Technical data

Force Sensor : HFD-20N-A02

1. Scope

This document describes usage of force sensor (HFD-20N-A02) made by Hokuriku Electric Industry Co., Ltd.

2. Glossary of Rating / Standard

2-1) Absolute maximum rating

This is the value which must not exceed in any moment and any one of two or more maximum ratings must not be exceeded, either.

(1) Applied Force

This is maximum force which can maintain performance continuously.

(2) Drive Voltage

This is voltage range which does not cause destruction, or degradation of characteristic or reliability, even if voltage is applied.

(3) Storage Temperature Range

This is temperature range which does not cause degradation of characteristic or reliability, even if it is left for a long time without drive voltage applied.

(4) Operating Temperature Range

This is maximum range of temperature which can maintain performance continuously, without drive voltage applied.

2-2) Rating

This is the condition which must be kept in order to guarantee electrical characteristic and maintain quality.

(1) Measurable Force Range

This is force range which can be measured in which electrical characteristic is guaranteed. Where, MAX value-MIN value shown here shall be defined as full-scale (FS).

(2) Drive Voltage

This is drive voltage in which electrical characteristic is guaranteed. If drive voltage is below maximum rating, it is operational. Where, output voltage at that time becomes ratiometric in reference to Vcc=3.0V.

(3) Bridge Resistance Rs

This is composite resistance when Wheatstone bridge formed. (between Vcc - GND)

(4) Offset Voltage

Offset voltage (25℃) is defined as output voltage when measured force is 0N.

(5) Full-scale Span

Full-scale span (25℃) is defined as change amount of output voltage in a full scale.

(6) Sensitivity

This is value which dividing full-scale span (25℃) by measurable force range (MAX value-MIN value). This value indicates change amount of output voltage per unit force change.

(7) Linearity

In characteristic graph of force vs. output voltage, linearity is indicated by how much at maximum actual output voltage shifts from the straight line which connects offset voltage and measured force (MAX value) voltage. This is value (%FS) which normalized difference of offset voltage and output voltage when applied middle force of MAX value, with full-scale span (25℃).

(8) Offset Temperature Characteristic

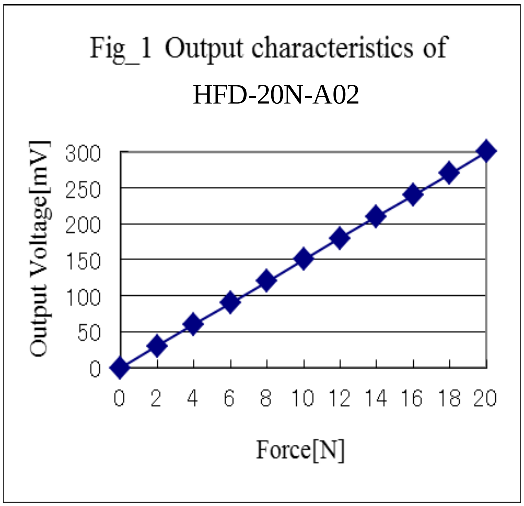
This is change rate of offset voltage in operating temperature range, MAX/MIN to the offset voltage at 25℃.

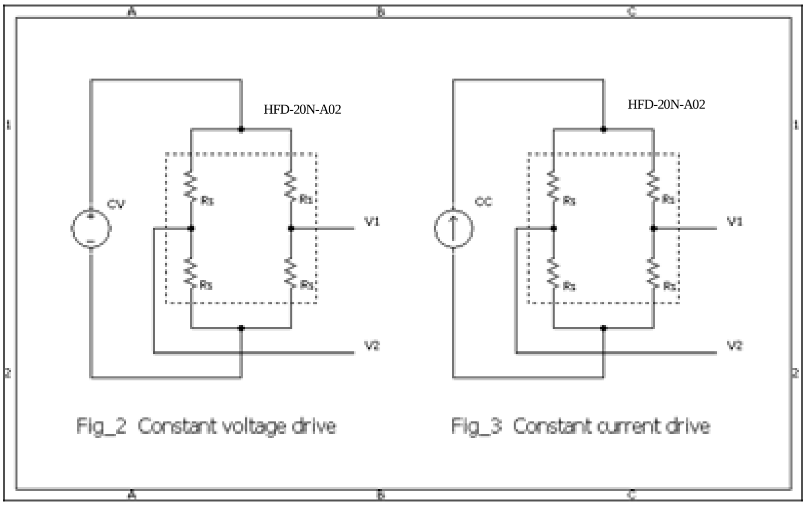
(9) Sensitivity Temperature Characteristic

This is change rate of full-scale span in operating temperature range, MAX/MIN to full-scale span at 25℃.

3. Drive Method and Element Characteristic

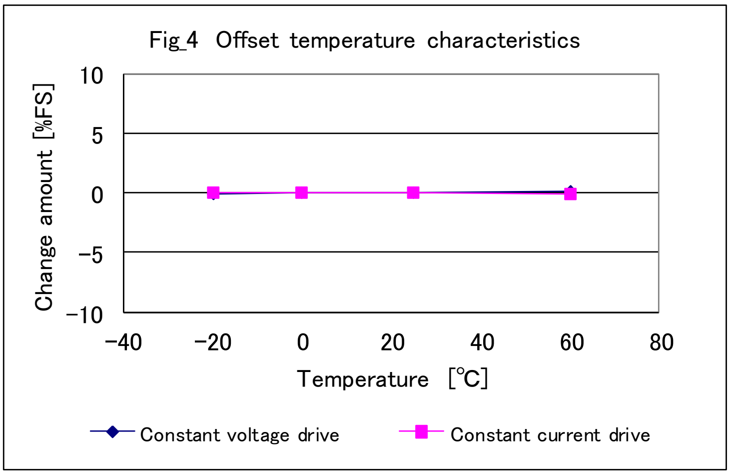
Force sensor (HFD-20N-A02) has diaphragm (pressure receiver) which made silicon substrate thin by etching etc., and uses piezo resistance effect of resistors formed by diffusion or ion implantation on the diaphragm.
When Wheatstone bridge (Fig.2, Fig.3) is formed by piezo resistors and current / voltage are applied, output potential proportional to applied force can be obtained.

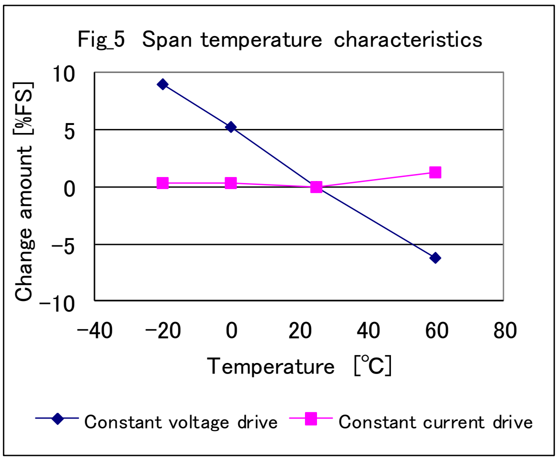




There are constant voltage drive and constant current drive in sensor driving method.
Constant current drive excels constant voltage drive in sensitivity temperature characteristic. Therefore, when using under the environment of large temperature change, constant current drive is recommended to use.
(Note) Constant current drive has larger bend characteristic of sensitivity temperature characteristic. Constant voltage drive has more linear change.

< Difference between offset temperature characteristic and sensitivity temperature characteristic by sensor drive method, (Fig.4, Fig.5) >





4. Circuit Configuration

4-1) Amplification circuit

Peripheral circuit is needed in order to use force sensor. Peripheral circuit consists of mainly drive circuit and amplification circuit. Function of adjusting offset and sensitivity should be set in amplification circuit.

Example of peripheral circuit is shown in Fig.6 and Fig.7.

Fig.6 consists of differential amplification circuits by one operational amplifier. Since this circuit has low input impedance of amplification circuit, resistance variation and temperature characteristic of sensor become the Gain change factor of an amplification circuit.

Fig.7 is the circuit which made input impedance of amplification circuit high by forming instrumentation amplifier, and suppressed influence of sensor resistance.

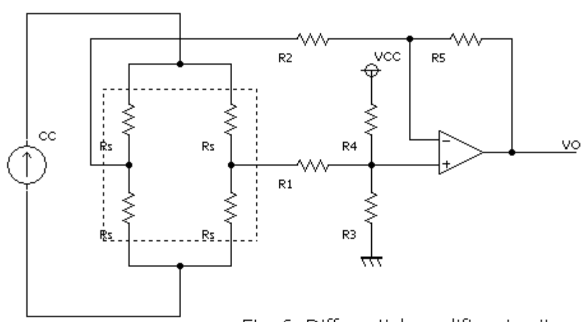


Fig_6 Differential amplifier circuit

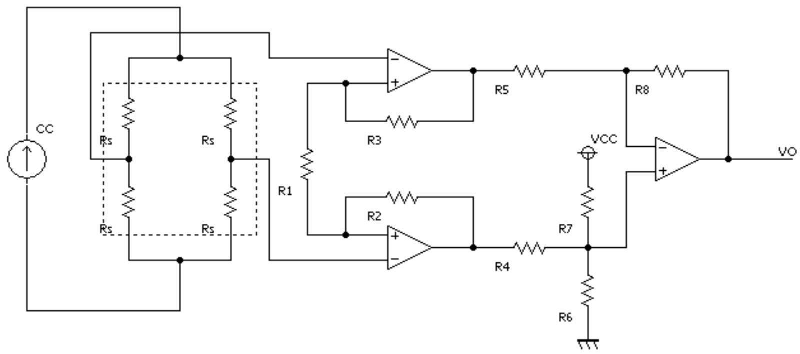


Fig_7 Instrumentation Amplifier circuit

[Fig .6, Calculation method of GAIN, OFFSET of differential amplification circuit]

R1 = R2, R3 // R4 = R5

GAIN = R5 / (R1+ (Rs / 2))

OFFSET = VCC x (R3 / (R3 + R4))

[Fig.7, Calculation method of GAIN, OFFSET of instrumentation amplifier]

R2 = R3, R4 = R5, R6 // R7 = R8

GAIN =(2 x (R2 / R1) + 1) x (R8 / R5)

OFFSET = Vcc x (R6 / (R6 + R7))

(*) On instrumentation amplifier, Rs (sensor resistance) does not influence GAIN.

4-2) Drive circuit

Fig.8-10 shows example of sensor drive circuit.

Fig.8 shows constant voltage drive circuit. Normally, circuit power supply is connected to sensor power supply terminal.

Fig.9 shows constant current drive circuit using operational amplifier. Since “V3=fixed value” is always true in this circuit, current flowing in the sensor can be controlled to constant current of V3/R3.

<Notes of constant current drive circuit>

(1) It is necessary to keep “source current capability of operational amplifier > constant current value”.
(Fig.10 is an example of circuit which has improved source current capability of operational amplifier.)

(2) Generally, when temperature rises, sensor resistance Rs becomes larger and V4 goes up.
Please consider rise of V4 voltage in high temperature, when deciding constant current value.

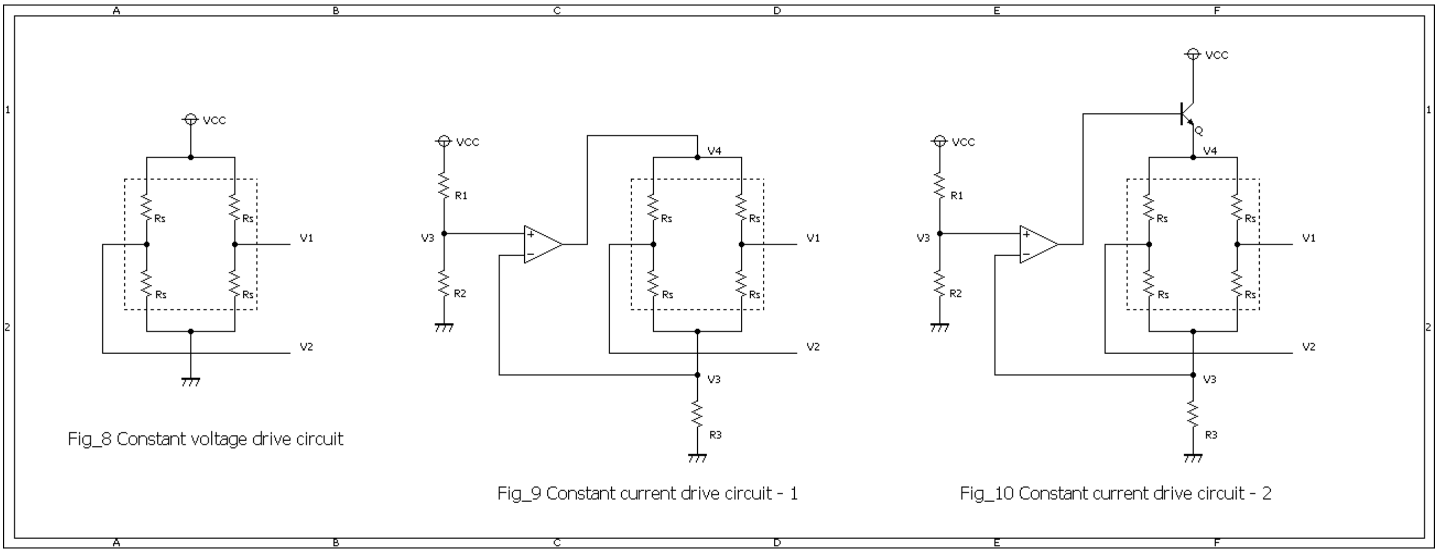


Fig_8 Constant voltage drive circuit

Fig_9 Constant current drive circuit - 1

Fig_10 Constant current drive circuit - 2

5. Recommended Circuit

Example of amplifier circuit (recommended circuits.1 and 2) for force sensor HFD-20N-A02 using operational amplifier is shown below.

< Recommended circuit 1 (Low cost type) >

Recommended circuit 1 (Fig.11) is the simplest circuit that consists of one operational amplifier.

The sensor is driven by constant voltage.

This circuit has fewer numbers of parts and advantage in cost. However, since resistance variation and temperature characteristic of the sensor affect to GAIN, please use it for application in which accuracy is not required specifically.

< Recommended circuit 2 (High precision type) >

Recommended circuit 2 (Fig.12) is high precision circuit in which instrumentation amplifier is used for amplifier circuit. In this circuit, sensor is driven by constant current drive. This has function of adjusting offset, gain and sensor current (constant current).

The following recommended circuit 2 is recommended.

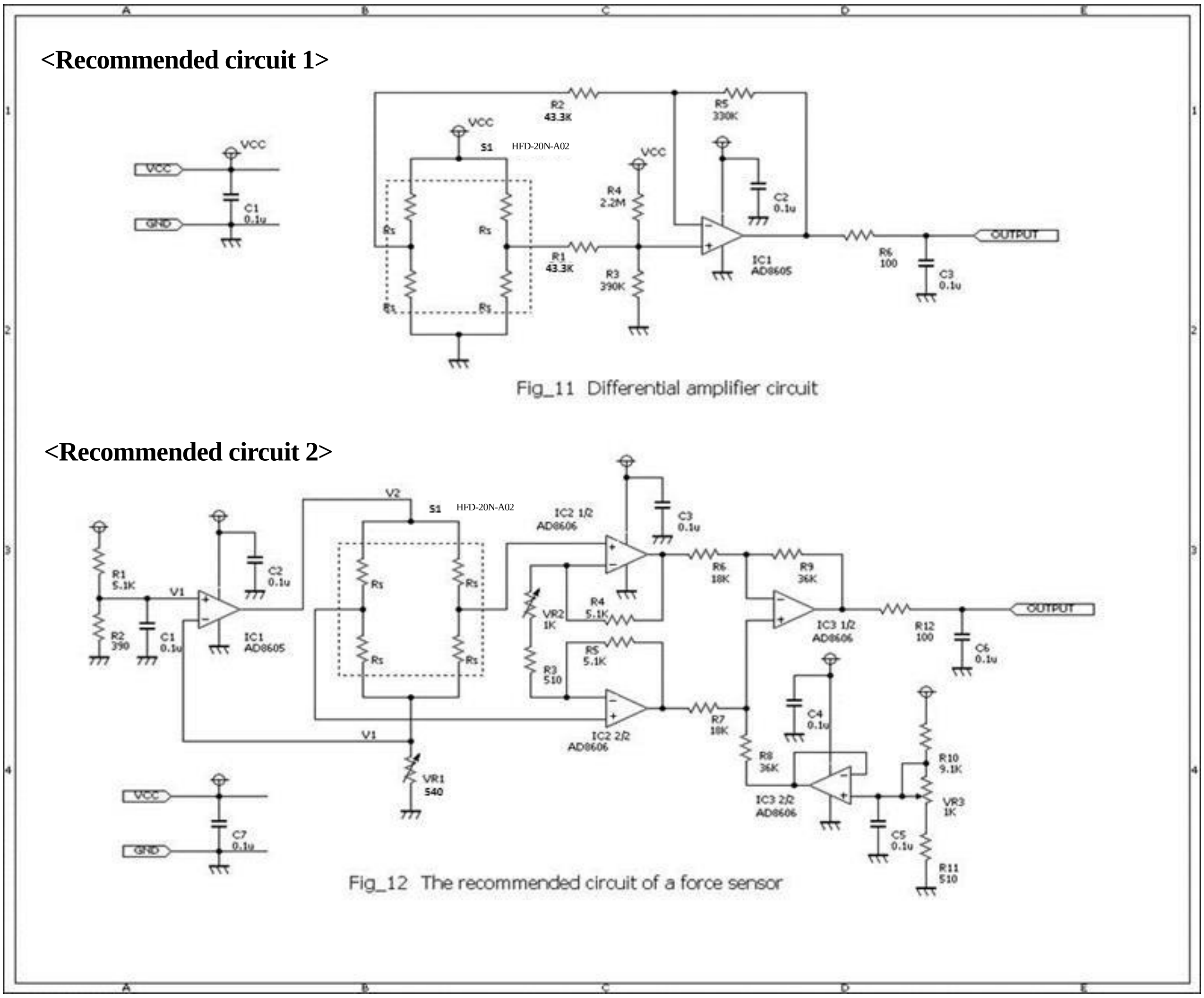


Fig_11 Differential amplifier circuit

Fig_12 The recommended circuit of a force sensor

AD8605, AD8606: Precision, Low Noise, CMOS, Rail-to-Rail, Input / Output Operational Amplifiers (ANALOG DEVICES)

Table.1 HFD-20N-A01 Rating

	Rating			Unit	
	Min	Typ.	Max		
Drive voltage	-	3	-	V	
Bridge resistance	3.5	5	6.5	kΩ	
Offset voltage	-10	-	10	mV	
Full-scale Span	210	300	390	mV/20N	
Sensitivity	-	15	-	mV/N	
Offset temperature characteristic	-5	-	5	%FS	⊿from 25℃ -20 ~ +60℃
Sensitivity temperature characteristic	-0.1	-	0	%FS/N/℃	

5-1) Recommended circuit 1 (Fig. 11)

R3//R4 = R5, R1 = R2

[Design value]

Vcc: 3.0V

Gain : Bridge resistance Rs = 5[kΩ], thus

Gain = R5 / (R2 + (Rs / 2)) = 330[kΩ] / (43.3[kΩ] + (5[kΩ] / 2)) = 7.2

Offset : Offset = Vcc x R3 / (R3+R4) = 3.0[V] x 390[kΩ] / (390[kΩ] + 2.2[MΩ]) = 0.452[V]

5-2) Recommended circuit 2 (Fig. 12)

R6 = R7, R9 = R8, R4 = R5

[Design value]

Vcc: 3.0V

Gain : When RG = VR2 + R3 = 2.2[kΩ],

Gain = (2 x (R4/RG) +1) x (R9/R6) = (2 x (5.1[kΩ] / 2.2[kΩ]) + 1) x (36[kΩ] /18[kΩ]) = 11.3

Offset : When Ro = VR3 + R11 = 1[kΩ], VR1 = 2.7[kΩ]

Offset = Vcc x Ro / (Ro + R10) = 3.0[V] x1[kΩ] / (1[kΩ] + 9.1[kΩ]) = 0.297[V]

Constant current : When VR1 = 540 [Ω],

V1 = Vcc x R2 / (R1 + R2) = 3.0[V] x 390[Ω] / (390 [Ω] + 5.1 [kΩ]) = 0.213[V]

Constant current = V1 / VR1 = 0.213[V] /540[Ω] = 394.4 [μA]

(Note) When HFD-20N-A01 is used by constant current drive of 394.4 [μA], drive voltage V2 to the sensor can be calculated as below,

V2 = bridge resistance x constant current value = 5[kΩ] x 394.4[μA] = 1.97 [V]

Sensor output becomes ratiometric to drive voltage.

Therefore, sensor output characteristic in the recommended circuit 2 (Fig.12) becomes as below.

Table.2 Output characteristic of Recommended circuit 2 (Constant current) for HFD-20N-A01

	Sensor characteristic at V2 = 1.97[V]			Unit	
	Min	Typ.	Max		
Drive voltage	-	1.97	-	V	
Offset voltage	-7	-	7	mV	
Full-scale Span	138	197	256	mV/20N	
Sensitivity	-	9.85	-	mV/N	
Offset temperature characteristic	-5	-	5	%FS	△from 25℃ -20 ~ +60℃
Sensitivity temperature characteristic	0	-	0.01	%FS/N/℃	

(※) The above value of sensitivity temperature characteristic is actual measured value