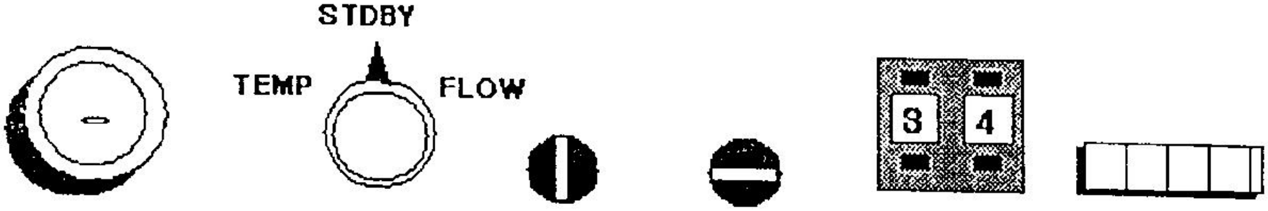
Instructions for Resistance Measurement Using the DANTEC 56C17 Bridge



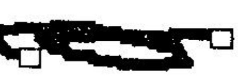
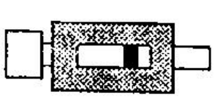
PROBE	Function Switch	TEMP.	FINE	Bridge Adjust		V_{out}
CONNECT	SWITCH	ADJUSTMENTS				READING
 Probe, Rp	STDBY		counter–clockwise	0	0	0 volts Zero using TEMP
 Support, Rs	TEMP			left digit ↑		Increase left digit until voltage changes from positive to negative, then decrease by one. +DC ► −DC
 Cable, Rc					right digit ↑	Repeat as above for right digit. +DC ► −DC
						0 volts Zero using FINE
 CTA Bridge Adapter set to SHORT	TEMP					V = Rtot / 10 Rtot = Rp + Rs + Rc

Chart by Michael Kotas October 1993

Example: Using the 56C17 Bridge to measure Resistance Rp + Rs + Rc .

Instructions for Operating the Dantec 56C17 Bridge

(This information is supplementary to section 3.3 in the DANTEC 56C17 CTA Bridge Instruction Manual.)

Following are the definitions of the variables used below:

Rp = probe resistance (ohms.) This includes the resistance of the wire and the resistance of the leads used to support the wire.

Rs = support resistance (ohms.) Electrical resistance of the probe support.

Rc = cable resitance (ohms.) Electrical resistance of the cable used to attach the probe support to the 56C17 Bridge.

RL = leads resistance (ohms.) Electrical resistance of the probe leads used to support the wire.

RO = probe (cold) resistance (ohms.) Resistance of wire at ambient temperature.

R = probe (hot) resistance (ohms.) Resistance of wire at operating temperature.

a = overheat ratio (dimensionless.) Ratio of probe hot resistance to probe cold resistance minus one. a = (R - RO) / RO

Step-By-Step Operating Procedure

Step 1) Determine resistance of (Rp + Rs + Rc) (see chart: "Instructions for Resistance Measurement Using the Dantec 56C17 Bridge.")

Step 2) Determine resistance of (Rs + Rc) using same procedure by replacing the probe with the SHORTING PROBE.

Step 3) Solve for probe (cold) resistance Rp:
Rp = (Rp + Rs + Rc) - (Rs + Rc)

Step 4) Read the value for the probe lead resistance RL from the probe container and solve for RO:
RO = Rp - RL

Step 5) Calculate operating resistance "R" using the desired overheat ratio "a:" ("a" = .8 for wire probes.)
R = (1 + a) RO

Step 6) Connect probe, cable, and support to the 56C17 Bridge connector marked "PROBE.". Adjust "Bridge Adjust" and "FINE" switches to achieve the desired operating resistance "R" measured as one tenth of the voltage output from the 56C17 when "Function Switch" is in position TEMP. (See chart for instructions on measuring resistance.)

Step 7) Switch "Function Switch" to FLOW and begin measuring.

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SCOPE of MANUAL

This manual describes the function and operation of the 56C17 CTA Bridge plug-in unit in the 56C01 CTA. Only the information pertaining to the function and operation of the CTA with this bridge plug-in is included. A description of the 56C01 CTA and the 56B10 and 56B12 Main Frames is given in the 56C01 CTA and 56B10/56B12 Main Frame Instruction Manual.

The technical aspects of the 56C17 are described to provide sufficient technical information for the user to enable him to utilize his equipment to its full potential.

Service information and circuit diagrams for the 56C01 CTA and the 56B10 and 56B12 Main Frames are provided in the 56C01 CTA and 56B10/56B12 Main Frame Service Manual.

1. INTRODUCTION

1.1 GENERAL DESCRIPTION

The type 56C17 CTA Bridge and the type 56C01 CTA Unit make up a flow anemometer for universal applications. All the DANTEC standard probes can be connected to the CTA module, either via 5 m (4 m + 1 m probe support), 20 m or 100 m probe cables.

The BCD switches on the front panel, together with 56N22 Mean Value Unit as display, enable measurement of the probe combination resistance for calculation of the probe resistance and to adjust the desired overheat.

Cable length, gain and filter settings are selected by programming the internal switches.

The 56C01 CTA with the 56C17 CTA Bridge is a module in the 56C00 CTA system. It fits into the 56B10 and the 56B12 Main Frames and may be used with other analog measuring or signal processing modules.

For details on the 56C00 CTA System and the 56B10 and 56B12 Main Frames, please refer to the 56C01 CTA and 56B10/56B12 Main Frame Instruction Manual.

1.2 BLOCK DIAGRAM

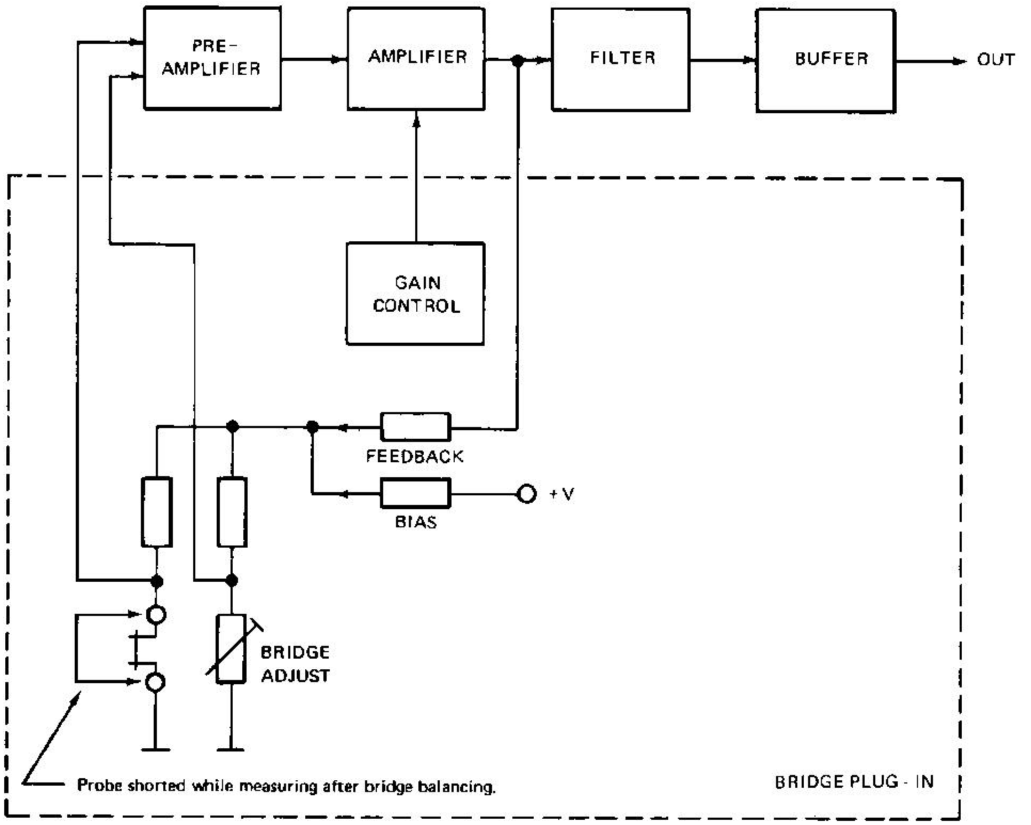
Fig. 1(a) shows a simplified block diagram of the 56C17 CTA Bridge used as a resistance measuring device. The probe is part of a bridge circuit which is connected to an amplifier. While the probe is connected, the bridge is balanced by means of BRIDGE ADJ., i.e. 0 V to the amplifier, which also has a 0 V output.
The probe plug is then shorted and only the voltage across the BRIDGE ADJ. resistance is fed to the amplifier.
A feedback circuit provides for a voltage over the BRIDGE ADJ. resistance which is equal to the value before shorting and which is therefore identical with the voltage over the probe circuit at bridge balance.
Amplification is chosen in such a way that the voltmeter which is connected to the output shows the value directly for the connected probe-cable resistance R.

$$R = 10 \times V(\Omega)$$

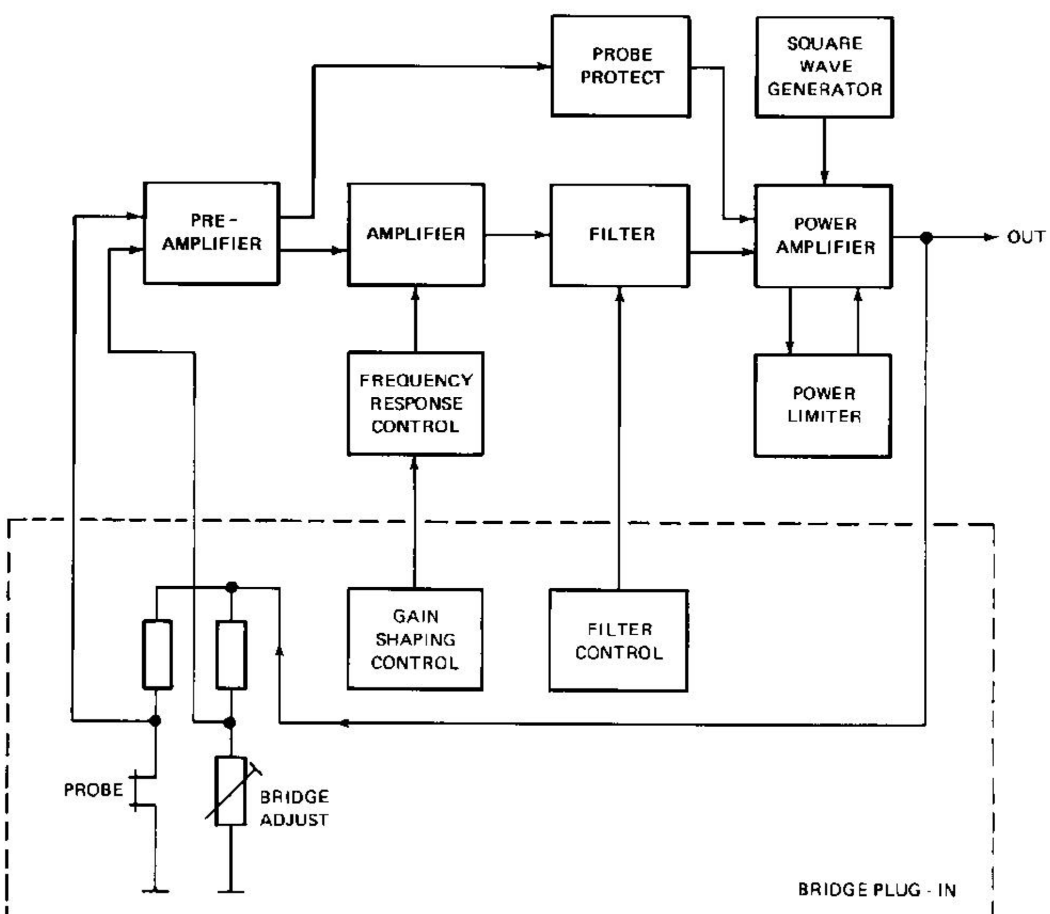
where V is the measured voltage.
With connected voltmeter, the BRIDGE ADJ. resistance can now be adjusted to the overheat value desired for the subsequent flow measurement.
Fig. 1(b) shows the unit as a Constant Temperature Anemometer, where the amplifier output is connected to the bridge top as a servo circuit which keeps the probe resistance on the selected value.

1.3 INTERACTION WITH SURROUNDINGS

The 56C01/C17 CTA Bridge combination is a complete analog, manually controlled unit. No provisions are made for remote control or interaction with the digital bus in the 56B10/12 Main Frames. The system is set up by the user according to the procedure described in this manual and in the 56C01 CTA and 56B10/56B12 Main Frame Instruction Manual.



(a) Block Diagram of 56C01 / C17 as Resistance Measuring Device.



(b) Block Diagram of 56C01 / C17 as Constant Temperature Anemometer.

Fig. 1

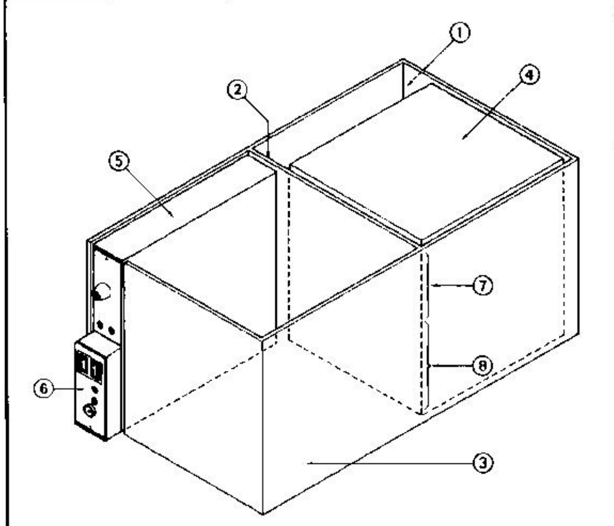


Fig. 2. Installation of the 56C17 Plug-in Unit.

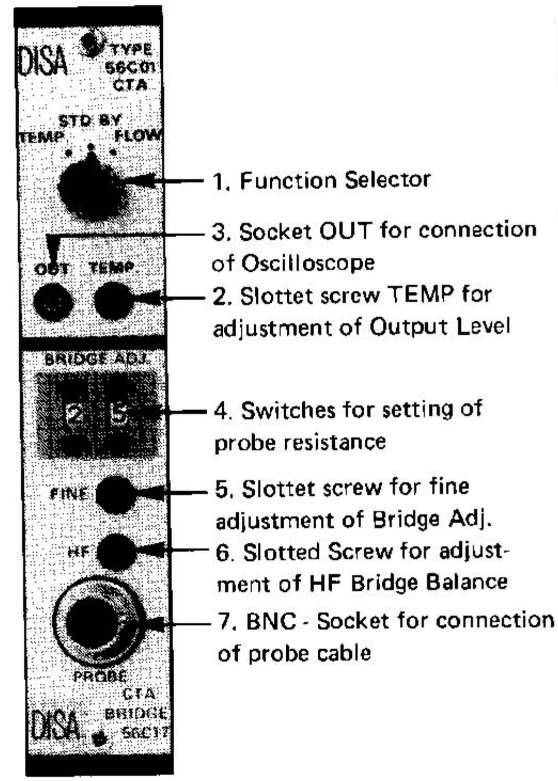


Fig. 3. Front Panel of the 56C01 CTA and the 56C17 CTA Bridge.

2. INSTALLATION

2.1 ASSEMBLY

If the 56C17 CTA Bridge is supplied as part of a 56C00 CTA System, the procedure described in the 56C01 CTA and 56B10/56B12 Main Frame Instruction Manual Section 3 Installation should be followed. If the unit is supplied as a plug-in module for an existing 56C01, it is simply inserted into the CTA and secured with the Allen screw supplied with the system.

2.2 SETTING BRIDGE SUPPLY VOLTAGE AND CTA MAX. CURRENT

Setting of bridge supply and CTA max. current is described in the 56C01 CTA and 56B10/56B12 Main Frame Instruction Manual. The maximum current per channel is calculated from the calibration curve:

$$I = \frac{V_{out} \cdot 1.05}{R + R_{lc} + 20} \ (A)$$

where
V_{out} is the maximum output voltage.
R is the probe hot resistance.
R_{lc} is the probe cable and probe lead resistance.

3. OPERATING INSTRUCTIONS

3.1 HARDWARE CONTROLS, 56C01/C17 CTA/BRIDGE COMBINATION

3.1.1 INDIVIDUAL CONTROLS AND THEIR FUNCTIONS

Fig. 3 shows the front panel of the 56C01 CTA with the 56C17 CTA Bridge. Below follows a description of the individual controls and their functions with reference to the numbers in the figure:

1. FUNCTION SWITCH.

   The Function Switch has three settings, TEMP., STD.BY and FLOW. In the TEMP. setting, a current is supplied to the bridge top. Any unbalance of the bridge will thus produce a voltage that is amplified and is available at the BNC-connector at the rear of the unit.

   Using the TEMP. setting of the Function Switch, it is possible to measure the resistance of the probe circuit with a voltmeter at the output.

In the STD.BY setting, there is no current on the bridge, and thus no signal is passed onto the amplifier.

In the FLOW setting, the amplifier output is connected to the bridge top, and a Constant Temperature Anemometer is obtained.

Moreover, the Function Switch can start the square-wave generator. In order to activate the square-wave generator, the switch is shifted quickly from TEMP. to FLOW. If this is done slowly, or when the switch is shifted from STD.BY to FLOW, the square-wave generator remains passive.

2. TEMP.

Screwdriver adjustment for amplifier offset. With Function Switch in position STD.BY, the TEMP. adjustment is used to select a suitable output level. In this case 0 V.

3. OUT.

Socket for 2 mm banana plug. An oscilloscope or another instrument may be connected to this socket for observation of the output signal. The normal connection for V_{out} is a BNC-socket at the rear of the unit.

4. BRIDGE ADJ.

The BCD switch BRIDGE ADJ. adjusts the bridge balance for measurement of probe resistance and the desired overheat.

5. FINE.

The slotted screw FINE ensures overlapping of the BCD switch steps. In this way, any resistance value from 3 - 30 Ω can be selected.

6. HF BALANCE.

Adjustment of bridge high-frequency balance using the slotted screw potentiometer H.F. BAL. with the Function Switch in position FLOW and activated square-wave generator.

Fig. 4 shows a typical response during a square-wave test at a velocity of approx. 100 m/sec.

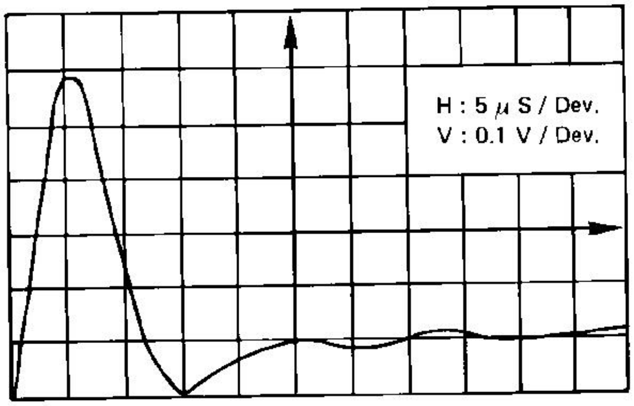


Fig. 4. Typical Square-Wave Response.

7. PROBE.

The probe is connected to the BNC-socket designated PROBE with a coaxial cable to which a probe support with a 1 m cable is connected.

3.2 PROGRAMMING INTERNAL SWITCHES

The 4 internal binary switches are accessible when the lowest Allen screw is removed and the 56C17 CTA Bridge is pulled out by using the BNC-socket as a knob.

The binary switches consist of two or four microswitches, each with two settings (Fig. 5). The upper position is designated logic 1 and the lower position logic 0. The setting is performed by means of a miniscrewdriver or the tip of a pencil. The location of the switches is shown in Fig. 6.

> **NOTE**
>
> The code number 1 must always be considered as pointing upwards. Please refer to Fig. 5.

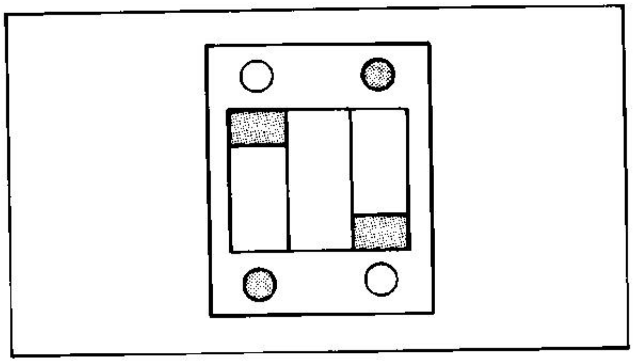


Fig. 5. The setup of the microswitch shown is I O, initiated by the white and black dots at the top.

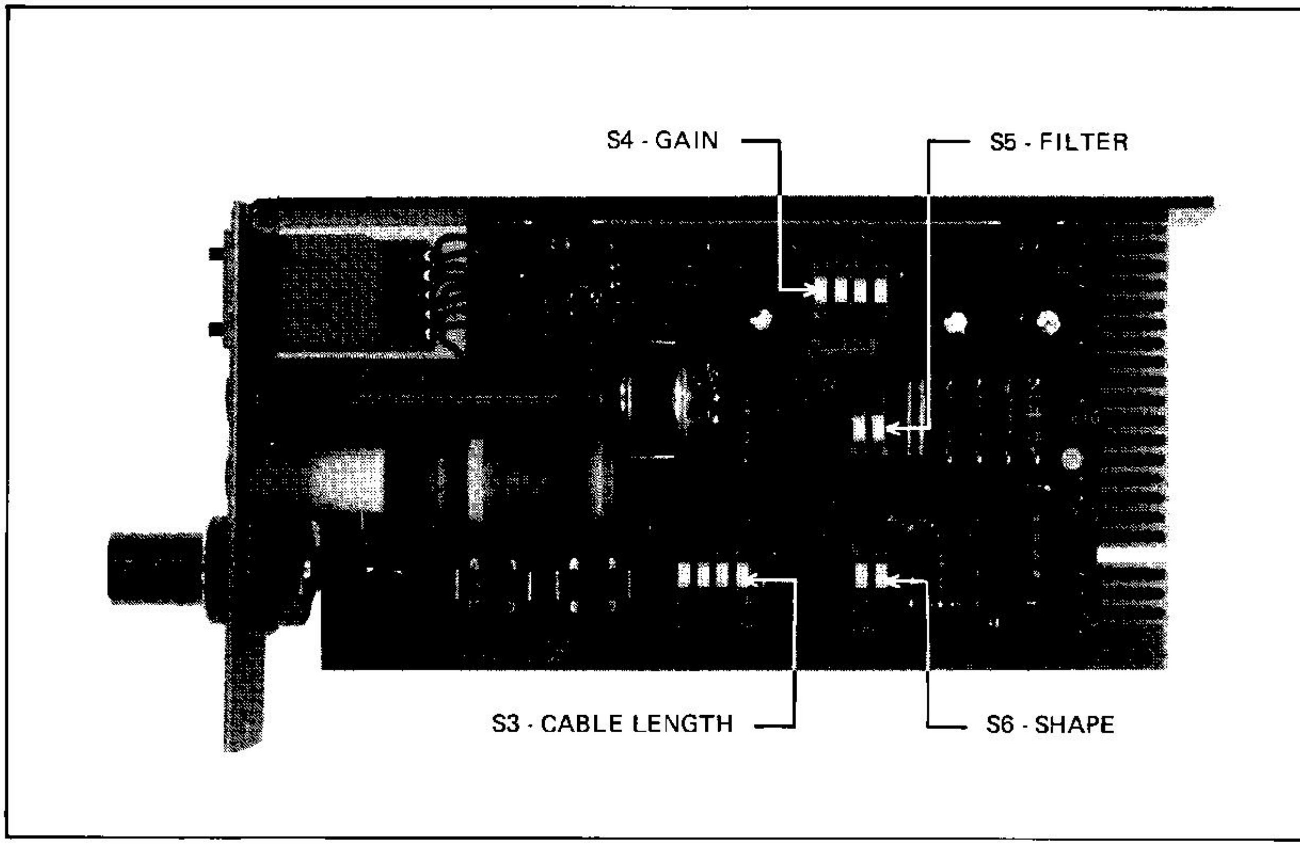


Fig. 6. Location of the Internal Switches.

3.2.1 CABLE LENGTH SETTING

The cable lengths 5 m, 20 m and 100 m are set by the internal switch designated CABLE LENGTH (Table 1).

Switch S3 Setting	Cable
1 0 0 0	5 m
0 1 0 0	20 m
0 1 1 1	100 m

Table 1

3.2.2 GAIN SETTING

If the optimum setting of the servo amplifier gain is unknown, the lowest value of GAIN, 0 0 0 0 is selected as the start-up position. Table 2 and Fig. 7 show that the DC-gain is greater than the AC-gain. The cross-over frequency is approx. 100 kHz. In position FLAT the gain is equivalent to the AC-gain.

Switch S4 Setting	Amplifier AC - GAIN	Amplifier DC - GAIN
0 0 0 0	166	3470
0 0 0 1	222	5579
0 0 1 0	293	8220
0 1 0 0	392	11912
0 1 1 0	519	16663
1 0 0 0	702	23488
1 1 0 0	927	31930
1 1 1 1	1111	38783

Table 2

3.2.3 FILTER SETTING

The upper frequency limit of the servo amplifier is selected by setting the internal switch designated FILTER (Table 3).

If the optimum setting of FILTER is unknown, the narrowest bandwidth 1 1 should be selected as the start-up position.

Switch S5 Setting	Bandwidth
0 1	330 kHz
1 0	100 kHz
0 0	50 kHz
1 1	25 kHz

Table 3

3.2.4 SHAPE SETTING

The amplifier frequency response is set via the internal switch designated SHAPE to obtain optimum bridge balance (Table 4).

Switch S6 Setting	Function
0 0	FLAT
1 0	FILM
1 1	WIRE

Table 4

Usually only two of the positions shown are used, viz. the binary indication 1 0 for fiber/film probes and 1 1 for wire probes. In position FLAT, the frequency response of the servo amplifier is unaffected (Fig. 7).

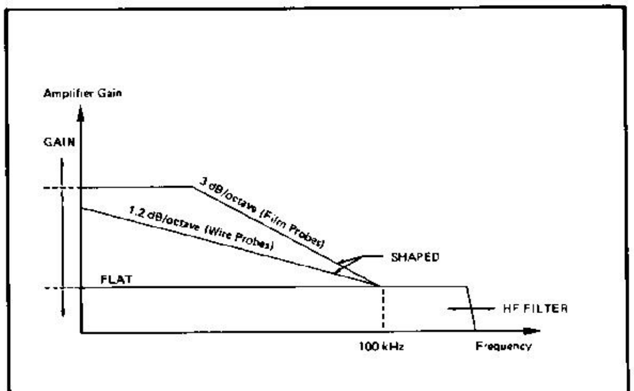


Fig. 7. Frequency Characteristics.

3.3 STEP-BY-STEP OPERATING PROCEDURE

When the internal switches are set, the 56C17 CTA Bridge is plugged into the 56C01 CTA module. The following steps can now be taken to start up the anemometer:

1. Connect the output to the 56N22 Mean Value Unit or connect a DC-voltmeter to the relevant BNC-connector on the rear panel.

2. Set the Function Switch to position STD. BY.

3. Turn on power.

4. Connect the probe with probe support and a 4, 20 or 100 m cable to the BNC-socket.

5. Set the BRIDGE ADJ. switch to 0 0 and the slotted screw FINE counterclockwise by means of a screwdriver.

6. Adjust the slotted screw designated TEMP. to 0 V output by means of a screwdriver.

7. Set the Function Switch to position TEMP., and the unit is ready for balancing and resistance measurements of connected resistances from 3 to 30 Ω.

3.3.1 BALANCING

1. Shift the left-hand BCD-switch BRIDGE ADJ. from 0 towards 9 by means of the pushbutton placed below the display. Shift the digits until the voltmeter shifts from a positive to a negative value.

2. Shift one digit back with the pushbutton above the display. The voltmeter now shows 0 or a positive value.
   If the voltmeter does not shift polarity, keep setting 9.

3. In the same way, activate the other BCD-switch from 0 to 9 until the voltmeter shows a negative value.

4. Adjust the slotted screw FINE to 0 Volt.

3.3.2 RESISTANCE MEASUREMENT

1. Set the function switch to STD.BY. and disconnect probe cable.

2. Short the BNC-plug designated PROBE after balancing by connecting the supplied adaptor to the probe plug and setting the adaptor switch to SHORT.

3. Set the function switch to TEMP.

4. The voltmeter now shows the resistance value of the circuit which was connected to the PROBE plug. The measured resistance is $R_{TOT} = V \times 10\ (\Omega)$.

5. The probe resistance cannot be measured directly due to cable resistance R_c and probe lead resistance R_L. The measured resistance is therefore the total resistance $R_{TOT(cold)}$.

6. To separate the individual resistance components, the cable resistance is measured alone. As 5 and 20 m cables normally have a smaller value than 3 Ω (the smallest value for the BRIDGE ADJ.) the supplied adaptor must be connected between the cable and the CTA bridge with the switch in setting 5 Ω (see Fig. 8). Connect a shorting probe to the free end of the cable.

7. Balance the bridge as in Section 3.3.1 and measure the resistance.

8. Set the adaptor switch to SHORT and measure the resistance.

9. If a shorting probe and 55H30 or 55H31 is mounted instead of a probe, the cable resistance is $R_c - R_{TOT} - 5\ (\Omega)$.

10. The probe lead resistance R_L cannot be measured directly and its value is therefore indicated on the probe cover.

11. The probe cold resistance R_o at T_{amb} can be calculated as:

$$R_o = R_{TOT} - (R_c + R_L)(\Omega).$$

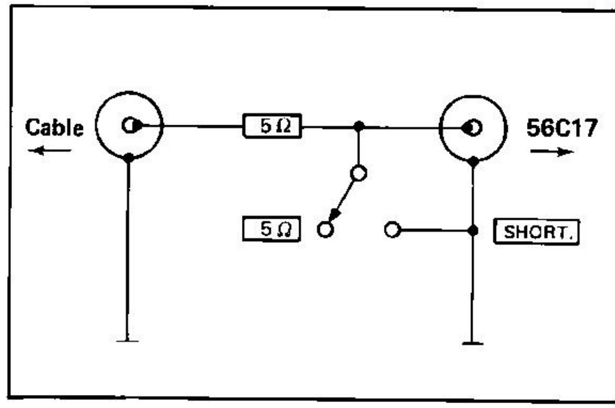


Fig. 8. Adaptor for 56C17 CTA Bridge.

3.3.3 SELECTION OF OVERHEAT

1. For an ambient temperature of about 20°C, the overheating ratio is calculated through the formula

$$a = \frac{R - R_o}{R_o}$$

R_o is the sensor cold resistance at ambient temperature (T_{amb}).
R is the sensor heated resistance.

As the probe resistance is an approximately linear function of the wire or film temperature T, R can be calculated from the desired mean operating temperature T:

$$R = R_{20}\ [1 + \alpha_{20}\ (T-20)]$$

Regarding selection of overheating ratio, please refer to the DANTEC Probe Catalog: "Direction for Use".
Normally the overheating ratio is chosen to be as high as possible so as to achieve the largest bandwidth and highest sensitivity. Further, the maximum independence of temperature change in the measuring medium is obtained.

2. Connect the adaptor to the BNC-plug PROBE. Set the switch to SHORT and adjust BRIDGE ADJ. until the voltmeter shows the desired resistance. As both cable resistance R_c and probe lead resistance R_L are parts of the total resistance, the BRIDGE ADJ. should be adjusted to a total resistance

$$R_{TOT(hot)} = (1 + a) R_o + R_c + R_L (\Omega).$$

3. Connect the cable with probe support and probe to the probe plug again. Connect an oscilloscope to the relevant BNC output plug at the rear of the Main Frame.

4. If the measurements are less critical, the resistance measurement procedure can be avoided.
The curve in Fig. 9 shows the relation between switch setting and resistance, connected to PROBE.

For resistance values up to approx. 12 Ω, the steps on the BCD switch are small. With the slotted screw FINE turned fully clockwise, the resistance value for overheat can be selected directly with an accuracy of approx. 5%.

Typical values of total cable and lead resistance $R_C + R_L$ are:

4 + 1 m cable ≃1.3 Ω
20 m cable ≃2.4 Ω
100 m cable ≃8 Ω

The resistance values for selecting overheat, a, can be found by inserting relevant values in the equation

$$R = (1+a)\ R_0 + R_C + R_L\ (\Omega)$$

where R_0 is approx. the value R_{20} as indicated on the probe cover.

The curve in Fig. 9 shows the switch setting which corresponds to the calculated value. As opposed to adjustment with a voltmeter, where the inaccuracy on overheat is very small in spite of an error of up to 5% on the measurement of the absolute value, a possible non-linearity here of the BCD switches etc. can cause an error of up to 5% on the selected overheat.

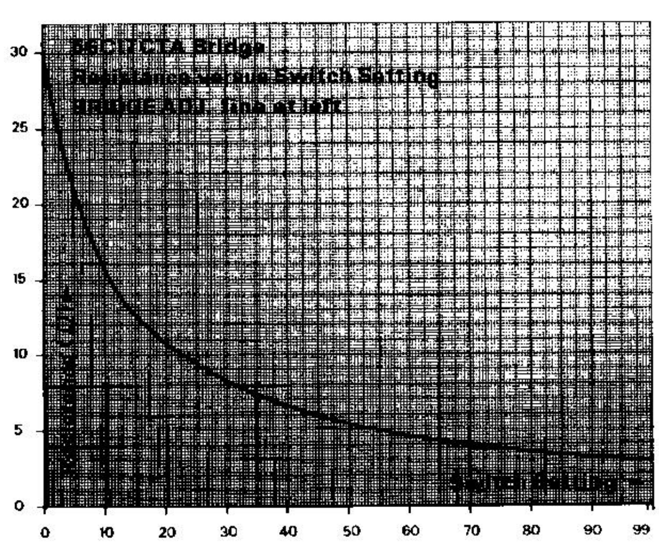


Fig. 9. Resistance Curve.

3.3.4 OPTIMIZING

1. If the Function Switch is shifted quickly from position TEMP. to FLOW, the square-wave generator is activated.

2. Adjust the HF BALANCE until the best possible response is obtained on the oscilloscope. Fig. 4 shows an example of an actual square-wave response, with a standard 5 μm wire probe in a flow of 100 m/sec.

3. Remove the plug-in and increase the gain and the bandwidth alternately step-by-step with the switches GAIN and FILTER, and readjust the HF BALANCE to a value which does not give oscillation.

4. The last adjustment should be carried out during a measurement at the proper flow velocity. Fig. 10 shows examples of incorrect square-wave response.

5. The square-wave generator is switched off by turning the Function Switch to STD.BY and back to FLOW position.

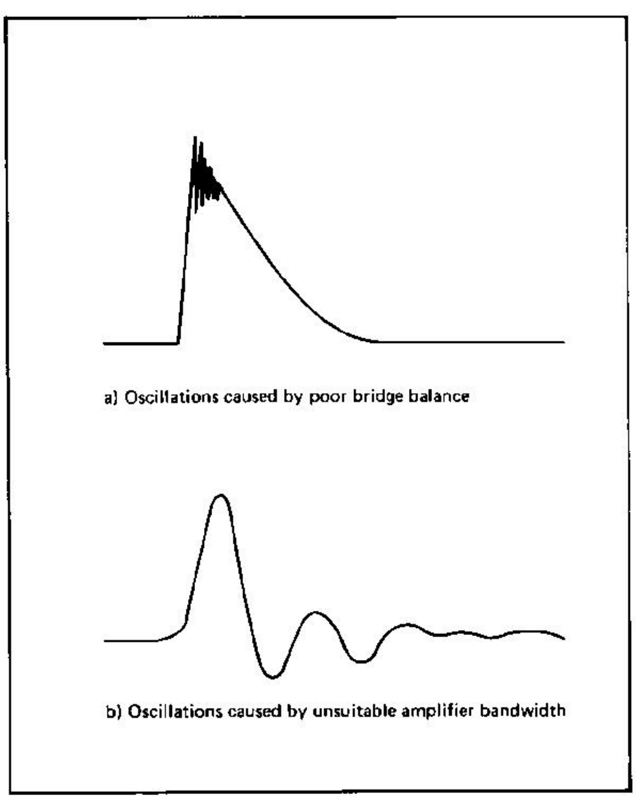


Fig. 10. Incorrect Calibration Curve.

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4 + 1 m cable ≈1.3 Ω
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100 m cable ≈8 Ω

The resistance values for selecting overheat, a, can be found by inserting relevant values in the equation

$$R = (1+a)\ R_0 + R_C + R_L\ (\Omega)$$

where R_0 is approx. the value R_{20} as indicated on the probe cover.

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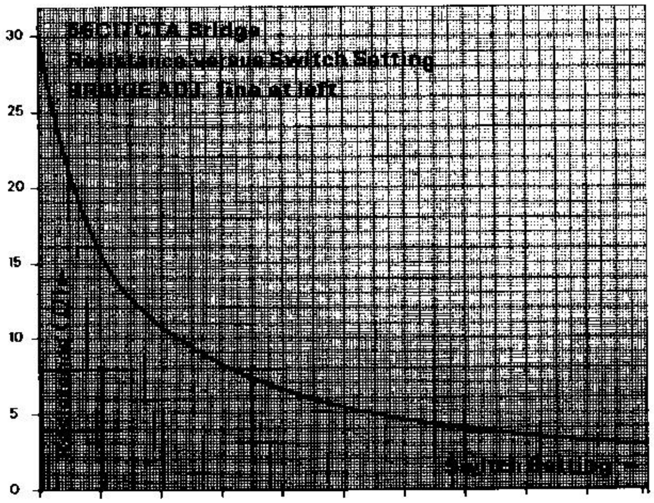

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2. Adjust the HF BALANCE until the best possible response is obtained on the oscilloscope. Fig. 4 shows an example of an actual square-wave response, with a standard 5 µm wire probe in a flow of 100 m/sec.

3. Remove the plug-in and increase the gain and the bandwidth alternately step-by-step with the switches GAIN and FILTER, and readjust the HF BALANCE to a value which does not give oscillation.

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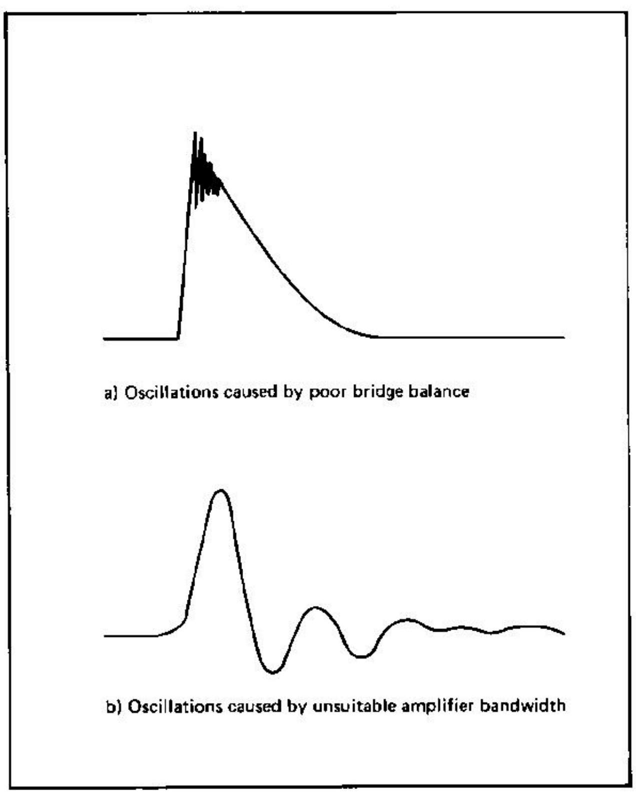

Fig. 10. Incorrect Calibration Curve.

3.3.5 TYPICAL EXAMPLE OF SETTING

As choice of measuring medium, probe, required overheat, cable length etc. influences adjustment, it is impossible to cover all possibilities, for which reason only one example is shown. Measurement in air, overheat 0.8 and bridge supply 8 V with a standard 5 µm wire probe (Table 5).

SWITCH	5 m Cable	20 m Cable	100 m Cable
BRIDGE ADJ.	33	28	14
CABLE LENGTH	1000	0100	0111
GAIN	0110	0010	0000
FILTER	10	00	11
SHAPE	11	11	11

Table 5

3.4 CALIBRATION OF THE ANEMOMETER

3.4.1 GENERAL CONSIDERATIONS

Heat transfer from a heated sensor positioned in a fluid medium depends on a great number of physical processes, such as fluid velocity, thermal buoyancy, compressibility, thermal and viscous diffusivity, molecular free path etc., as well as on specific probe-related characteristics, such as sensor geometry, length-to-diameter ratio and overheating ratio. However, a satisfactory mathematical description based on physical theory does not exist.

Traditionally, the shape of CTA calibration curves for velocity measurements in incompressible, isothermal flows has been based on the early works of L.V. King on the heat transfer of infinite, circular cylinders in a uniform flow normal to the cylinder axis. This work resulted in the so-called King's Law, which affords a reasonable approximation to the overall shape of a hot-wire calibration curve:

$$Q = RI^2 = A + B \cdot \sqrt{u}$$

where Q is the heat loss (by convection) from the sensor, RI^2 is the electric power dissipated in the sensor while A and B are constants derived by King.

An often used and more accurate, but purely empirical expression for the calibration curve of a hot-wire (or hot-film) anemometer, is the so-called generalized King's Law:

$$V^2 = A' + B' \cdot (U_e)^{n'}$$

where V is the output voltage of the anemometer, A', B' and n' are empirical constants and U_e is the so-called effective cooling velocity. For most hot-wire probes, n' is approximately 0.45 (for a velocity range in air between 0.3 and 80 m/s), but the optimum value of n depends on probe geometry and velocity range. Effective cooling velocity can in most cases be taken as the velocity component normal to the wire, but for more accurate measurements the directional sensitivity of the wire must be taken into account.

On the assumption that the basic heat transfer mechanism from the sensor is convection, the temperature dependence on the calibration curve can be shown explicitly:

$$V^2 = [A'' + B'' \cdot (U_e)^{n''}] \cdot a$$

where a is the overheating ratio and A'', B'' and n'' are empirical constants nearly independent of temperature. However, it must be noted that the above assumption only holds in very special cases, e.g. for wires with a very large l/d ratio.

Many other analytical expressions have been used to model the calibration curve, even though in most cases the generalized King's Law yields remarkably good results with only 3 adjustable parameters.

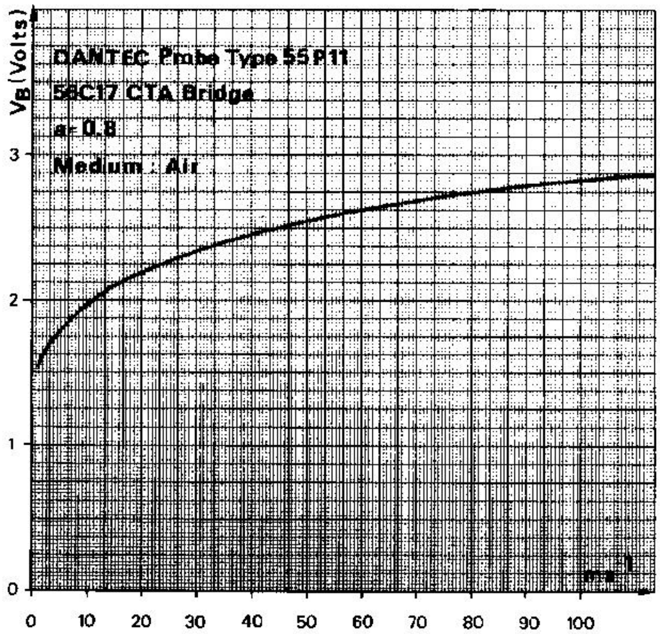

Fig. 11. Typical Calibration Curve.

3.4.2 TYPICAL CALIBRATION CURVE

Fig. 11 shows a typical calibration curve for the 56C17 CTA Bridge with a 5 µm wire probe (55P11).

During calibration, the probe should be positioned in a flow with a known variable velocity, e.g. mounted on the Type 55D90 Calibration Equipment.

> **NOTE**
>
> A calibration curve for a probe connected to a 56C01/C17 CTA Bridge, is not necessarily valid if 56C17 CTA Bridge is moved to another 56C01 CTA.

4. MAINTENANCE AND SERVICE

Fig. 12 shows the 56C17 CTA Bridge circuit diagram. It is normally used together with the diagram in the Service Manual for the CTA system. Here it substitutes the standard plug-in. The 56C17 CTA Bridge contains few active elements. Troubleshooting on the unit alone is normally limited to a visual control or resistance measurement for locating the fault or the defective component.

5. TECHNICAL DATA

Top Resistance
20 Ω

Bridge Ratio
1 : 20

Sensor Resistance Range
3 - 30 Ω
(R_{probe} + R_{cable})

Resistance Measuring Sensitivity
0.1 V/Ω

Resistance Measurement Accuracy
Better than 5%

Overheat Setting
Any value between 3 and 30 Ω
Accuracy better then 1%
(voltmeter as indicator)

Probe Cable Length
1) 5 m (4 m + 1 m probe support) ±0.5 m
2) 20 m + 1 m probe support ±2 m
3) 100 m + 1 m probe support ±2 m

Amplifier Shape
Wire, Film or Flat

Probe Current
1) Bridge Supply 8 Volt:
0.21 A
(R_{probe} + R_{cable} + R_{lead} = 7.8 Ω)
2) Bridge Supply 16 Volt:
0.315 A max.
3) Resistance Measuring
approx. 0.5 mA

Maximum Bandwidth
150 kHz (with 5 m cable)

Temperature Dependent Drift of Bridge Resistors
⩽100 ppm/°C

Temperature Range
+5 to +40°C

Manufacturer's Responsibility

DANTEC is responsible for the safety, reliability and performance of the equipment only if:

1. Assembly operations, extensions, readjustments, modification or repair are carried out by persons authorized by DANTEC.

2. The specific environmental conditions correspond to the requirements in the IEC 359 Group 1.

3. The equipment is used in accordance with the instructions for use.

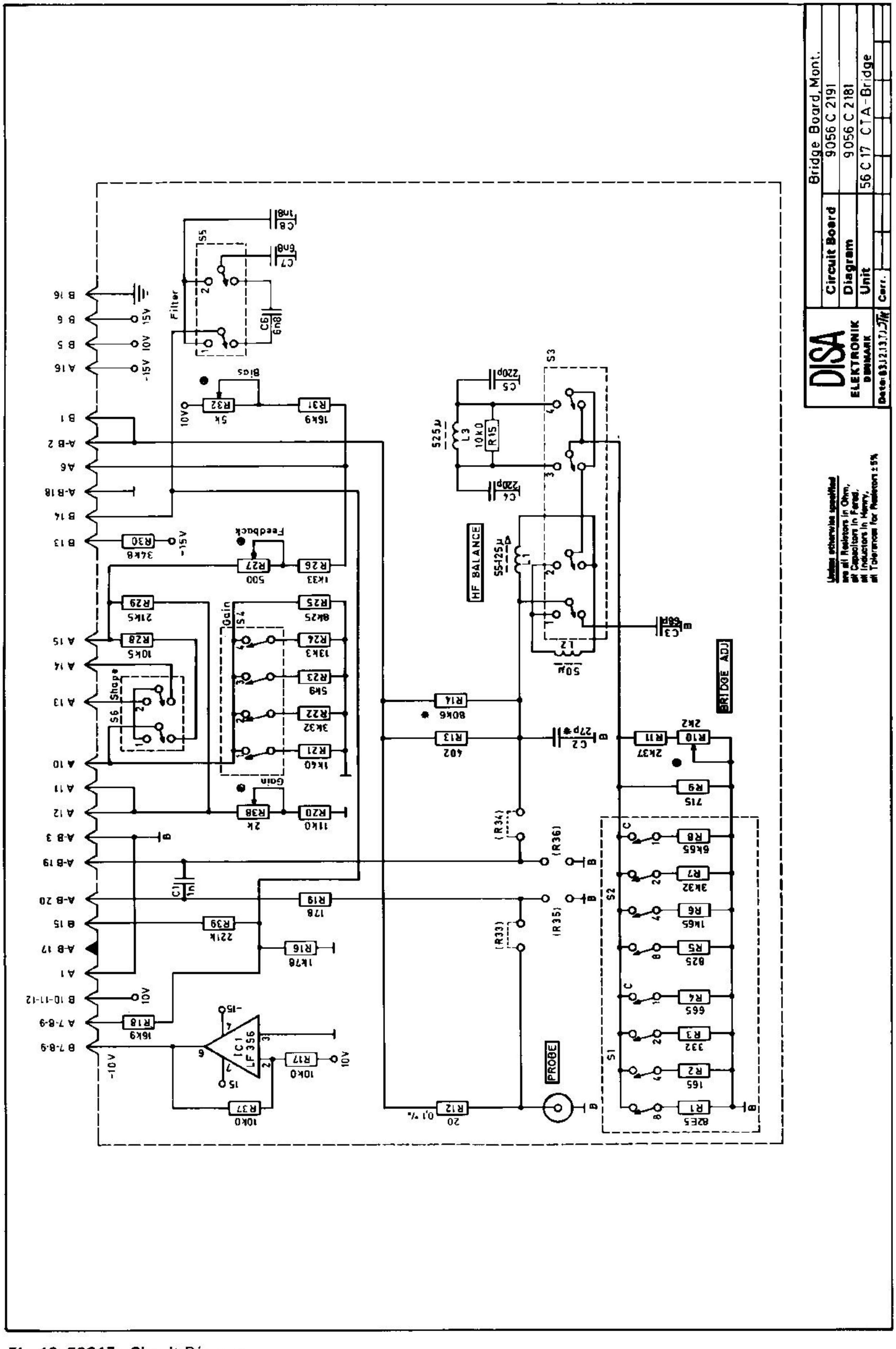

Fig. 12. 56C17 - Circuit Diagram.