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Model HB-01

HiBand Amplifier

Instruction Manual

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Introduction

The Model HB-01 HiBand Amplifier is a charge amplifier intended for use with capacitive probes. The HB-01 contains a low-noise, high-efficiency switching power supply, which generates a dc voltage of approximately 100 volts for biasing the capacitive probe. The change in the amplifier output voltage is proportional to the change in the capacitance of the probe. The output stage of the HB-01 is capable of driving 50-ohm cables up to 1000 feet or more in length.

The HB-01 is described in US Patent 5,723,980 entitled Clearance Measurement System, which issues on March 3, 1998.

Principle of Operation

A simplified schematic of the HB-01 is shown in Figure 1.

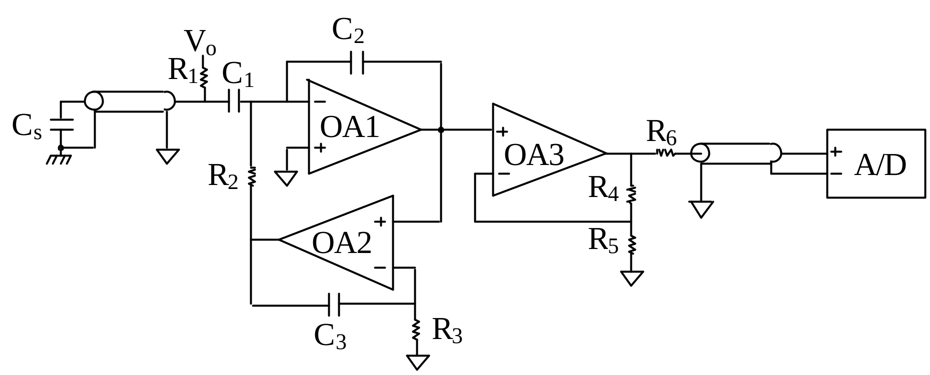

Figure 1. Simplified Schematic of HB-01

A capacitive sensor, shown as Cs in Figure 1, consists of a spark-plug type of electrode plus a grounded target, such as a compressor blade of a jet engine. This structure can be modeled as a grounded capacitor, whose capacitance changes (increases) when a blade passes in front of the sensor. A coaxial cable connects the sensor capacitor, Cs, to the HB-01 HiBand Preamp. The center conductor of the coaxial cable is attached to the sensor electrode, and the shield of the cable is attached to the engine casing, which is at ground potential. At the HB-01 end of the cable, the center conductor is connected the input of the first stage amplifier and the shield of the cable is connected to the analog ground of the circuit.

A switching power supply generates a high voltage (typically 100 volts) and applies this voltage to the capacitive sensor through resistor R1. The dc voltage of the sensor is blocked by capacitor C1, and any change in voltage at the sensor is applied to the negative input of operational amplifier OA1 by capacitor C1. Amplifier OA1 has a feedback capacitor, C2, which causes the amplifier to act as a charge amplifier. OA1 will try to keep the voltage on Cs to be constant (at the dc bias voltage). As a result, the amplifier output is proportional to the change in charge required to keep the capacitive probe at the constant bias voltage. If the capacitance of Cs changes, due to a blade passing in front of the sensor, the charge on Cs must change, and this charge is supplied by OA1 through capacitor C2. The change in output voltage on OA1 will be equal to:

$$\Delta V = (\Delta Cs)\,(Vo) / (C2) \qquad (1)$$

where

ΔV is the change in output voltage at the output of OA1,
ΔCs is the change in capacitance at the sensor, and
C2 is the value of the feedback capacitor.

Typical numbers for the gain setting components are:

Vo 100 volts
C2 47 pF or 10 pF, depending on desired gain

Thus a change in capacitance of the sensor equal to 0.47 pF will cause a change in the output voltage of OA1 to be 1 volt.

Amplifier OA3 provides additional gain to the signal at the output of OA2 and also provides a low output impedance to drive a coaxial cable. Resistors R4 and R5 are typically the same value, so that the gain of the output stage is 2.00. For the example of a change of sensor capacitance of 0.47 pF above, the output of the HB-01 would change 2 volts.

The bandwidth of the HB-01 depends on the particular choice for amplifiers OA1 and OA2. For the components installed at the factory, the bandwidth is approximately 5 MHz.

Amplifier OA2, resistors R2 and R3, and capacitor C3 – operating as an integrating current source – provide local feedback to keep the dc voltage at the output of OA1 close to ground. In effect, resistor R2 supplies the necessary dc input current to OA1 in order to keep the output of OA1 at ground.

Resistor R6 is typically 50 ohms in order to back-terminate the output coaxial cable (which has a characteristic impedance of 50 ohms). Resistor R6 insures that any signals that may be reflected by an impedance mismatch at the far end of the cable are eliminated when they return to the HB-01. As a result, the length of the coaxial cable between the HB-01 and any A/D converter or data acquisition system can be quite large: at least 1000 feet, if desired.

Resistor R1 is typically 50 K ohms. If the sensor becomes corroded, which results in an apparent resistor across capacitor Cs, then the voltage on Cs would normally drop due to the resistor divider between R1 and the sensor resistor. Referring to Equation 1, the sensor resistance would cause a change in gain for the HB-01. However, the high-voltage converter in the HB-01 actually senses the voltage on the input pin of the preamp and adjusts the value of Vo so that the dc voltage on the sensor remains at 100 volts. The high-voltage converter is designed to clamp at about 250 volts, which means that as long as the resistance on the probe is larger than 33 K ohms, the dc voltage on the sensor capacitance will be 100 volts and the gain of the HB-01 is unchanged.

The length of the input coaxial cable between the sensor and the HB-01 does not affect the gain or the bandwidth of the HB-01. However, the capacitance of the cable has a direct effect on the noise level at the output of the HB-01. A large cable capacitance causes the noise gain of the preamp to increase. Even though OA1 is a low-noise op amp, a large capacitance due to a large cable length will degrade the signal to noise of the system (by increasing the noise). For this reason, the input cable should have as low a capacitance per foot as is practical, and the length should be kept to a minimum. Cable lengths less than 30 feet, with cables having 30 pF per foot are recommended; ideally, cable lengths are less than 15 feet.

A clamp circuit (not shown) prevents the voltage at the internal connection between OA1 and OA3 from exceeding +/- 2 volts. As a result, the output voltage of the HB-01 is limited to approximately +/- 4 volts.

Grounding and Shielding Considerations

As can be seen by equation 1, the input of the HB-01 is extremely sensitive to electrostatic fields. Consequently, the connection between the sensor capacitor, Cs, and the preamp input must be done through a shielded coaxial cable.

The entire HB-01 HiBand Preamp is housed in a metal box that shields the entire unit from electrostatic fields. In addition, the input section of the HB-01 is surrounded by an internal shield in order to reduce noise pickup. In addition, the high-voltage switching converter is also surrounded by an internal shield to reduce any coupling of the switching transients to the preamp input. The result of all the shielding is that the noise at the output of the HB-01 due to the switching converter is considerably less than the noise due to the preamp input stage. The noise on the 100 volt dc power supply (Vo) is typically less than 100 micro volts. That is, the coupling to the preamp input is below –120 dB.

An internal jumper is installed at the factory to connect the chassis of the HB-01 to the analog ground of the circuit. This jumper is located on the bottom of the printed circuit board adjacent to the output BNC connector, as shown in Figure 2. If the jumper is removed, the chassis should be connected to either the circuit analog ground or to the ground at the capacitive sensor. A connection to the chassis is available at a pin on the power connector.

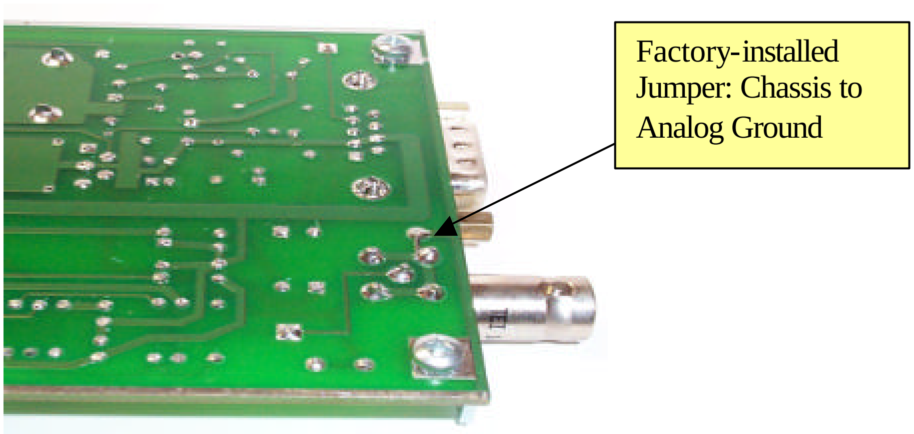

Figure 2. HB-01 Printed Circuit Board

A word of caution: care must be exercised in connecting the output cable to a data acquisition system. Generally speaking, the data acquisition system may be some distance away from the capacitive probe, so that data acquisition ground potential may be quite different from that of probe. Power line currents can easily generate tens to hundreds of millivolts in difference in ground potentials with most of the signals being at frequencies that are multiples of the line frequency. Large differences in ground potentials can occur even over short distances if high-power equipment is involved.

If the data acquisition system input is fully differential – that is, the negative input is floating relative to the local ground -- then no problems will occur due to the differing ground potentials. However, as is often the case, the negative side of the data acquisition system may be internally connected to the local ground. In this case, the voltage difference between the two grounds will appear as a signal on top of the regular preamp output. Thus the output signal of the preamp will be corrupted by the ground signals. In many cases, the desired signal may be considerably smaller than that of the ground signals.

In order to eliminate the effect of the differing ground potential, a differential amplifier, such as a DA-01, should be placed between the output of the coaxial cable and the input to the data acquisition system.

Input/Output Connections

Figure 3 shows the input and output connectors for the HB-01. The input to the HB-01 is a BNC connector for connecting a coaxial cable to the capacitive probe. The output to the HB-01 is a BNC cable for connecting a coaxial cable to the data acquisition system. A cable with a characteristic impedance of 50 ohms is recommended. If a cable of other than 50 ohms is desired, the series termination resistor inside the HB-01 should be changed to match the characteristic impedance of the cable in order to eliminate reflections.

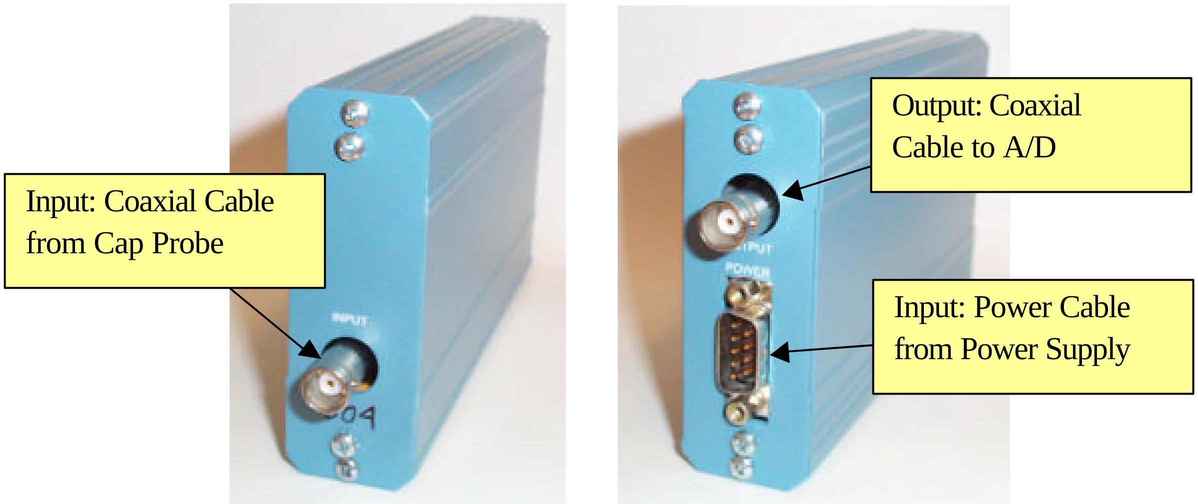

Figure 3. Input/Output Connections to HB-01

Power requirements for the HB-01 are:

Input connected to Capacitive Probe:

Voltage	Current (typical)
+ 15 volts	75 ma
-15 volts	30 ma

Input shorted to ground due to shorted Capacitive Probe:

Voltage	Current (typical)
+15 volts	250 ma
-15 volts	30 ma

The power connections for the 9-pin D connector are:

Pin Number	Voltage
1	No Connection
2	High Voltage monitor output at 10 mV per volt
3	-15 Volts
4	Analog Ground
5	+15 Volts
6	Chassis Ground (tied to the box)
7	-15 Volts
8	Analog Ground
9	+15 Volts

Pins 3 and 7 are connected internally, pins 4 and 8 are connected internally, and pins 5 and 9 are connected internally.

An optional internal connection between Analog Ground (pins 4 and 8) and the Chassis Ground (tied to the box and to pin 6) is shown in Figure 2. This connection is normally factory installed, but is available should the user want to keep the two ground connections separated.

Adjustments and Calibration

There are no user calibration adjustments available to the user.

Safety Issues

Caution should be observed when operating electronics with high voltages. The HB-01 generates a 100-volt bias for the capacitive probe. A resistor of 50 K ohms is in series with the power supply output capacitor and limits the short circuit current to approximately 5 ma.

Do not operate the HB-01 under power with the printed circuit board removed from the box, as numerous high-voltage points would be accessible to the user.

An internal resistor of 50 K ohms will discharge the high voltage in about 10-15 seconds (the time constant is approximately 5 seconds). Do not open the HB-01 box without first waiting for 15 seconds after removing power.

Turn-On Delay

When power is first applied to the HB-01, the high-voltage switching power supply must charge up to 100 volts. During this time, the output of the HB-01 will be saturated at approximately +/- 4 volts.

The dc voltage for the capacitive probe reaches approximately 90 volts in about 1-2 minutes, at which point the amplitude of the output pulses due to targets passing in front of the probe are at approximately 90% of their final value. For fully calibrated output signals, the power supply should be on for 5-10 minutes.

The value of the high voltage at the capacitive probe can be monitored by the 100:1 resistor divider connected to pin 2 of the D connector. If the probe voltage is 100 volts, the monitor voltage will be 1 volt.

Troubleshooting Tips

1. To verify the dc voltage on the probe, disconnect the capacitive probe from the HB-01. Connect the positive lead of a digital voltmeter (DVM) to the center conductor of the input BNC and the negative lead to the outer body of the BNC connector. The voltage should read approximately 100 volts after the power has been applied for about 5 minutes. If the voltage reads zero, check the connections to the power supply and the D connector.

2. If the power has been applied for about 5 minutes, the dc voltage on the probe should be nominally 100 volts. Connect an oscilloscope to the output of the HB-01. The dc voltage should be in the range of +/- 100 millivolts. Lightly tap the front of the input BNC connector with your finger. The output voltage on the HB-01 should have a small pulse (on the order of 50-100 millivolts) due to the change in capacitance at the input.

3. If the HB-01 passes items 1 and 2 above, check the impedance of the capacitive probe with an ohmmeter. The resistance of the probe should typically be greater than 10 meg

ohm for most capacitive probes. If the impedance of the probe is less than about 35 K ohms, the HB-01 cannot maintain a 100-volt bias on the probe. If this occurs, check the probe and the probe cable.

4. If the output of the HB-01 appears excessively noisy, disconnect the probe cable at the input to the HB-01 and recheck the output noise. If the noise disappears, check the impedance of the capacitive probe and input cable. A low impedance (50K to 1 M) may indicate the presence of moisture in the cable or corrosion on the probe.