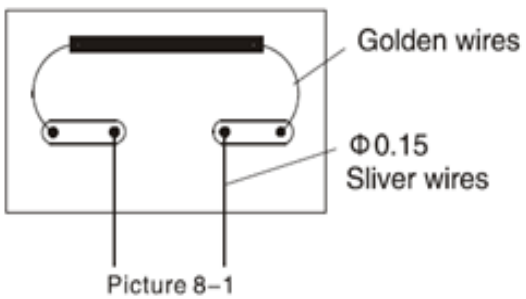
Product geometry	Product code	Nominal resistance (Ω)		Backing size: Length (L) x Width (W) (mm)
		Initial resistance	Adjustable up to	
	RCF1–BS24	2.0	42.5	8.4 × 8.4
	RCF5–BS27	6.0	52	8.5 × 8.5
	RCF1–CS60	2.3	0.6	7.4 × 5.4
	RCF2–BS19	2.0	22.0	6.6 × 3.6
	RNF05–BT20	0.3	3.3	8.0 × 5.0
	RCF5–BS56	55	74	9.4 × 7.8
	RCF10–BS30	11.0	36.5	7.7 × 5.4
	RCF25–DS61	37.0	16.0	10.5 × 7.7
	RCF28–CS47	36.0	8.5	14.0 × 11.0
	RCF30–CS42	41.5	8.0	15.0 × 10.0

Semi-conductor strain gauges

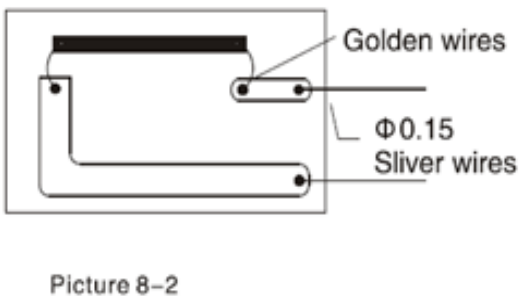
Semi–conductor strain gauges are primarily produced from Silicon, Germanium, Antimony steel, Gallium Phosphide and other materials with a large sensitivity factor and therefore have a far larger signal output that ordinary strain gauges. It has a small transverse effect factor, small mechanical hysteresis, small size and are easy to use with the manufacturing of large and small transducers.

Semi-conductor designation





Picture 8–1



Picture 8–2

Linear compensation principle of semi-conductor strain gauges

Due to unbalance caused by transverse (Poisson Strain) and axial strain in a column or similar structure transducers elements, a non–linearity error arises in the bridge output. On top of that the non–linearity between load and strain, material non–linearity and transverse load non–linearity will cause a severe accuracy error of column or similar structure transducers. Therefore a correction has to be made to meet the high accuracy required for production of high precision transducers.