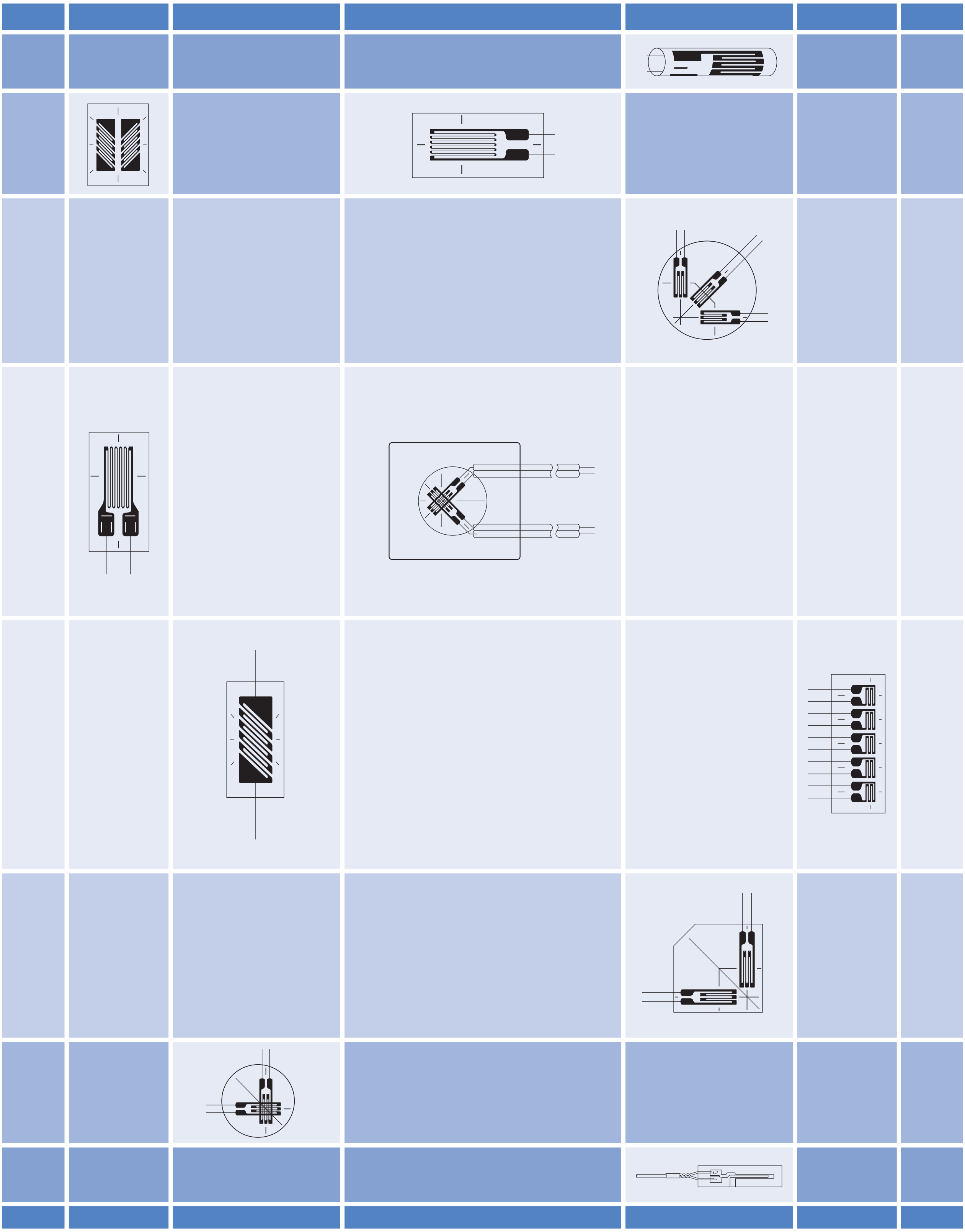
A&D Company, Ltd.

Foil strain gauge·High-precision measurement gauge

STRAIN GAUGE



A&D Company, Ltd.

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STRAIN GAUGE

This device is used in a wide range of fields for stress measurement. It is attached directly to the surface of structures with various shapes and converts the amount of mechanical strain into electricity.
Compared with the other strain measurement methods, the following features have dramatically expanded the field of use.

The advantage of the strain gauge is:
- **The measurement accuracy is good**
- **It is highly responsive**
- **High concurrent measurement at other points**
- **Field measurement can be performed easily**
- **It can be used as a converter that measures various physical quantities**

For example.

Strain gauges with these advantages are currently used in a wide range of fields, including airplanes, ships, transportation equipment, railways, iron manufacturing, heavy engineering, electric power, machinery, civil engineering, architecture, clinics, rehabilitation, and ergonomics
In these fields, they are also widely used as sensitivity devices for converters used in measuring physical quantities (loads, pressures, displacement, acceleration, torque, etc.).
In order to respond to these diverse needs, we are using our extensive experience as a strain measurement device manufacturer to prepare to be able to provide solutions for general stress measurement, high-precision measurement, and special-purpose gauges.

Specifications

Item		FA series	MA series
Grid length	mm	0.3 ~ 0.6	0.3 ~ 10
Gauge resistance value	Nominal resistance	± 0.5 % or less	
Gauge Material		Advanced Foil	
Base Material		Polyester	Polyimide-based
Gauge Factor	Nominal value	Within ± 2 %	
Maximum strain measurement range		± 2 ~ 4%	
Operating temperature range	°C	- 30 ~ + 80	- 30 ~ + 180
Thermal outputs (see Fig1)	At room temp. + 80°C	± 2 × 10^{-6} strain / °C	
	At room temp. + 160°C		± 2 × 10^{-6} strain / °C
Gauge factor by temperature change (see Fig. 2)		± 0.015%/°C or less	
Fatigue life	± 1000 × 10^{-6} strain	10^5 or more times	
Coefficient of linear expansion for the compatibility measurement object	Normal Stiffness	α = 11 × 10^{-6} / °C	
	Stainless steel	α = 16 × 10^{-6} / °C	
	Aluminum alloy	α = 23 × 10^{-6} / °C	

Supplementary figure

Common characteristics of N11-MA-5-120-11

Fig 1 Thermal Output Characteristics

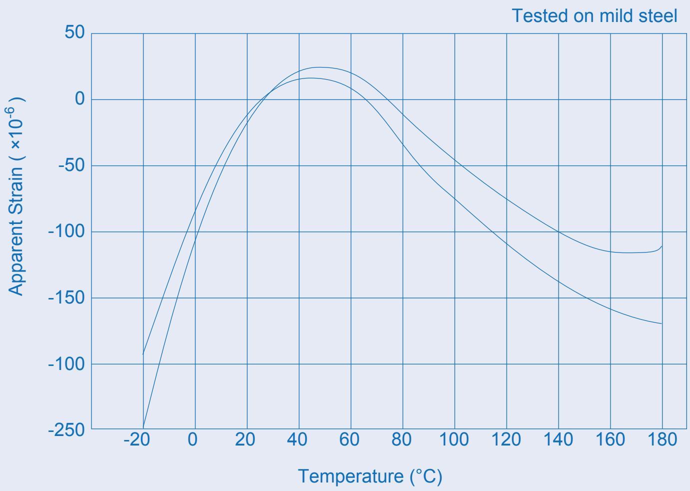
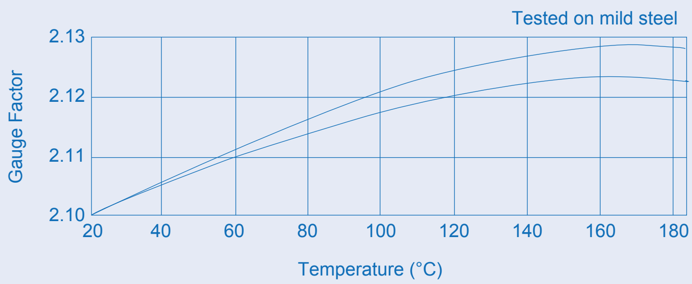
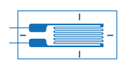
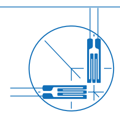
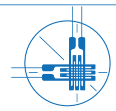
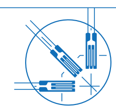
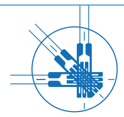
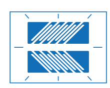
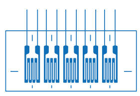
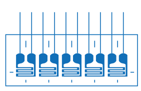


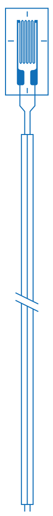
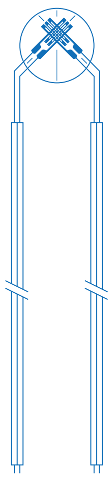
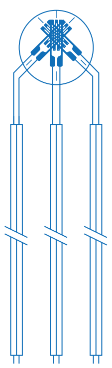
Fig 2 Gauge Factor variation with temperature



Gauge pattern	Format	Typical uses
	N11-	Extensive strain measurement
	N21-	Two-axis strain measurement Used whenperforming temperature compensation
	N22-	Same application as the N21- Beware of temperature drift In the lower gauge
	N31-	Rosette analysis If the strain gradient is large, error are more likely to occur
	N32-	Same application as the N31- Beware of temperature drift In the lower gauge
	Z23-	For twist strain and torque measurement
	N51-	For sectional strain measurement and stress-intensive measurement
	R51-	

Lead strain gauge (2-wire)

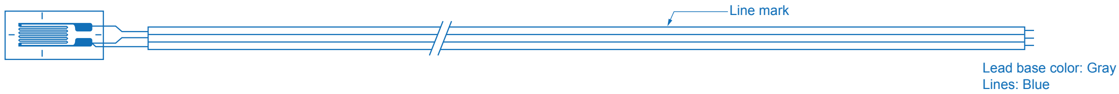
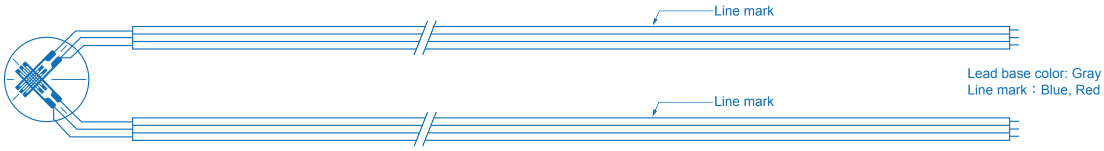
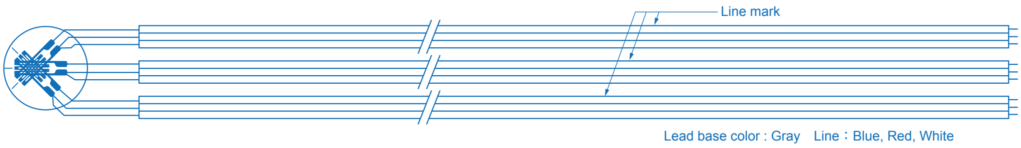
Self-temperature compensating compatible material, normal stiffness 11 x 10^{-6} / °C

Model		Nominal resistance (Ω)	Gauge efficiency (Nominal)	Dimensions				Lead wire length (m)	
				Grid (mm)		Base (mm)			
				Length	Width	Length	Width		
	**N11-FA-03-120-VSE03**	120	1.9	0.3	1.8	3.5	2.5	0.3	
	N11-FA-03-120-VSE1							1	
	N11-FA-03-120-VSE3							3	
	N11-FA-03-120-VSE5							5	
	N11-FA-1-120-P4-VSE03	120	2.0	1.0	1.0	4.0	2.0	0.3	
	N11-FA-1-120-P4-VSE1							1	
	N11-FA-1-120-P4-VSE3							3	
	N11-FA-1-120-P4-VSE5							5	
	N11-FA-2-120-VSE03	120	2.0	2.0	1.6	6.0	2.5	0.3	
	N11-FA-2-120-VSE1							1	
	N11-FA-2-120-VSE3							3	
	N11-FA-2-120-VSE5							5	
	N11-FA-5-120-VSE03	120	2.1	5.0	1.8	9.5	3.5	0.3	
	N11-FA-5-120-VSE1							1	
	N11-FA-5-120-VSE3							3	
	N11-FA-5-120-VSE5							5	
	N11-MA-03-120-FE5	120	1.9	0.3	1.8	3.5	2.5	5	※
	N11-MA-1-120-P4-FE5		2.0	1.0	1.0	4.0	2.0	5	
Lead Color : Green	**N11-MA-2-120-FE5**		2.0	2.0	1.6	6.0	2.5	5	※
	N11-MA-5-120-FE5		2.1	5.0	1.8	9.5	3.5	5	※
	**N22-FA-1-120-VS03**	120	2.0	1.0	1.5	φ6.0		0.3	
	N22-FA-1-120-VS1							1	
	N22-FA-1-120-VS3							3	
	N22-FA-1-120-VS5							5	※
	N22-FA-2-120-VS03	120	2.0	2.0	1.6	φ8.0		0.3	
	N22-FA-2-120-VS1							1	
	N22-FA-2-120-VS3							3	
	N22-FA-2-120-VS5							5	※
	N22-FA-5-120-VS03	120	2.1	5.0	1.8	φ11.0		0.3	
	N22-FA-5-120-VS1							1	
	N22-FA-5-120-VS3							3	
	N22-FA-5-120-VS5							5	※
	N22-FA-10-120-VS03	120	2.1	10.0	2.2	φ18.0		0.3	
	N22-FA-10-120-VS1							1	
	N22-FA-10-120-VS3							3	
	N22-FA-10-120-VS5							5	※
Lead Color : Green, Red	**N22-MA-2-120-FE5**	120	2.0	2.0	1.6	φ8.0		5	※
	N22-MA-5-120-FE5		2.1	5.0	1.8	φ11.0		5	※
	**N32-FA-1-120-VS03**	120	2.0	1.0	1.5	φ6.0		0.3	
	N32-FA-1-120-VS1							1	
	N32-FA-1-120-VS3							3	※
	N32-FA-1-120-VS5							5	※
	N32-FA-2-120-VS03	120	2.0	2.0	1.6	φ8.0		0.3	
	N32-FA-2-120-VS1							1	
	N32-FA-2-120-VS3							3	※
	N32-FA-2-120-VS5							5	※
	N32-FA-5-120-VS03	120	2.1	5.0	1.8	φ11.0		0.3	
	N32-FA-5-120-VS1							1	
	N32-FA-5-120-VS3							3	※
	N32-FA-5-120-VS5							5	※
Lead Color : Green, Red, White	**N32-MA-2-120-FE5**	120	2.0	2.0	1.6	φ8.0		5	※
	N32-MA-5-120-FE5		2.1	5.0	1.8	φ11.0		5	※

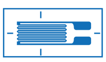
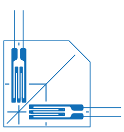
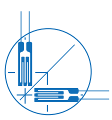
Lead wires can be attached to any strain gauge other than the above.Please contact us for details.

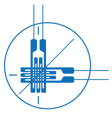
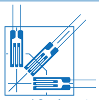
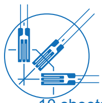
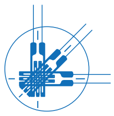
※ : 2 boxes (each box contains 5 sheets)

Lead strain gauge (3-wire)

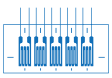
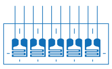
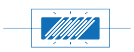
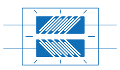
Model	Nominal resistance (Ω)	Gauge efficiency (Nominal)	Dimensions				Lead wire length (m)
			Grid (mm)		Base (mm)		
			Length	Width	Length	Width	
							
N11-FA-2-120-11-VM5T	120	2.0	2	1.6	6.0	2.5	5
N11-FA-5-120-11-VM5T	120	1.9	5	1.8	9.5	3.5	5
							
N22-FA-2-120-11-VM5T	120	2.0	2	1.6	φ 8.0		5
N22-FA-5-120-11-VM5T	120	2.1	5	1.8	φ 11.0		5
							
N32-FA-2-120-11-VM5T	120	2.0	2	1.6	φ 8.0		5
N32-FA-5-120-11-VM5T	120	2.1	5	1.8	φ 11.0		5

General use foil strain gauge (no coated leads)

Gauge pattern	Model	Nominal resistance (Ω)	Gauge efficiency (Nominal)	Dimensions			
				Grid (mm)		Base (mm)	
				Length	Width	Length	Width
 10 sheets per box	N11-FA-03-120-(11,16,23)	120	1.9	0.3	1.8	3.5	2.5
	N11-FA-1-120-(11,16,23)-P4	120	2.0	1.0	1.0	4.0	2.0
	N11-FA-2-120-(11,16,23)	120	2.0	2.0	1.6	6.0	2.5
	N11-FA-5-120-(11,16,23)	120	2.1	5.0	1.8	9.5	3.5
	N11-FA-8-120-(11,16,23)	120	2.1	8.0	2.0	13.0	4.0
	N11-FA-10-120-(11,16,23)	120	2.1	10.0	2.2	15.0	5.0
	N11-FA-30-120-(11.16.23)	120	2.1	30.0	2.2	40.0	4.5
	N11-FA-60-120-(11.16.23)	120	2.1	60.0	2.2	65.0	5.5
	N11-FA-2-350-(11,16,23)	350	2.0	2.0	2.2	7.0	3.5
	N11-FA-5-350-(11,16,23)	350	2.1	5.0	2.6	11.0	4.0
	N11-FA-8-350-(11,16,23)	350	2.1	8.0	4.0	14.0	6.0
	N11-FA-10-350-(11,16,23)	350	2.1	10.0	4.5	18.0	6.5
	N11-MA-03-120-(11,16,23)	120	1.9	0.3	1.8	3.5	2.5
	N11-MA-1-120-(11,16,23)-P4	120	2.0	1.0	1.0	4.0	2.0
	N11-MA-2-120-(11,16,23)	120	2.0	2.0	1.6	6.0	2.5
	N11-MA-5-120-(11,16,23)	120	2.1	5.0	1.8	9.5	3.5
	N11-MA-8-120-(11,16,23)	120	2.1	8.0	2.0	13.0	4.0
	N11-MA-10-120-(11,16,23)	120	2.1	10.0	2.2	15.0	5.0
	N11-MA-2-350-(11.16.23)	350	2.0	2.0	2.2	7.0	3.5
	N11-MA-5-350-(11.16.23)	350	2.1	5.0	2.6	11.0	4.0
	N11-MA-8-350-(11.16.23)	350	2.1	8.0	4.0	14.0	6.0
	N11-MA-10-350-(11.16.23)	350	2.1	10.0	4.5	18.0	6.5
 10 sheets per box	N21-FA-2-120-(11,16,23)	120	2.0	2.0	1.6	7.5 × 7.5	
	N21-FA-5-120-(11,16,23)	120	2.1	5.0	1.8	12.0 × 12.0	
	N21-FA-5-350-(11.16.23)	350	2.1	5.0	2.6	16.0 × 16.0	
	N21-MA-2-120-(11,16,23)	120	2.0	2.0	1.6	7.5 × 7.5	
	N21-MA-5-120-(11,16,23)	120	2.1	5.0	1.8	12.0 × 12.0	
	N21-MA-5-350-(11.16.23)	350	2.1	5.0	2.6	16.0 × 16.0	
 10 sheets per box	N21-FA-8-120-(11,16,23)	120	2.1	8.0	2.0	φ 21.0	
	N21-FA-10-120-(11,16,23)	120	2.1	10.0	2.2	φ 25.0	

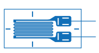
 10 sheets per box	**N22-FA-1-120-(11.16.23)**	120	2.0	1.0	1.5	φ 6.0
	N22-FA-2-120-(11,16,23)	120	2.0	2.0	1.6	φ 8.0
	N22-FA-5-120-(11,16,23)	120	2.1	5.0	1.8	φ 11.0
	N22-FA-8-120-(11,16,23)	120	2.1	8.0	2.0	φ 15.0
	N22-FA-10-120-(11,16,23)	120	2.1	10.0	2.2	φ 18.0
	N22-FA-5-350-(11.16.23)	350	2.1	5.0	2.6	φ 15.0
	N22-MA-2-120-(11,16,23)	120	2.0	2.0	1.6	φ 8.0
	N22-MA-5-120-(11,16,23)	120	2.1	5.0	1.8	φ 11.0
	N22-MA-5-350-(11.16.23)	350	2.1	5.0	2.6	φ 15.0
 10 sheets per box	**N31-FA-2-120-(11,16,23)**	120	2.0	2.0	1.6	9.0 × 9.0
	N31-FA-5-120-(11,16,23)	120	2.1	5.0	1.8	14.0 × 14.0
	N31-MA-2-120-(11,16,23)	120	2.0	2.0	1.6	9.0 × 9.0
	N31-MA-5-120-(11,16,23)	120	2.1	5.0	1.8	14.0 × 14.0
 10 sheets per box	**N31-FA-8-120-(11,16,23)**	120	2.1	8.0	2.0	φ 24.0
	N31-FA-10-120-(11.16.23)	120	2.1	10.0	2.2	φ 28.0
 10 sheets per box	**N32-FA-1-120-(11.16.23)**	120	2.0	1.0	1.5	φ 6.0
	N32-FA-2-120-(11,16,23)	120	2.0	2.0	1.6	φ 8.0
	N32-FA-5-120-(11,16,23)	120	2.1	5.0	1.8	φ 11.0
	N32-FA-8-120-(11,16,23)	120	2.1	8.0	2.0	φ 16.0
	N32-FA-10-120-(11,16,23)	120	2.1	10.0	2.2	φ 18.0
	N32-MA-2-120-(11,16,23)	120	2.0	2.0	1.6	φ 8.0
	N32-MA-5-120-(11,16,23)	120	2.1	5.0	1.8	φ 11.0

Special strain gauge

Gauge pattern	Model	Nominal resistance (Ω)	Gauge efficiency (Nominal)	Dimensions			
				Grid (mm)		Base (mm)	
				Length	Width	Length	Width
 10 sheets per box	**N51-FA-1-120-(11,16,23)**	120	2.0	1.0	1.5	12.0	4.0
	N51-FA-2-120-(11,16,23)	120	2.0	2.0	1.6	15.0	6.0
	N51-MA-1-120-(11,16,23)	120	2.0	1.0	1.5	12.0	4.0
	N51-MA-2-120-(11,16,23)	120	2.0	2.0	1.6	15.0	6.0
 10 sheets per box	**R51-FA-1-120-(11,16,23)**	120	2.0	1.0	0.5	11.0	4.0
	R51-FA-2-120-(11,16,23)	120	2.0	2.0	0.8	15.0	4.5
	R51-MA-1-120-(11,16,23)	120	2.0	1.0	0.5	11.0	4.0
	R51-MA-2-120-(11,16,23)	120	2.0	2.0	0.8	15.0	4.5
 10 sheets per box	**Z11-FA-2-120-(11,16,23)**	120	2.0	2.0	4.0	13.0	5.0
	Z11-FA-5-120-(11,16,23)	120	2.0	5.0	2.6	15.0	10.0
	Z11-FA-10-120-(11,16,23)	120	2.1	10.0	5.0	26.0	16.0
	Z11-MA-2-120-(11,16,23)	120	2.0	2.0	4.0	13.0	5.0
	Z11-MA-5-120-(11,16,23)	120	2.0	5.0	2.6	15.0	10.0
	Z11-MA-10-120-(11,16,23)	120	2.1	10.0	5.0	26.0	16.0
 10 sheets per box	**Z23-FA-2-120-(11,16,23)**	120	2.0	2.0	–	13.0	7.0
	Z23-FA-5-120-(11,16,23)	120	2.1	5.0	–	15.0	14.0
	Z23-FA-10-120-(11,16,23)	120	2.1	10.0	–	26.0	25.0
	Z23-MA-2-120-(11,16,23)	120	2.0	2.0	–	13.0	7.0
	Z23-MA-5-120-(11,16,23)	120	2.1	5.0	–	15.0	14.0
	Z23-MA-10-120-(11,16,23)	120	2.1	10.0	–	26.0	25.0

Large-elongation strain gauge

This strain gauge has an improved strain limit, which allows for plastic strain measurement of up to + 10 %.

 10 sheets per box	**Y11-FA-2-120**	120	2.0	2.0	1.7	7.5	3.5
	Y11-FA-5-120	120	2.0	5.0	1.6	11.0	3.5
	Y11-FA-8-120	120	2.0	8.0	2.1	14.0	5.0

Piping strain gauge

This strain gauge is embedded in a bolt and performs axis force measurement when the bolt is tightened.

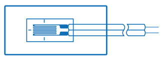
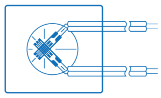
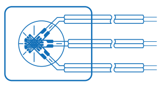
 25 sheets / 1 box	**P11-FA-3-120-(11)**	120	2.1	3.0	–	10.0	φ 2 ± 0.1
	P11-MA-3-120-(11)	120	2.1	3.0	–	10.0	φ 2 ± 0.1

For information about single-axis special strain gauges, classic strain gauges, and crack propagation strain gauges, please contact us.

Special strain gauge

Waterproof mold strain gauge

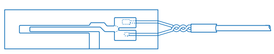
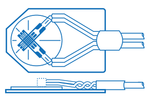
・Self-temperature compensating compatible material, normal rigidity 11 x 10^{-6} / °C

Gauge pattern	Model	Nominal resistance (Ω)	Gauge efficiency (Nominal)	Dimensions				Lead wire length (m)	
				Grid (mm)		Base (mm)			
				Length	Width	Length	Width		
 10 sheets per box	N11-FA-1-120-P4-W1	120	2.0	1.0	1.0	25	10	1	
	N11-FA-1-120-P4-W3	120	2.0	1.0	1.0	25	10	3	
	N11-FA-2-120-W1	120	2.0	2.0	1.6	25	10	1	
	N11-FA-2-120-W3	120	2.0	2.0	1.6	25	10	3	
	N11-FA-5-120-W1	120	2.1	5.0	1.8	25	10	1	
	N11-FA-5-120-W3	120	2.1	5.0	1.8	25	10	3	
 10 sheets per box	N22-FA-1-120-W1	120	2.0	1.0	1.5	25	20	1	
	N22-FA-1-120-W3	120	2.0	1.0	1.5	25	20	3	
	N22-FA-2-120-W1	120	2.0	2.0	1.6	25	20	1	
	N22-FA-2-120-W3	120	2.0	2.0	1.6	25	20	3	
	N22-FA-5-120-W1	120	2.1	5.0	1.8	25	20	1	
	N22-FA-5-120-W3	120	2.1	5.0	1.8	25	20	3	
 10 sheets per box	N32-FA-1-120-W1	120	2.0	1.0	1.5	25	20	1	
	N32-FA-1-120-W3	120	2.0	1.0	1.5	25	20	3	※
	N32-FA-2-120-W1	120	2.0	2.0	1.6	25	20	1	
	N32-FA-2-120-W3	120	2.0	2.0	1.6	25	20	3	※
	N32-FA-5-120-W1	120	2.1	5.0	1.8	25	20	1	
	N32-FA-5-120-W3	120	2.1	5.0	1.8	25	20	3	※

※ Five pieces per box, two boxes

Non-inductive strain gauge

This strain gauge is designed for use in inductive noise environments and can be used to dislodge special resistance elements and structures to effectively eliminate inductive noise.

Gauge pattern	Model	Nominal resistance (Ω)	Gauge efficiency (Nominal)	Dimensions				
				Grid (mm)		Base (mm)		
				Length	Width	Length	Width	
Operating temperature range : - 30 °C ~ 180 °C  5sheets / 2boxs	M11-ME-5-120-11-SC1	120	2.0	5.0	0.6	12.5	3	※
Operating temperature range : - 30 °C ~ 180 °C  5sheets / 2boxs	M22-ME-5-120-11-SC1	120	2.0	5.0	0.6	30.0	20	※

※ Five pieces per box, two boxes

Accessories for strain gauges

Adhesive

To obtain good data for strain measurement, select a strain gauge and adhesive for use in accordance with the measurement conditions.

Format	Component system	Adhesive material	Capacity	Bonding method	Gluing temperature (°C)	Storage	Notes
EXTRA4000	Cyanoacrylate (Instant adhesive)	Metal Plastic Composite material	2 g x 5	Apply pressure with fingers for at least 30 seconds, but time varies depending on the temperature conditions.	- 30 ~ + 70	Cool dark location for 3 months	Except P11 and Y11
F31	Epoxys 2 Fluid Mix (Room-temperature setting adhesive)	Metal Plastic Composite material	A Fluid 65g x 1 B Fluid 35 g x 1	Pressure (0.5 ~ 1.5 kg / cm²) 24 hours at room temperature Mixing ratio of A fluid to B fluid = 2 : 1	- 30 ~ + 80	Cool dark location for 6 months	
PR7781	Phenolic epoxys (heat setting adhesive)	Metal Composite material	50 g	Pressure (0.5 ~ 1.0 kg / cm²) 140 °C for 30 minutes	- 30 ~ + 180	Cool dark location for 3 months	
F1	Epoxys 2 Fluid Mix (heat setting adhesive)	Metal Plastic Composite material	A Fluid 65 g x 1 B Fluid 35 g x 1	Pressure(0.5 ~ 1.5 kg / cm²) 2 hours at 100 °C Mixing ratio of A fluid to B fluid = 2 : 1	- 30 ~ + 130	Cool dark location for 6 months	Except Y11

Coatings

The humidity processing coating is used in order to prevent accidents due to isolation problems or poor strength due to dampness of the adhered strain gauge and gauge terminals. It should be used when measurement is performed outdoors or over a long period.

Product name	Format	Capacity	Material	Operating temperature	Usages	Storage condition	Notes
RTV Silicon Rubber	TSE397	100 g	Silicone rubber	Air : - 55 to + 200	Apply this material to the protection area. Quick-dry tube-type, reacts to water bubbles in the air and hardens.	Cool dark location for 3 months	

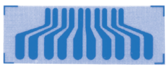
Format	Protected objects						Curing condition		
	External force	Humidity	Weather	Water	Oil	Solvent	Not required	Air drying	Heating
TSE397		○	○	△				○	

Accessories for strain gauges

Gauge terminal

The gauge terminal is used as a connection between the gauge lead wires and the leads to the instrument. It protects the gauge lead wires and prevents accidents such as disconnection or isolation failures that can easily occur at the point of connection.

Format	Operating temperature range
FG	+ 140 °C
SFG	+ 50 °C

Type	Shaping	Model	External dimensions (mm)	Applicable gauge length (mm)	Quantity per box (sheets)	Notes
Foil type		FG - 5T	6 × 20 × 0.15	0.3 ~ 2	10	
		SFG - 5T	6 × 20 × 1.0			Self-adhesive type
		FG - 7T	7 × 26 × 0.15	2 ~ 6	10	
		SFG - 7T	7 × 26 × 1.0			Self-adhesive type
		FG - 10T	12 × 40 × 0.15	6 ~ 8	10	
		SFG - 10T	12 × 40 × 1.0			Self-adhesive type
		FG - 15T	16 × 56 × 0.15	8 ~ 60	10	
		SFG - 15T	16 × 56 × 1.0			Self-adhesive type
		FGR - 10T	10 × 25 × 0.15	1 ~ 2	10	For rosette cross gauges
		SFGR - 10T	10 × 25 × 1.0			For rosette cross gauges Self-adhesive type
		FGR - 15T	15 × 38 × 0.15	5 ~ 10	10	For rosette cross gauges
		SFGR - 15T	15 × 38 × 1.0			For rosette cross gauges Self-adhesive type
		FGF - 5T	15 × 40 × 0.15	0.3 ~ 2	10	Five element gauges
		SFGF - 5T	15 × 40 × 1.0			Five element gauges Self-adhesive type

● Strain gauge model

N11-FA-5-120-11

① ② ③ ④ ⑤

①Gauge Pattern
- N1□ : Single axis — N□1: Single axis only
- N2□ : 2-axis — N□2 : Multi-axis cross gauge (with gauge overlap)
- N3□ : 3 Axis — N□3 : Multi-axis (no gauge overlap)

②Base material
- FA polyester, MA polyimide

③Grid length

④Gauge resistance
- 120：120 Ω、350：350 Ω

⑤Self-temperature compensated strain gauge linear dilation factor
- 11 : Normal Stiffness（11×10^{-6} / °C）
- 16 : Stainless steel（16×10^{-6} / °C）
- 23 : Aluminum alloy（23×10^{-6} / °C）

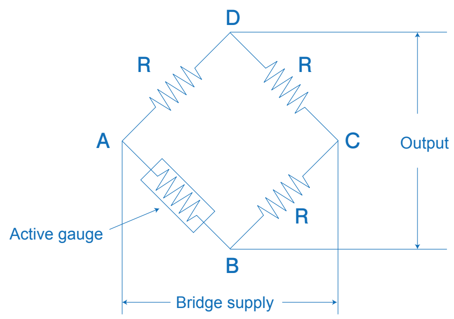
• Gauge factor correction formula

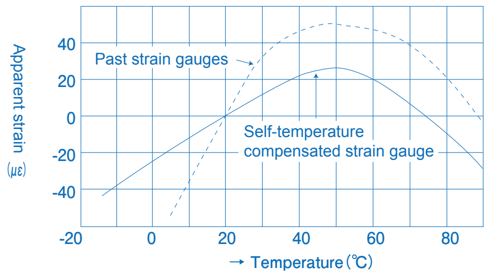
If the gauge ratio (2.0) of your instrument is different from the gauge ratio of your gauge, compensate for true strain values.

$$\text{True strain values} = \frac{2.0}{K} \times \text{measurement strain}$$

K : Strain gauge of gauge factor

• Self-temperature compensated strain gauge





The relationship between the resistance change and the temperature change of the strain gauge is generally the same as the relationship between the gauge resistance change and the temperature change of the strain gauge when the object to be measured is a flat surface.

$$\frac{\triangle R / R}{\triangle T} = \alpha + K \; (\beta_S - \beta_g)$$

Left: Rate of resistance change for resistance foils per 1 °C (Copper Nickel Alloy : ± 20 × 10 - 6 / °C)

α : Resistance temperature coefficients of resistance foils
K : Strain gauge of gauge factor
B s : Linear dilation factor of the object to be measured
B g : Linear dilation factor of resistance foil

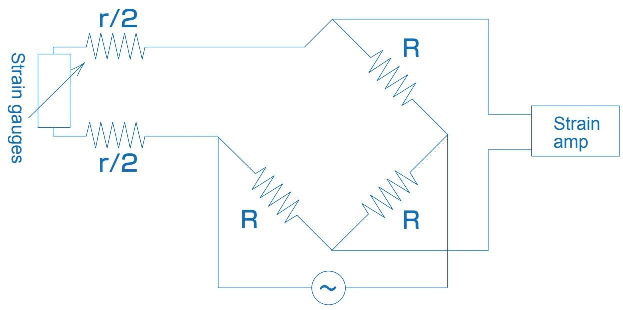
If a relationship in which the value on the right side becomes zero is established in the above equation, there is no effect related to temperature change.

As a result, strain gauges with an adjusted degree factor of alpha for the resistance temperature of the strain gauge resistance foils is called a self-temperature compensation gauge.

• Precautions for strain measurement

1) Effects of connection leads

In the single gauge 2-wire system that is commonly used, since the side of the bridge includes not only the gauge resistor but also the resistance of the lead line, bridge unbalance, a decrease in the gauge factor, and an increase in the temperature drift by the connection lead cannot be avoided in principle.



Lead length and resistance

2) How lead resistance affects gauge factor

The gauge factor when the lead resistance γ is 0

$$K = \frac{\triangle R / R}{\varepsilon}$$

ε : Strain
R : gauge resistance
△ R : Resistance change of R due to strain ε

However, the gauge factor is reduced when the lead resistance γ is included.

$$K' = \frac{\triangle R / R + \gamma}{\gamma}$$

K' : True gauge factor
γ : Round-trip resistance value of the lead

3) Affect of lead temperature

If the ambient temperature changes during strain measurement, the resistance γ of the lead (copper) changes at a rate of 3930 × 106 / °C. The △ γ change is measured as if an apparent strain were generated by the change of the gauge resistance R.

To the error of the apparent distortion öt and the nominal measurement by temperature

The magnitude of the appearance is given by.

$$\varepsilon_t = \frac{\triangle \gamma}{R + \gamma} \cdot \frac{1}{K}$$

The resistance change amount △ γ depending on the temperature of the lead wire is calculated as follows:

$$\triangle \gamma = \gamma \cdot \alpha \cdot t$$

$$\varepsilon_t = \frac{\gamma \cdot \alpha \cdot t}{(R + \gamma) \cdot K}$$

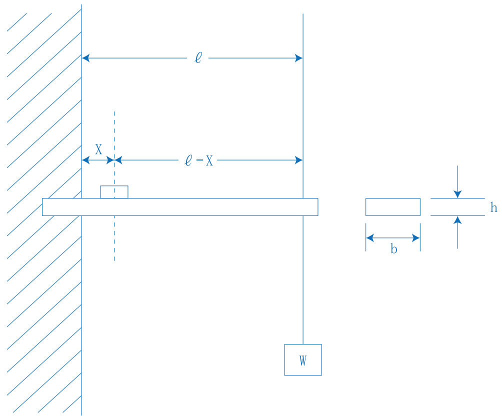
α : Temperature coefficient of the resistance
K : True gauge factor t: Lead temperature
t : Lead temperature change amount

Effect of connection leads

	Resistance value Ω of the gauge lead wire			Lower gauge factor percentage			Strain output by temperature με/°C		
Length (m)	A (thin) 0.44Ω/m	B(mid-diameter) 0.3Ω/m	C (thick) 0.2Ω/m	Lead wire A	Lead wire B	Lead wire C	Lead wire A	Lead wire B	Lead wire C
	0.44	0.3	0.2	0.4	0.2	0.2	7	5	3
1	0.88	0.6	0.4	0.7	0.5	0.3	14	10	7
2	1.32	0.9	0.6	1.1	0.7	0.5	21	15	10
3	1.76	1.2	0.8	1.4	1.0	0.7	28	19	13
4	2.20	1.5	1.0	1.8	1.2	0.8	35	24	16
5	2.64	1.8	1.2	2.2	1.5	1.0	42	29	19
6	3.08	2.1	1.4	2.5	1.7	1.2	49	34	23
7	3.52	2.4	1.6	2.8	2.0	1.3	56	39	26
8	3.96	2.7	1.8	3.2	2.2	1.5	63	43	29
9	4.40	3.0	2.0	3.5	2.4	1.6	70	48	32
10	6.60	4.5	3.0	5.2	3.6	2.4	102	71	48
15	8.80	6.0	4.0	6.8	4.8	3.2	134	94	63
20	11.00	7.5	5.0	8.4	5.9	4.0	165	116	79
25	13.20	9.0	6.0	9.9	7.0	4.8	195	137	94

※The most commonly used lead is A. ※The lead resistance indicates the round-trip resistance. ※The gauge resistance is calculated as 120Ω.

• Cantilever beam strain measurement



Method of theoretical calculation

The stress σ of part of the cantilever beam is expressed by the following equation.

$$\sigma = \frac{Mx}{Z}$$

In addition, bend moment $Mx = W \cdot (\ell - x)$、

The cross-section coefficients Z are based on $Z = \frac{1}{6} bh^2$

$$\sigma = \frac{6W(\ell - x)}{bh^2}$$

Cantilever beam surface stress $\sigma = \varepsilon E$

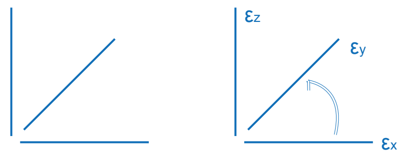
Cantilever beam surface stress ε is expressed by the following equation.

$$\varepsilon = \frac{6W(\ell - x)}{Ebh^2}$$

• Rosette analysis method

In general, if stress is measured when the principal stress direction is unknown, stress measurement must be performed in three directions in order to know the stress and direction. Draw at least three straight lines around the point you want to measure and measure distortion on those lines. This set of lines is called a rosette. Since the direction of the principal force is the same as the direction of the principal strain in an isometric or isometric elastic body, a theoretical formula can be used to determine the value of the principal force and its direction. In this way, obtaining the principal stress, the magnitude of the principal stress, and the direction of that point from the strain amount in several directions is called rosette analysis.

• Right-axis triangular rosette strain gauge



Right-axis Triangular

Max. principle strain ε_{max}

$$\varepsilon_{max} = \frac{1}{2}\left[\varepsilon_x + \varepsilon_z + \sqrt{2\{(\varepsilon_x - \varepsilon_y)^2 + (\varepsilon_y - \varepsilon_z)^2\}}\right]$$

The minimum principal strain isε_{min}

$$\varepsilon_{min} = \frac{1}{2}\left[\varepsilon_x + \varepsilon_z - \sqrt{2\{(\varepsilon_x - \varepsilon_y)^2 + (\varepsilon_y - \varepsilon_z)^2\}}\right]$$

The direction of the principal strain φ from the strain gauge ε_x is

$$\varphi = \frac{1}{2} \cdot \tan^{-1} \frac{2\varepsilon_y - (\varepsilon_x + \varepsilon_z)}{\varepsilon_x - \varepsilon_z}$$

Max. principle strain ε_{max} direction θ

$\varepsilon_z - \varepsilon_x < 0 \cdot \cdot \cdot \cdot \cdot \theta = \varphi$

$\varepsilon_z - \varepsilon_x > 0 \cdot \cdot \cdot \cdot \cdot \theta = \varphi + \frac{\pi}{2}$

Maximum principle stress σ max

$$\sigma_{max} = \frac{E}{1 - v^2}(\varepsilon_{max} + v\varepsilon_{min})$$

Minimum principal stress σmin

$$\sigma_{min} = \frac{E}{1 - v^2}(\varepsilon_{min} + v\varepsilon_{max})$$

v : Poisson's ratio

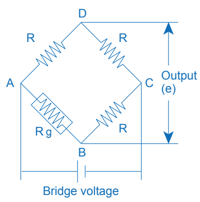
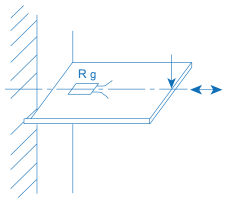
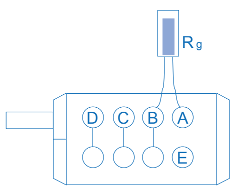
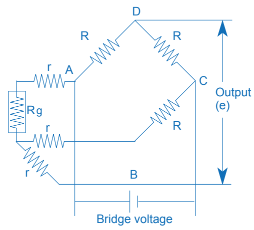
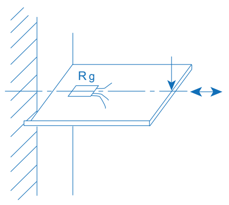
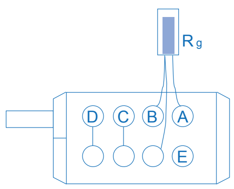
Max. shear strain γmax

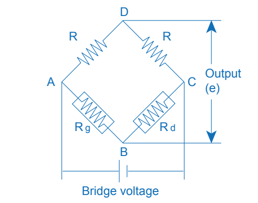
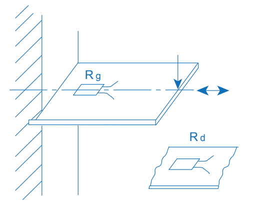
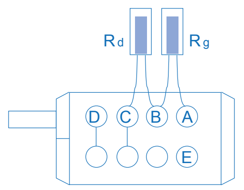
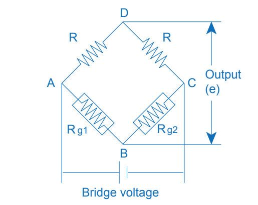
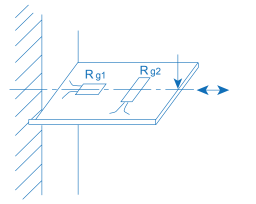
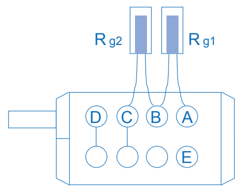
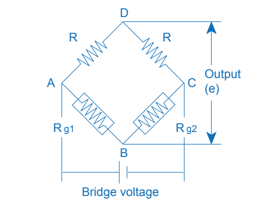
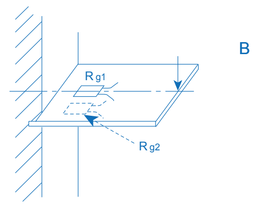
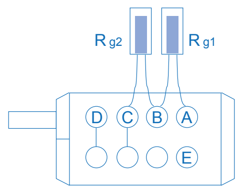
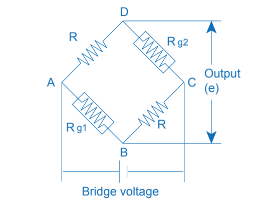
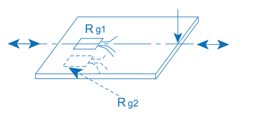
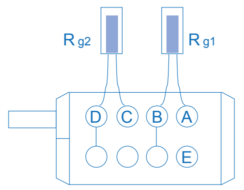
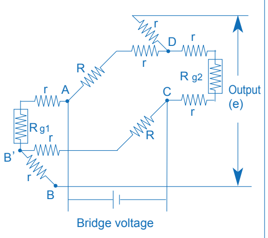
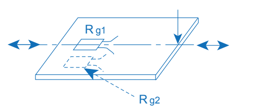
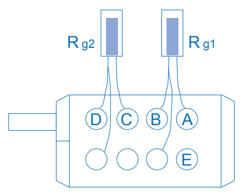
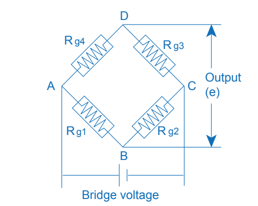
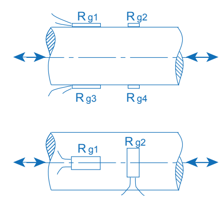
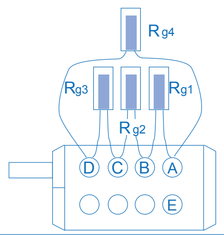
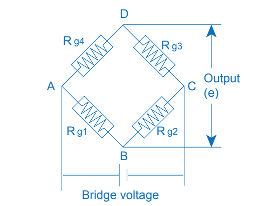
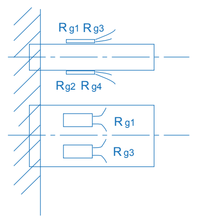
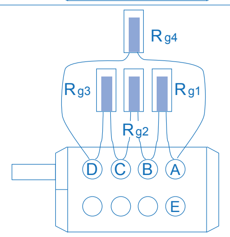
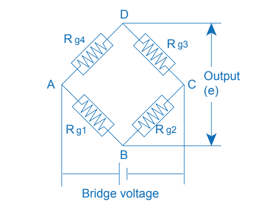
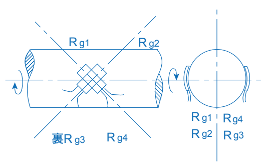
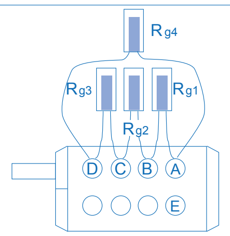
$$\gamma_{max} = \sqrt{2\{(\varepsilon_x - \varepsilon_y)^2 + (\varepsilon_y - \varepsilon_z)^2\}}$$

Maximum shear stress τmax

$$\tau_{max} = \frac{E}{2(1 + v)} \cdot \gamma_{max}$$

• How to assemble a bridge circuit for measurement

Circuit	Gauge technique	Specific example	Bridge box wiring method	Notes
	**Quarter bridge gauge technique**			**·Suitable for simple tension, compression, or simple bends.** **·Appropriate for when ambient temperature changes are small** **·Calculate the calibration value as is**
	**Quarter bridge gauge Three wire system**			**·Suitable for simple tension, compression, or simple bends.** **·Temperature compensation for strain gauge leads** **·Calculate the calibration value as is**

Circuit	Gauge technique	Specific example	Bridge box wiring method	Notes
	**1 Active active-dummy gauge technique**			**·Suitable for simple tension, compression, or simple bends.** **·Temperature compensation** **·Calculate the calibration value as is**
	**2 active gauge technique**			**·Suitable for simple tension, compression, or simple bends.** **·Temperature compensation** **·Calculated by the calibration value × 1 / (1 + *v*) or the phenomenon value × 1 / (1 + *v*).**
	**2 active gauge technique**			**·Bend strain detection** **·Pull, compression distortion erase** **·Temperature compensation** **·Calculated with calibration value × 1 / 2 or problem value × 1 / 2.**
	**Opposite 2 active gauge method**			**·Detect tension and compression strain** **·Remove bend strain** **·The impact of temperature changes is doubled.** **·Calculated with calibration value × 1 / 2 or problem value × 1 / 2.**
	**Opposite 2 active gauge three wire system**			**·Remove bend strain** **·The impact of temperature changes is doubled.** **·Temperature compensation for strain gauge leads** **·Calculated with calibration value × 1 / 2 or problem value × 1 / 2.**
	**4 active gauge technique**			**·Detect tension and compression strain only** **·Remove bend strain** **·Temperature compensation** **·Calculated by calibration value × 1 / 2 (1 + *v*) or phenomenon value × 1 / 2 (1 + *v*)**
	**4 active gauge technique**			**·Detect bend only** **·Remove tension and compression strain** **·Temperature compensation** **·Calculated with calibration value × 1 / 4 or problem value × 1 / 4.**
	**4 active gauge technique**			**·Detect twist strain only** **·Remove tension, compression, and bend strain** **·Temperature compensation**

A&D Company, Ltd.

Discover Precision

A&D Company, Ltd.
3-23-14 Higashi-Ikebukuro, Toshima-Ku, Tokyo, 170-0013, Japan Tel: +81 3-5391-6132 Fax: +81 3-5391-1566 http://www.aandd.jp

A&D Engineering, Inc.
1756 Automation Parkway, San Jose, CA 95131, U.S.A. Tel: +1 408-263-5333 Fax: +1 408-263-0119

A&D Australasia Pty Ltd.
32 Dew Street, Thebarton, South Australia 5031, Australia Tel: +61 8-8301-8100 Fax: +61 8-8352-7409

A&D Instruments Ltd.
Unit 24/26 Blacklands Way, Abingdon Business Park, Abingdon, Oxfordshire, OX14 1DY, United Kingdom Tel: +44 1235-550420 Fax: +44 1235-550485
<German Sales Office>
Hamburger Straße 30, D-22926, Ahrensburg, Germany Tel: +49 4102-459230 Fax: +49 4102-459231

A&D Korea Ltd.
8F Manhattan Bldg., 33, Gukjegeumyung-ro 6-gil, Yeongdeungpo-gu, Seoul, 07331, Korea Tel: +82 2-780-4101 Fax: +82 2-782-4280

A&D Rus Co., Ltd.
Vereyskaya Str. 17, 121357, Moscow, Russia Tel: +7 495-937-33-44 Fax: +7 495-937-55-66

A&D Instruments India (P) Ltd.
509 Udyog Vihar Phase V Gurgaon-122 016, Haryana, India Tel: +91 (124) 471-5555 Fax: +91 (124) 471-5599

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