VERY - BROAD - BAND FEEDBACK SEISMOMETERS

STS-1V/VBB and STS-1H/VBB

MANUAL

G. Streckeisen AG Messgeraete CH-8422 Pfungen Switzerland

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1) Introduction

The STS-1V/VBB and STS-1H/VBB seismometers are highly sensitive, remotely controlled seismic sensors for wide-band and long-period recording. Their extremely high dynamic range and their stable transfer characteristics make them ideal for a wide range of applications. The basic response of the instrument is that of a long-period seismometer with 360 sec free period and 0.707 of critical damping; the response is flat to ground velocity from 0.1 to 360 sec period. The whole spectrum of teleseismic signals, from 0.1 sec to about 1 hour period, is resolved in the VBB output signal and can be recorded in a single digital data stream when a suitable digitizer is used.

The sensors can be converted to a free period of 20 sec with internal jumpers. Except for the upper corner period which is 0.1 sec in place of 0.2 sec, the response is then identical to that of the 20 sec STS-1V and STS-1H seismometers.

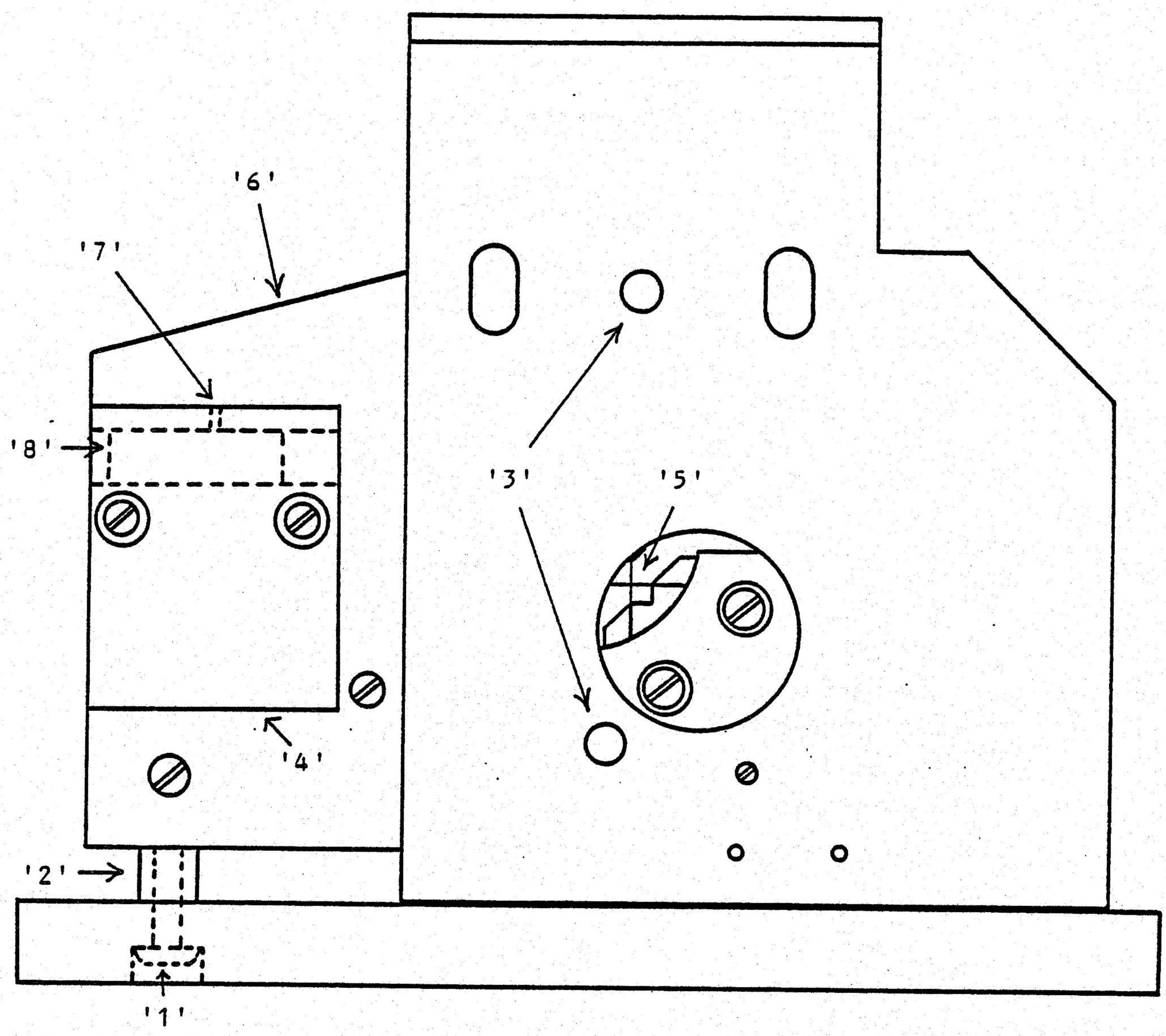
As with all other long-period seismometers, certain precautions must be observed during the installation. The sensors are completely assembled and calibrated before shipment and can therefore be installed with a minimum amount of work. The high sensitivity of this instrument, especially at long periods, depends on the elimination of environmental noise such as caused by temperature, air pressure and magnetic fields.

Thermal stability is achieved by the massive inner cover of the sensor and by an outer cover, still in the glass bell, which is in thermal contact with the ground. Air pressure is eliminated by operating the instrument under a partially evacuated glass bell. A Permalloy container provides magnetic shielding for the vertical sensor.

Choice of the Site

Obvious prerequisites for an installation site are remoteness from traffic, a solid subsoil, and a stable temperature. It is, however, difficult to predict for a given site how large the seismic noise will be. Short-period noise can easily be measured with portable seismic equipment, but the long-period noise is normally not known before the seismometer is installed. A test record can be made with the glass base plate resting on three pieces of metal, in place of being cemented to the floor. It is necessary to use the vacuum bell even in the test phase. Satisfactory vertical long-period seismograms are often obtained in places that would normally be considered as unsuitable for seismic recording, e. g. in the basement of ordinary office buildings. Good horizontal long-period records are far more difficult to obtain and will normally require an underground installation in or on solid rock.

However, the requirements for visible wide-band recording are less stringent because this usually implies lower gain, and acceptable wide-band three-component records can be expected wherever the short-period noise is sufficiently low.



'1'	Clamping Screws
'2'	Spacer Block
'3'	Retention Pins
'4'	Seismic Mass
'5'	Hinges
'6'	Boom
'7'	Locking Srew
'8'	Balancing Weight

2) Handling

Handling of the Vertical Sensor

For shipment the boom of the vertical sensor is secured to the base plate by two screws '1' which are visible between the two front legs. They must be removed, together with a spacer block '2' between the boom and the base plate, before the seismometer can be tested or installed.

(1) Remove the six small screws that hold the cover to the base plate

(2) Lift off the cover, or hold the sensor at its legs and pull it out of the cover

(3) Put the sensor on a clean table with its rear side down and the seismic masses '4' up

(4) Make sure that the retention pins '3' are properly inserted

(5) Remove the clamping screws '1' and the spacer block '2'

CAUTION Once the boom is unclamped, the seismometer must be handled with care. The axis of rotation (as defined by the hinges '5') must always remain horizontal, i. e. the seismometer must not be tilted with the side up or down. It is recommended to secure the retention pins '3' with adhesive tape whenever the instrument is moved without cover. The hinges '5' are the most delicate parts and can be damaged when the boom is hit, even with the retention pins inserted.

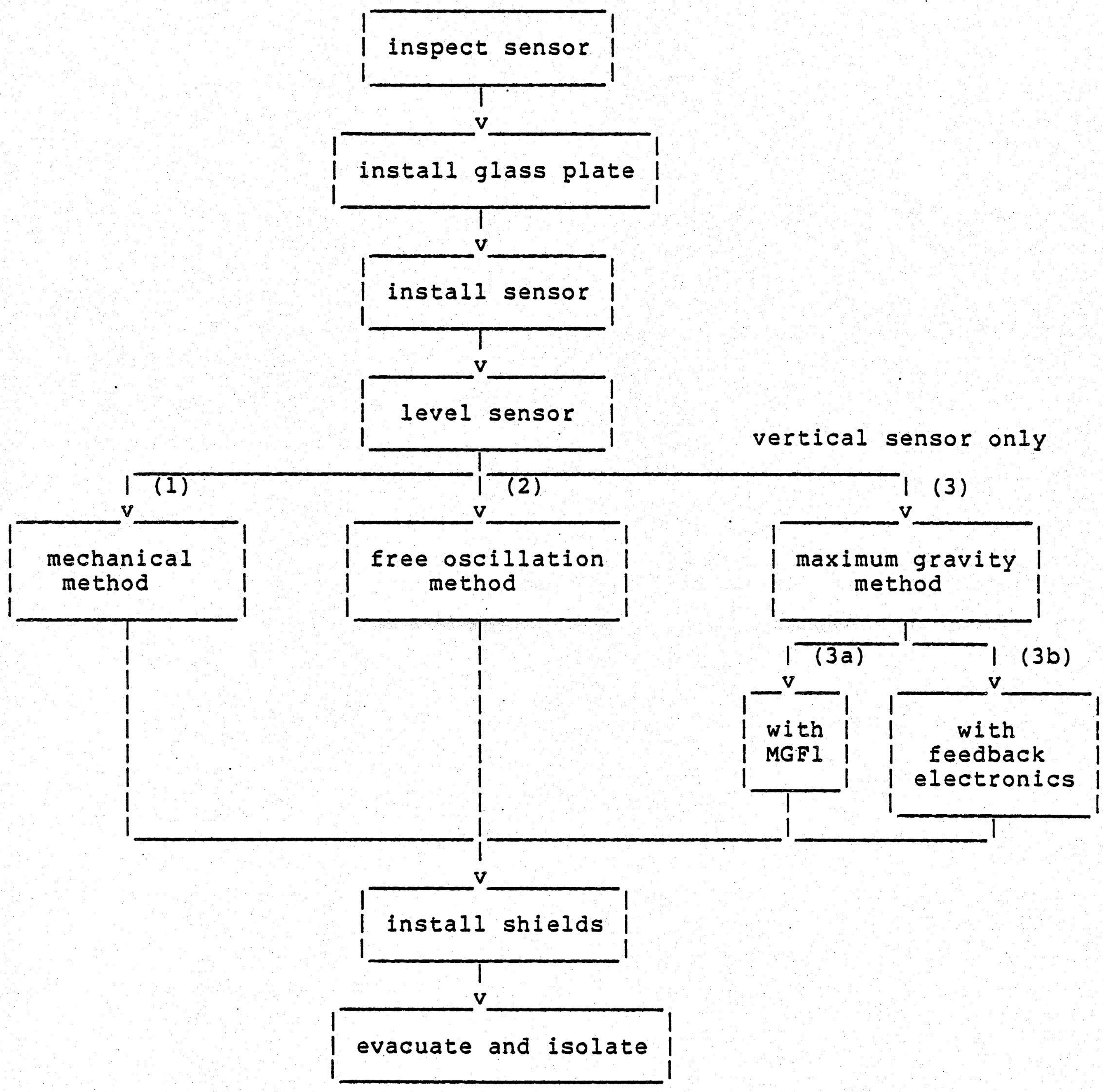
Never move the instrument without retention pins!

Handling of the Horizontal Sensor

The boom is secured by a rectangular plate on top of the hinges that is easily removed. The boom then moves freely when a retention ring clamping its front end is pulled out of the front support.

3) Installation

Installation Procedure: Oversight



Mechanical Inspection

Mechanical Inspection of the Vertical Sensor

Put the seismometer on a horizontal surface and adjust the foot screws until the base plate is horizontal. Then screw out the single rear foot screw by about 3 turns or 2mm such that the instrument is slightly inclined towards the front face. Loosen the small locking screw '7' of the balancing weight '8'. Remove the two retention pins '3'. The boom should now move freely. Adjust the balancing weight '8' until the boom is in equilibrium. The boom should now oscillate with a period of several seconds. If it does not, check for particles that may cause friction, and for damaged hinges. Friction may also result from improper operation of the boom-centering motor which is accessible through a window in the base plate. The motor should disengage as soon as the feedback electronics are connected and powered.

If the hinges do not appear straight when the pendulum is free, or a clicking noise occurs when the pendulum is moved from one stop to the other, proceed as follows: Insert the retention pins, the spacer block and the locking screws. Put the seismometer with the bottom up on a table. Open the lid in the base plate. Loosen that clamp of the horizontal hinges that is nearer to the seismic mass and tighten it again. Remove the locking parts and test again for proper function. If necessary, repeat the procedure with the vertical hinges (specially bent hex keys are required for this). If the hinges are permanently bent they must be replaced. It is normal that the hinges appear slightly bent while the pendulum is clamped.

V Insert retention pins and put on the cover after the inspection.
V
V The retention pins must always be inserted before putting the
V
V cover on or off. They are accessible through four holes in the
V
V cover which are normally closed with lids. The lids should be
V
V in their place when the cover is being lifted off, otherwise the
V
V cover may be retained by the pins.

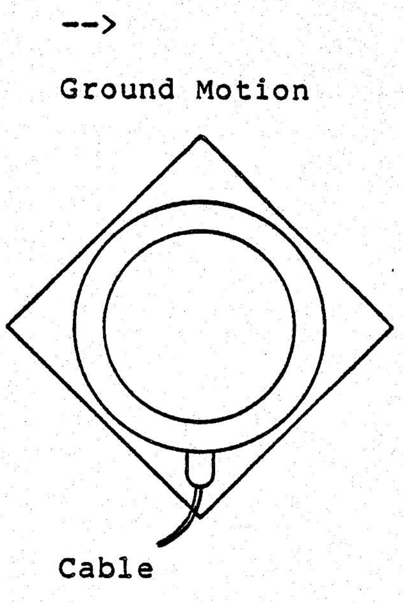
Machanical Inspection of the Horizontal Sensor

H The horizontal sensor is checked in a similar way. Its boom
H
H is centered by tilting the instrument laterally, rather than
H
H by moving a weight.

See next section for details.

Installation of the Glass Plate

The glass base plate (35 cm x 35 cm x 2 cm) has to provide both mechanical and thermal contact with the ground. It should be cemented or glued to a pier, a cement floor, or a rock. For permanent installations we recommend the use of normal cement to fix the plate. Quick-drying cement is not recommended because it tends to crack after some time. If it is intended to remove the plate later, sealing compounds based on silicone rubber may be used as a glue. They can later be cut with a loop of steel wire when the layer is not too thin. Observe the proper orientation of the glass plates for the horizontal instruments.



Positive output signal at brb+
Negative output signal at brb-

Mount the glass cock with the rubber stopper in the boring of the aluminum ring on the glass plate, using a small amount of silicone vacuum grease. Plug the waterproof connector of the orange cable into its counterpiece in the aluminum ring.

Installation of the Vertical Sensor

Open the sensor as previously described. - Remove the clamping screws and the spacer block from the seismometer as previously described but keep the retention pins inserted. Fasten the lower lid of the Permalloy shield to the round aluminum base plate with the three screws supplied, unless it is already in place.

Plug the connector of the flat cable fastened to the glass plate into the base of the seismometer and install the seismometer on the glass plate with its legs in the appropriate holes of the permalloy shield. Avoid tilting the seismometer sidewise during this operation.

Levelling the Vertical Sensor

The seismometer must now be levelled so that its sensitive axis is vertical and its mechanical free period is nearly infinite. This adjustment can coarsely be made using the mechanical sensor alone but for a more precise adjustment the feedback electronics, or the special MGF1 feedback box must be used. We describe these three methods in detail in the subsequent section. It is convenient to adjust the position of the vertical sensor to an output signal of +6V before the shields are installed. The boom will then be nearly centered after evacuation. Secure the balancing weight with the small headless screw after the final adjustment.

Three different methods can be used to level the vertical seismometer. We call them the Mechanical Method, the Method of the Electrical Free Oscillation, and the Maximum-Gravity method. The Mechanical Method is simple and can be performed with the sensor alone, i. e. without the feedback electronics; but it is not very precise. The Free-Oscillation Method is applied with the feedback electronics connected to the sensor. It can be used both for the 360 sec - and the 20 sec - mode of operation and provides the best agreement of the response with the manufacturer's calibration. The Maximum-Gravity method makes the sensor most unsensitive to horizontal ground noise. It is applied either with the feedback electronics in the 20 sec - mode or, preferably, with a special tool, the MGF1 feedback box, in its place. The latter two methods are in most cases practically equivalent, except at sites with very high horizontal noise.

Precise levelling of the sensor is important for two reasons: the exact closed-loop response of the system depends to some degree on the mechanical adjustment of the sensor; and a tilted vertical seismometer is sensitive to horizontal ground noise and may therefore fail to resolve vertical ground noise at a site where there is large long-period horizontal noise.

The following adjustments require that the sensor has been installed on the glass plate, with the transportation lock removed and the retention pins inserted. Tighten the counternuts of the foot screws slightly before making the final adjustment.

(1) The Mechanical Method

Remove the cover of the sensor. Level the sensor mechanically with the foot screws, using a bubble level. The top surface of the sensor (without cover) may serve as a reference. Secure the two front foot screws with the counternuts and use only the single rear foot screw for further adjustments. Tilt the sensor forward by screwing the rear foot screw out by about three turns. Remove the retention pins. The pendulum should now move freely. (Consult the section on Mechanical Inspection if it does not)

Balance the sensor against gravity by adjusting the position of the horizontal balancing weight inside one of the two seismic masses. The pendulum should now oscillate with a period of several seconds. Adjust the period of oscillation to 5.2 sec by screwing the rear foot in if the period is short, and out if it is long. Then screw in the rear foot by exactly two turns. This will bring the pendulum close to indifferent equilibrium, which is the condition under which the feedback system was calibrated. Alternatively, the pendulum may be adjusted to a free period of 7.5 sec and the rear foot subsequently screwed in by exactly one turn. It may be necessary to correct the balancing weight during these adjustments. Six small holes are provided in the knurled part of the footscrews to facilitate precise adjustments.

(2) The Method of Electrical Free Oscillations

Connect the feedback electronics to the seismometer. Connect the monitor instrument MON1 to the feedback electronics via the center connector, and supply +-15V to the electronics via the appropriate connectors of the monitor instrument unless the power is supplied through the "remote" connector (= righthand connector) of the feedback electronics. In the 20 sec mode, the sensor can also be controlled and observed from the Signal Conditioner and Remote Control Unit ST-CCU which forms part of the standard amplifier-filter set. Note that the DA functions of the MON1 box and of the Remote Control and Test module in the ST-CCU unit are not the same in the 360 sec mode (an explanation is given below). If none of these two devices is available, a moving-coil voltmeter with center zero, a power supply and a switch connected directly to the damping relay of the feedback electronics can do the same job.

The mechanical adjustments are then made as follows:
Level the sensor mechanically with a bubble level as in method (1).
Set the Monitor Instrument to the position "POS" or connect a moving-coil voltmeter to the "POSITION" output of the feedback electronics, and adjust the balance of the boom until a position near zero is indicated. This adjustment should be made to whithin 1% of the operating range (i. e. +-100mV) in the 360 sec mode, otherwise the system may enter uncontrollable oscillations in the next step. In the 20 sec mode, the adjustment is not critical. Use the balancing weight for coarse and the motor for fine adjustment.

Remove damping from the feedback system by switching to "DA" on the Monitor Instrument, or apply 12 to 15V to the damping relay input "+REL" "-REL". (Observe the polarity)

Observe the free oscillations of the output signal. They have a period close to 20 sec in the 20 sec - mode and close to 36 sec in the 360 sec - mode. (Otherwise the feedback circuit is not working properly)

If the oscillations go out of range, restore damping and center the boom more precisely. If the oscillations are too small to be conveniently observed, they may be excited by

- blowing air against the boom
- sending a DC current (1 mA max) into the calibration coil
- connecting a small DC motor (such as used in battery-operated toys) to the calibration coil and driving it by hand, thus using it as a signal generator. This is by far the most convenient method.

Observe the exponential growth or decay of the oscillations and adjust the rear foot screw until the amplitude remains constant within 1% per cycle. Damping will increase when the sensor is tilted forward. The sensor should be covered for a precise measurement.

Additional explanations on the "DA" function and on remote centering can be found after the section on the installation of the horizontal sensor.

(3) The Maximum - Gravity Method

This method is based on the fact that the vertical sensor "sees" maximum gravity when its sensitive axis is precisely vertical. Maximum gravity is associated with a minimum of the "POS" output signal of the seismometer.

(3a) The Maximum - Gravity Method with the MGF1 feedback box

Level the seismometer mechanically with a bubble level as desribed above. Connect the battery- powered MGF1 feedback box to the seis- mometer. Adjust the balancing weights in the seismometer until the voltmeter in the MGF1 box gives a reading between -2V and +2V. Then level the seismometer, using all three foot screws, until the volt- meter gives a minimum (i.e. most negative) reading. Wait a few se- conds after each manipulation until the instrument settles. It may be necessary to readjust the balancing weight in the process. The final position of each foot screw is most easily determined as the median between two positions that give identical non-minimum rea- dings on the voltmeter.

(3b) The Maximum - Gravity Method with the Feedback Electronics in the 20 sec - Mode

Select the 20 sec - mode of the feedback electronics with the appropriate jumpers (see section 4).

Connect the feedback electronics to the seismometer as described above under the Free - Oscillation Method.

Observe the voltmeter in switch position "POS". Use the same procedure as described under (3a) to find the maximum - gravity position of the sensor. Due to the longer time constants involved, the feedback electronics require about 45 sec to settle after each manipulation. The maximum - gravity position is therefore difficult to determine when the seismometer drifts. The procedure should only be attempted when the seismometer is in thermal equilibrium. Recording the "POS" signal on a chart recorder will help to identify the desired minimum.

Reset the jumpers to the 360 sec - mode if desired. The maximum-gravity position of the mechanical sensor is the same for both modes of operation of the feedback electronics.

Installation of the Shields and Evacuation

When the sensor is levelled and its cover is in place, the Permalloy shield and the outer aluminum shield are installed. There is only little space between the sensor and the permalloy shield; make sure that they do not touch each other. Some thermal compound or silicone grease may be applied to the lower rim of the aluminum shield in order to improve the thermal contact with the base plate.

Clean the grooves in the aluminum ring if necessary. Apply silicone grease to both sides of the two rubber fittings and fit them into the grooves. Make sure that the rim of the glass bell is clean, and mount it carefully. Evacuate the glass bell with any kind of vacuum pump. There is no need to reduce the pressure in the bell to less than 10% of the atmospheric pressure. A higher vacuum, or repeated pumping, however, may help to remove humidity possibly collected by the sensor during installation.

Install additional insulations around the glass bell according to local requirements. Cover the whole installation, including an area of about 1 sqare meter around the sensor, with a single piece of a heat-reflecting blanket.

Check the vacuum after one day and after one month by opening the valve during a fraction of a second.

To remove the bell from the base plate, aerate it and blow air into it by means of a mouth-piece tube, and close the cock again. After a while, the overpressure will detach the bell from the gaskets. Do not use a pump for this purpose!

Note that the silicone rubber coating of the glass plate is not stable to solvents.

Installation of the Horizontal Sensor

This section duplicates to some extent the section on the installation of the vertical sensor; we will again describe each step for clarity.

Remove the cover and the rectangular clamping plate from the seismometer but keep the retention ring inserted. Plug the connector of the flat cable fastened to the glass plate into the base of the seismometer and install the seismometer on the glass plate with its legs in the appropriate holes of the aluminum plate.

Levelling the Horizontal Sensor

(1) The Mechanical Method

Remove the retention ring and level the seismometer coarsely with the two adjustable foot screws until its boom is near indifferent equilibrium. Tilt the seismometer forward to obtain a stable equilibrium, then backward to indifferent equilibrium. Reinsert the retention ring. The position is adjusted by turning the two free foot screws by equal amounts in the same direction, and the period by turning them oppositely.

ORIENTATION

The sensor must now be precisely oriented. Seismometers delivered after mid- 1986 have a hollow boom and can be optically aligned; the boom can also be extended with a rod of 5 mm diameter.

The next step is the fine levelling. Either the Mechanical Method or the Method of Electrical Free Oscillations can be applied, the latter being more precise. The mechanical levelling has already been described (1); the free period should now be brought to a value between 30 sec and infinity (indifferent equilibrium).

Tighten the counternuts slightly before making the final adjustment.

The Method of Electrical Free Oscillations (2) is described below.

(2) The Method of Electrical Free Oscillations

Connect the feedback electronics to the seismometer. Connect the monitor instrument MON1 to the feedback electronics via the center connector, and supply +-15V to the electronics via the appropriate connectors of the monitor instrument unless the power is supplied through the "remote" connector (righthand connector) of the feedback electronics. In the 20 sec mode, the sensor can also be controlled and observed from the Signal Conditioner and Remote Control Unit ST-CCU which forms part of the standard amplifier - filter set. Note that the DA functions of the MON1 box and of the Remote Control and Test module in the ST-CCU unit are not the same in the 360 sec mode (an explanation is given below). If none of these two devices is available, a moving-coil voltmeter with center zero, a power supply and a switch connected directly to the damping relay of the feedback electronics can do the same job.

The mechanical adjustments are then made as follows:

Level the sensor mechanically with a bubble level as in method (1).

Set the Monitor Instrument to the position "POS" or connect a moving-coil voltmeter to the "POSITION" output of the feedback electronics, and adjust the balance of the boom until a position near zero is indicated. This adjustment should be made to within 1% of the operating range (i. e. +- 100mV) in the 360 sec mode, otherwise the system may enter uncontrollable oscillations in the next step. In the 20 sec mode, the adjustment is not critical. Use the balancing weight for coarse and the motor for fine adjustment.

Remove damping from the feedback system by switching to "DA" on the Monitor Instrument or apply 12 to 15V to the damping relay input "+REL" "-REL". (Observe the polarity)

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- blowing air against the boom
- sending a DC current (1 mA max) into the calibration coil
- connecting a small DC motor (such as used in battery-operated toys) to the calibration coil and driving it by hand, thus using it as a signal generator. This is by far the most convenient method.

Observe the exponential growth or decay of the oscillations and adjust the foot screws until the amplitude remains constant within 1% per cycle. Damping will increase when the sensor is tilted forward. The sensor should be covered for a precise measurement.

Additional explanations on the "DA" function and on remote centering can be found after the section on the installation of the shields and evacuation.

Installation of the Shields and Evacuation

Mount the cover and the outer aluminum shield. Some thermal compound or silicone grease may be applied to the lower rim of the aluminum shield in order to improve the thermal contact with the base plate.

Clean the grooves in the aluminum ring if necessary. Apply silicone grease to both sides of the two rubber fittings and fit them into the grooves. Make sure that the rim of the glass bell is clean, and mount it carefully. Evacuate the glass bell with any kind of vacuum pump. There is no need to reduce the pressure in the bell to less than 10% of the atmospheric pressure. A higher vacuum, or repeated pumping, however, may help to remove humidity possibly collected by the sensor during installation.

Install additional insulations around the glass bell according to local requirements. Cover the whole installation, including an area of about 1 sqare meter around the sensor, with a single piece of a heat-reflecting blanket.

Check the vacuum after one day and after one month by opening the valve during a fraction of a second.

To remove the bell from the base plate, aerate it and blow air into it by means of a mouth-piece tube, and close the cock again. After a while, the overpressure will detach the bell from the gaskets. Do not use a pump for this purpose!

Note that the silicone rubber coating of the glass plate is not stable to solvents.

The "DA" Function

The "DA" function, which can be activated locally or remotely, removes the electrical damping from the feedback circuit as described below in the "Theory of Operation". However, the apparent damping of the closed - loop system also depends on the free period of the mechanical system, which fact is used in the free- oscillation method to adjust the latter. Thus, tilting the sensor will change the (mechanical) free period when the feedback electronics are disconnected, and the overall damping of the closed - loop system. Note that the observed free period of the closed - loop system is not identical to its nominal free period that appears in the transfer function. So the electrical oscillations cannot be used to calibrate the free period. The difference between the two periods is however small when the DA function is activated from the Remote Control and Test module of the ST-CCU unit, i.e. over the "Remote" connector of the feedback electronics. The electrical oscillations can be therefore be used for a remote test of the system. The difference is also small if the DA function is activated in the 20 sec mode from the MON1 monitor box, i.e. via the monitor connector. However, if the same function is activated via the monitor connector in the 360 sec mode (which should only be done with the POS signal within +- 100mV) it reduces the free period by a factor of about 10 in order to facilitate the installation with the free - oscillation method.

Remote Boom Centering

The boom of the STS-1 seismometers remains always centered (at least in the time average) while the feedback is operating. Any mechanical drift is compensated by a restoring force derived from the output of an integrator in the feedback circuit. In order to keep the integrator within its operating range, the mechanical equilibrium must occasionally be restored. For compatibility with conventional seismometers we will describe this process as "boom centering"; what is centered is actually the output signal of the integrator, from which the signal referred to as "boom position" is derived.

A special printed - circuit board is included in the seismometer electronics to facilitate boom centering. This is necessary because the slow response of the feedback electronics in the 360 sec mode does not permit an instantaneous determination of the boom position, and because the centering mechanism of the vertical seismometer causes irregular boom motions. The POS signal normally indicates the true position of the boom, but while the centering motor is running, the POS signal is replaced by an extrapolated signal that indicates where the boom position will settle when the motor stops.

The centering motor can be switched on and off remotely by a digital command to the ST-CCU unit, or by the MOT switch in the Remote Control and Test module, or from the monitor box when its rotary switch is in the MOT position.

After any manipulation of the centering mechanism, wait at least during one free period (i. e. 20 sec or 360 sec) for settlement of the system.

The boom centering mechanisms are protected against running out of their ranges. The motor of the horizontal instruments will stop and that of the vertical will idle at the end of the range. However, the range of operation in both instruments is so large that the mechanism is not expected to ever reach its stop except in the case of a mismanipulation. Both centering mechanisms will return to normal operation when the motor switch is reversed.

4) Conversion Between the 20 Sec and 360 Sec Modes

The conversion is done by jumpers in the feedback electronics. Jumpers must be changed in three subunits: in the auxiliary print VBB1 of the motherboard SFE, in the demodulator, and in the integrator (see pages 44, 60 and 65)

Motherboard: Two little jumpers must be installed in one of two possible positions which are marked with "20" and "360", on the auxiliary print VBB1 bearing the feedback resistors

Demodulator: An 8-pin socket bearing 4 resistors must be installed in one of two possible positions. The 360 sec position is nearer to the relay (or to the top of the subunit when it is plugged into the motherboard)

Integrator: Two red wires with miniature connectors must be plugged either into pins on two ceramic isolators (20 sec) or into unconnected pins in the PC board (360 sec)

5) Theory of Operation

The STS-1 sensors are force-balance instruments, which means that the boom is always kept close to its neutral position by an electrically generated restoring force. The current required to generate the force is proportional to the seismic acceleration acting on the instrument and provides the output signal. Since electromagnetic transducers have a very large dynamic range, the same applies to the output signal. Practically the dynamic range is only limited by the ability to measure or record the feedback current.

The feedback circuit (see next figure) provides three feedback paths where the current is proportional to the instantaneous deflection of the boom, to its first time derivative, and to its integral. Let us first consider the integral path. At sufficiently long periods the current in this path will dominate over those in the other paths and will thus measure the seismic acceleration. The signal at the LP output is directly proportional to the integral feedback current, the conversion depending on a single resistor R3 through which the current flows. No active electronic components are involved, thus no noise and no distortions enter here. This principle contributes significantly to the high overall dynamic range of the instrument.

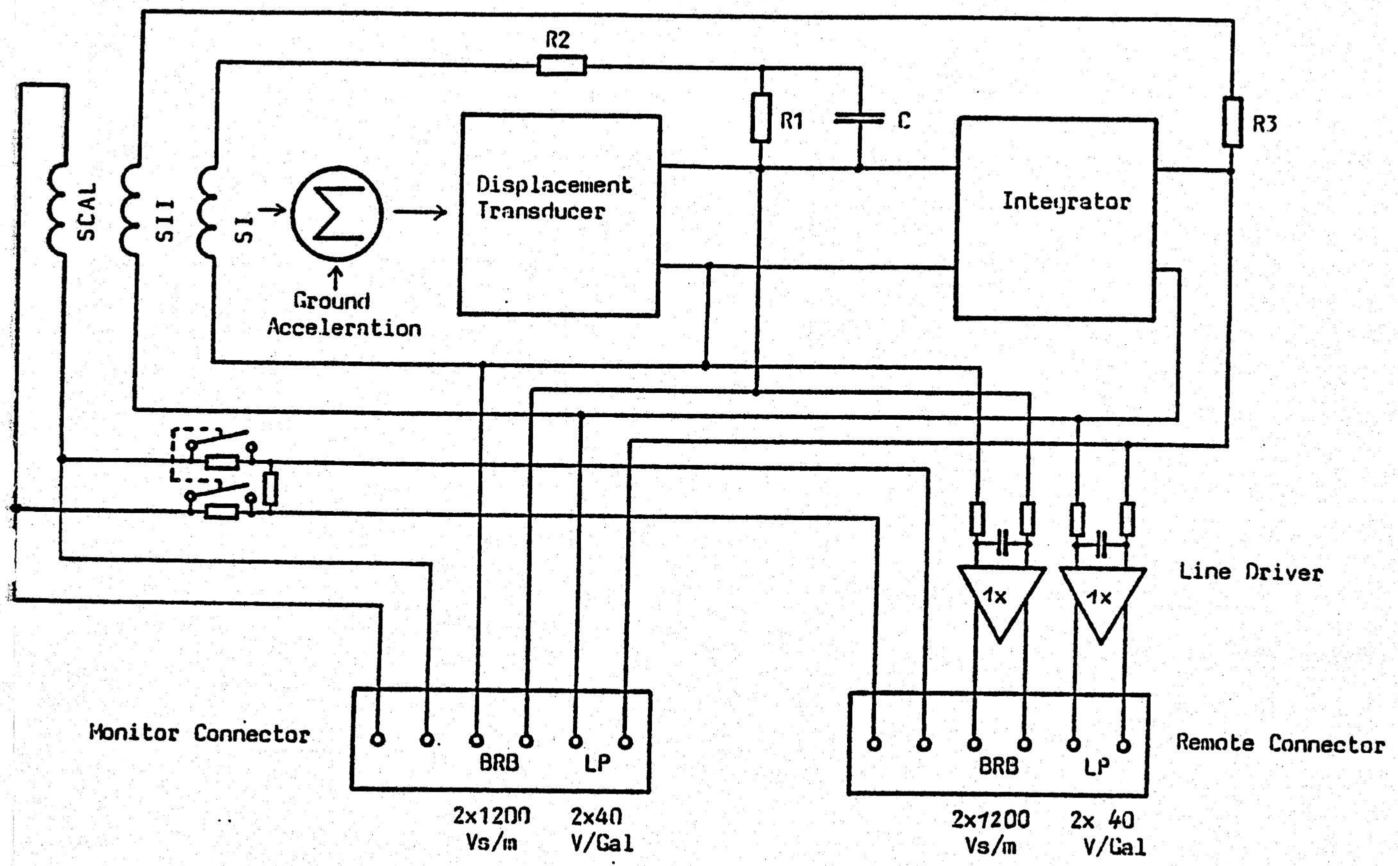
The LP output signal is however not normally used in the 360 sec mode because all seismic signals of interest are resolved in the VBB output signal.

In a similar way we can understand how the signal at the broad-band output is generated. At periods shorter than the free period of the feedback system (20 or 360 sec), the differential feedback current dominates and is thus proportional to the seismic acceleration. It flows through the capacitor C and produces there a voltage that is proportional to the seismic velocity; this is the BRB output signal. Again no active components are involved and we have the full dynamic range of the instrument available at the BRB output.

R3 and C are chosen such that the integral and differential currents produce the same feedback force at the desired free period; however, they are of opposite phase. There would be no negative feedback at all and the system would therefore have a resonance if there were not provided a third feedback path, over the resistor R1, in which the current is proportional to the displacement of the boom. This current cannot be cancelled by the other two and eliminates the resonance. R1 can thus be considered as a damping resistor for the feedback circuit. It can be seen that any restoring force resulting from the mechanical suspension has the same effect on the overall transfer function as making the proportional feedback current larger. When no mechanical restoring force exists and R1 is disconnected, the system will perform undamped oscillations at its free period. We make use of this effect when we adjust the mechanical system to zero restoring force. A mathematical analysis shows that, with R1 connected, the system will behave like a moving - coil 20 or 360 sec LP seismometer with a velocity transducer (BRB output) and a displacement transducer (LP output).

The change between the 20 sec and the 360 sec mode is made with jumpers in the feedback electronics; damping can be switched off remotely in different ways. More information on the theory of operation of the 360 sec mode can be found in a publication by Wielandt and Steim in Annales Geophsicae B4 (1986).

FEEDBACK CIRCUIT



SI SII SCAL — Coils

RSI RSII RSCAL — Resistances of corresponding coils

At short periods this simple picture must slightly be modified. Due to reduced displacement amplitudes (relative to a given acceleration or velocity) the loop gain diminishes towards higher frequencies and the feedback becomes ineffective at 10 Hz. The system then is no longer a force-balance system but simply a seismometer with a displacement transducer generating the BRB output signal. With a little trick we can, however, still describe the overall response in terms of a familiar wide-band recording system.

When we add somewhere in the external signal circuit a first-order RC low-pass combination with a time constant (RSI + R2)*C (approx. 13 msec), then the overall response will be that of a LP seismometer combined with a 0.1 sec short-period galvanometer or an equivalent short-period recording system. Since such a system is more familiar to seismologists than the bare feedback system, we will for the purpose of calibration always assume that the external RC combination has been added. The RC combination is included in the Line Drivers which feed the "remote" output.

However, the "monitor" output does not include the RC combination. Therefore, when the "monitor" output is used for calibration, an external RC combination must be added, either in the circuit that feeds the calibration coil, or in the output circuit.

The 0.1 sec second-order low-pass filter which then limits the high-frequency response may be considered as part of an anti-aliasing filter for digital recording.

6) Calibration Procedures

The STS-1 sensors are calibrated by the manufacturer in two steps: first an absolute calibration at zero frequency is obtained on a tilt table, then a relative calibration at periods between 360 and 0.1 sec. One very precise method of calibration is the comparison with an electronic standard circuit that has the desired transfer function. The latter consists of a second-order high-pass filter with 360 sec corner period and 0.7071 of critical damping, and a second-order low-pass filter with 0.1 sec corner period and 0.623 of critical damping.

a) Absolute Calibration (20 sec mode only)

The seismometer is put on a tilt table, which is in the simplest case a solid metal plate of suitable size resting on three foot screws of which one has a micrometer scale. A tilt resolution of 0.001 degrees is desirable. When a horizontal seismometer is tilted in its sensitive direction, the signal at the LP output will settle to a value directly proportional to the tilt angle.

The quantity

$$\frac{\Delta u_{LP}}{\Delta g} = \frac{\Delta u_{LP}}{g \Delta \varphi} \qquad \text{where } g = \text{gravity; } \Delta\varphi = \text{tilt angle}$$

describes the responsivity of the LP output to horizontal accelerations. For a vertical sensor tilting has the effect that the instrument sees only that component of the gravity that is parallel to its sensitive axis; the relationship between tilt and LP output signal is therefore described by a cosine function or, since the angles are small, by a quadratic function. To determine the responsivity to vertical accelerations, one has to form the second-order differences $\Delta^2 \bar{u}_{LP}$ of the output signal. The increments of the tilt angle must be constant in this experiment. The responsivity is then obtained as

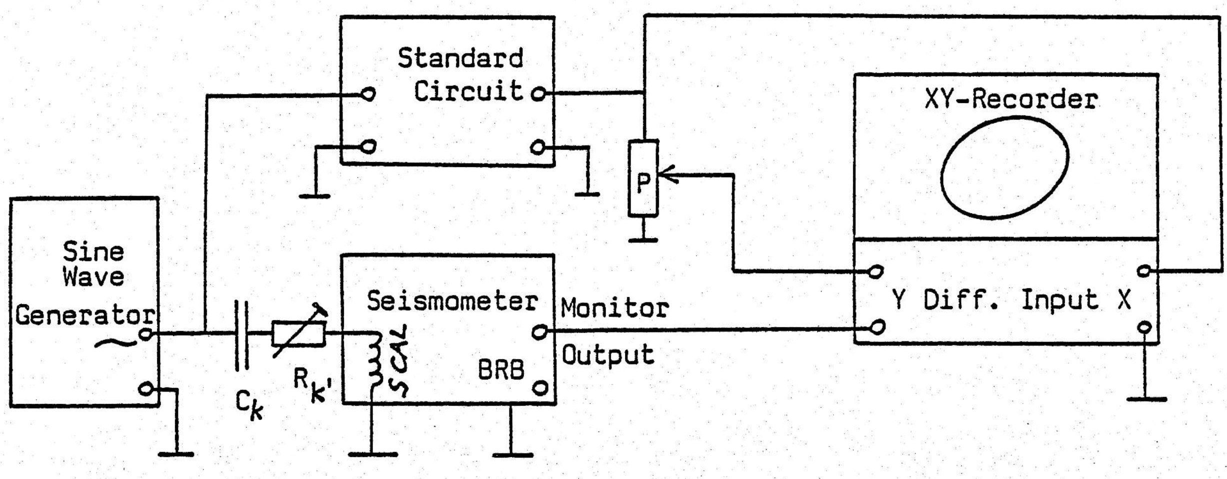
$$\frac{\Delta u_{LP}}{\Delta g} = \frac{\Delta^2 u_{LP}}{g_0 (\Delta \varphi)^2} = \frac{u^+_{LP} - 2 u^0_{LP} + u^-_{LP}}{g_0 (\Delta \varphi)^2}$$

where g_0 is the normal gravity (9.81 m/sec^2)

Repeated measurements up and down are recommended to eliminate temperature drift. The absolute calibration procedure can only be performed in the 20 sec mode, but the results are valid for the 360 sec mode as well.

b) Relative Calibration

This calibration requires, besides the above-mentioned standard circuit, a good low-frequency sinewave generator (preferably a digital synthesizer with subsequent low-pass filtering), and an XY recorder with a good response up to 10 Hz. The setup of the instruments is shown in the following figure. To obtain an input signal proportional to velocity, the calibration coil is exited over a large capacitor (order of 100uF, solid dielectric). The output signal at the BRB output has then a constant level between the corner periods at 0.1 and 20 resp. 360 sec. A series resistor Rk' together with the resistance of the coil introduces the prescribed external phase lag corresponding to a time constant of 13 msec. The XY-recorder records the error between the output signal of the seismometer and that of the standard circuit. The feedback components, the gain of the displacement transducer, and the potentiometer P are then adjusted such that the error is minimized over the whole passband of the instrument.

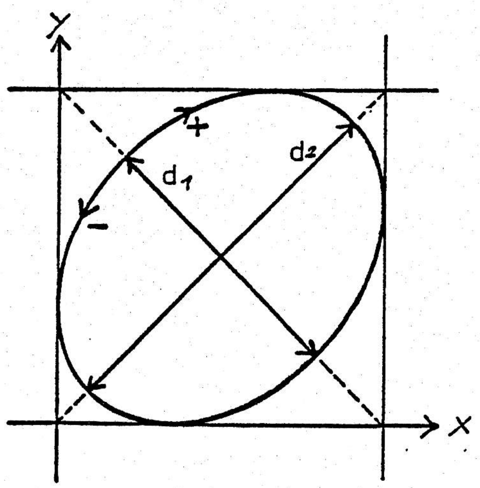


c) Check of the Phase Response

When no standard circuit is available, the amplitude and phase response can still be measured with great accuracy with the ellipse method proposed by Mitronovas and Wielandt (BSSA vol. 65 pp. 411-424, 1975). The seismometer is excited as before but the X input of the XY-recorder is connected to the input signal (before the capacitor) and the Y input to the output signal. For a quick comparison we tabulate below the phase shift, in degrees, of the BRB output with respect to the input signal at the capacitor.

The method can also be used with the LP output in the 20 sec mode and with a resistor, in place of the capacitor, in series with the calibration coil. The output signal is then of constant amplitude at long periods. The 13 msec time constant must be provided separately but can be neglected at long periods. Alternatively, the "remote" output can be used which includes the mecessaty time constant.

Period (sec)	Phase (degrees)	
	20 sec mode	360 sec mode
600	177.29	127.01
360	175.47	89.98
200	171.83	48.61
100	163.51	22.99
50	145.90	11.18
20	89.64	4.15
10	41.60	1.54
5	19.23	-0.30
2	4.55	-3.13
1	-3.12	-6.95
0.5	-12.54	-14.45
0.2	-38.93	-39.69
0.1	-89.59	-89.98
0.05	-140.06	-140.25



Determination of the Phase from Conjugated Diameters of the Ellipse

φ = +- 2 arctan (d_1 / d_2)

Seismometer Transfer Function

All STS-1 VBB seismometers have exactly the same transfer function corresponding to that of a 20 / 360 sec LP seismometer coupled to a 0.1 sec recording galvanometer. The response of the BRB output to ground velocity is

$$T(\omega) = \frac{-\omega^2 S}{-\omega^2 + 2i\omega\omega_- h_- + \omega_-^2} \cdot \frac{\omega_+^2}{-\omega^2 + 2i\omega\omega_+ h_+ + \omega_+^2}$$

The same transfer function with a nominator $-\omega^2 W$ in place of $-\omega^2 S$ is valid for the displacement response of the LP output. A first-order lowpass filter (RC filter) with a time constant $\tau \approx 13$ msec must be incorporated in the subsequent amplifier in order to make these transfer functions valid. However, it may be omitted in long-period applications.

Numerical values of the constants are:

$\omega_- = 2\pi/20$ sec or $2\pi/360$ sec

$h_- = 1/\sqrt{2}$

$\omega_+ = 2\pi/0.1$ sec

$h_+ = 0.6235$

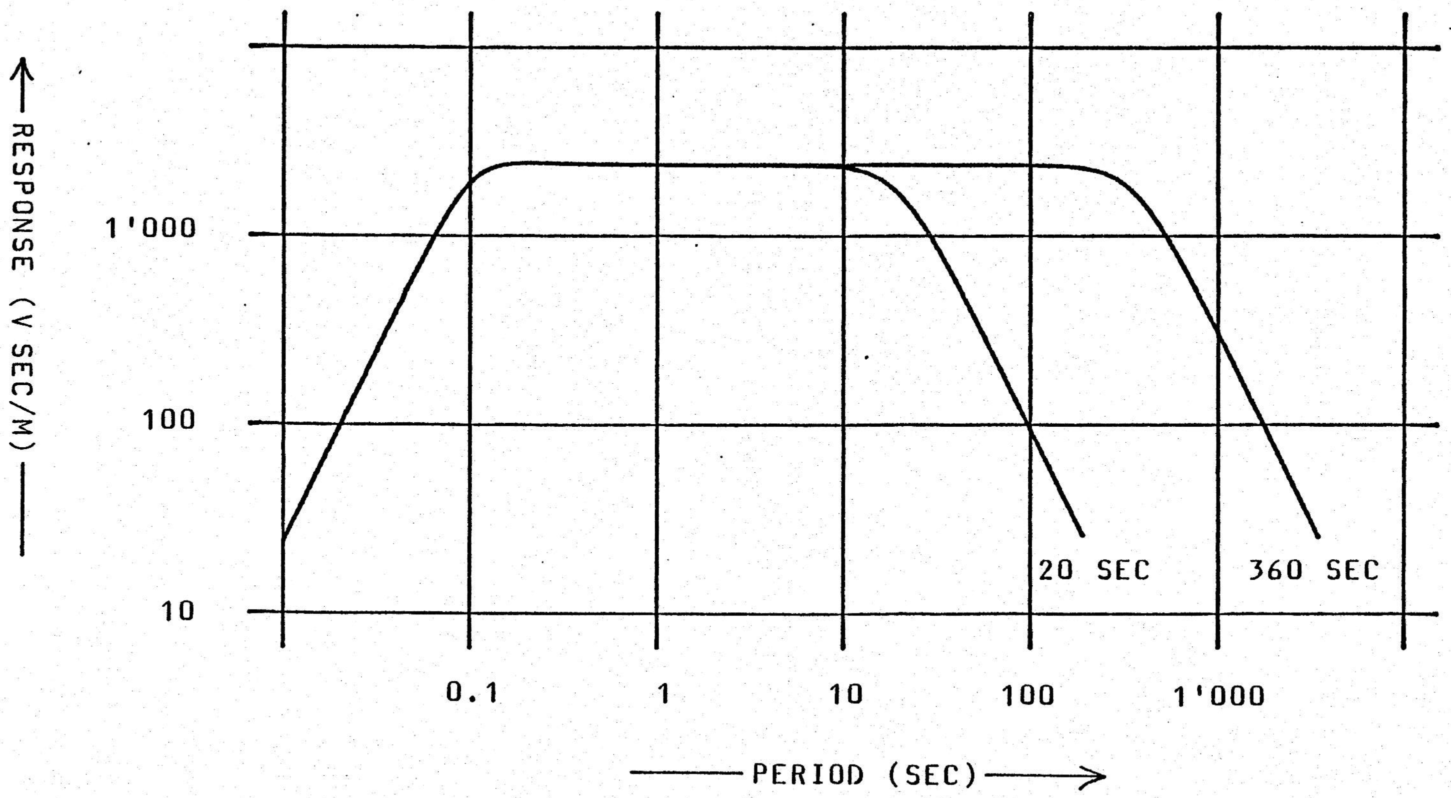
$S \approx 2400$ Vsec/m (see calibration sheet)

$W/\omega_-^2 \approx 80$ V/gal (see calibration sheet)

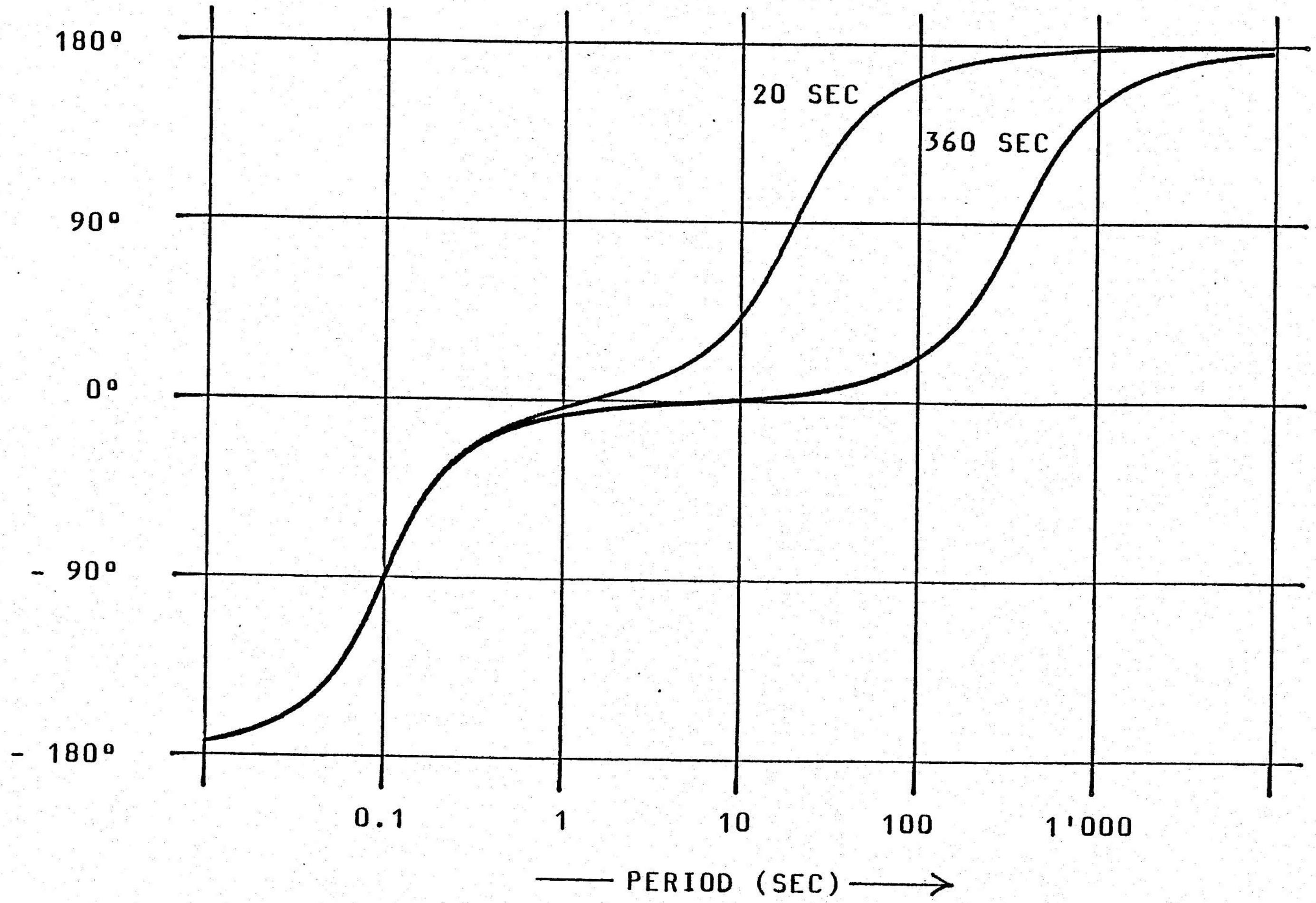
$\tau = (R_2 + R_{ST}) \cdot C$ (see calibration sheet)

It is however sufficient to use a time constant of 13 msec for all instruments since these differ only by fractions of a millisecond.

VELOCITY RESPONSE AT BRB OUTPUT

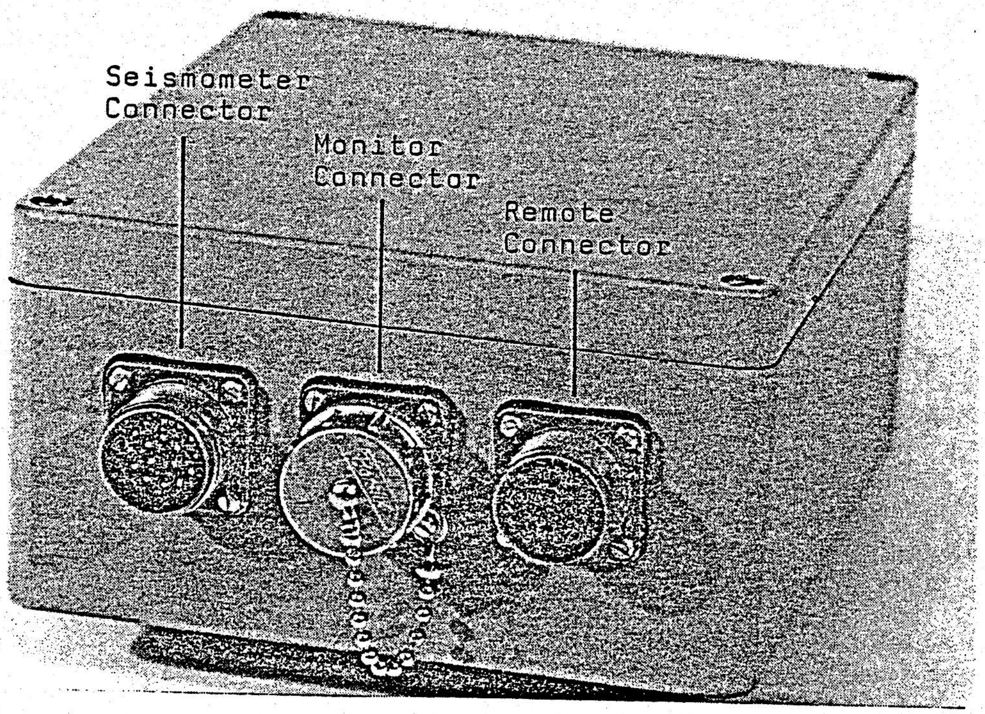


PHASE RESPONSE AT BRB OUTPUT



7) Feedback Electronics

The calibration of the STS-1 sensors is only valid with their specific feedback unit (Near-Seismometer Electronics). This unit is housed in a moistureproof box with three connectors for the sensor, the Signal Conditioner and Remote Control Unit ST-CCU, and the Monitor Instrument MON1 (On-Place Test and Control Box). The Monitor Instrument is essentially a simplified version of the "Remote Control and Test" subunit in the ST-CCU and provides immediate control of the sensor during installation and testing. The feedback electronics must be installed within two meters from the sensor. The signal cable to the ST-CCU unit can be up to 100m long. Electric power is supplied from the ST-CCU unit through the signal cable.

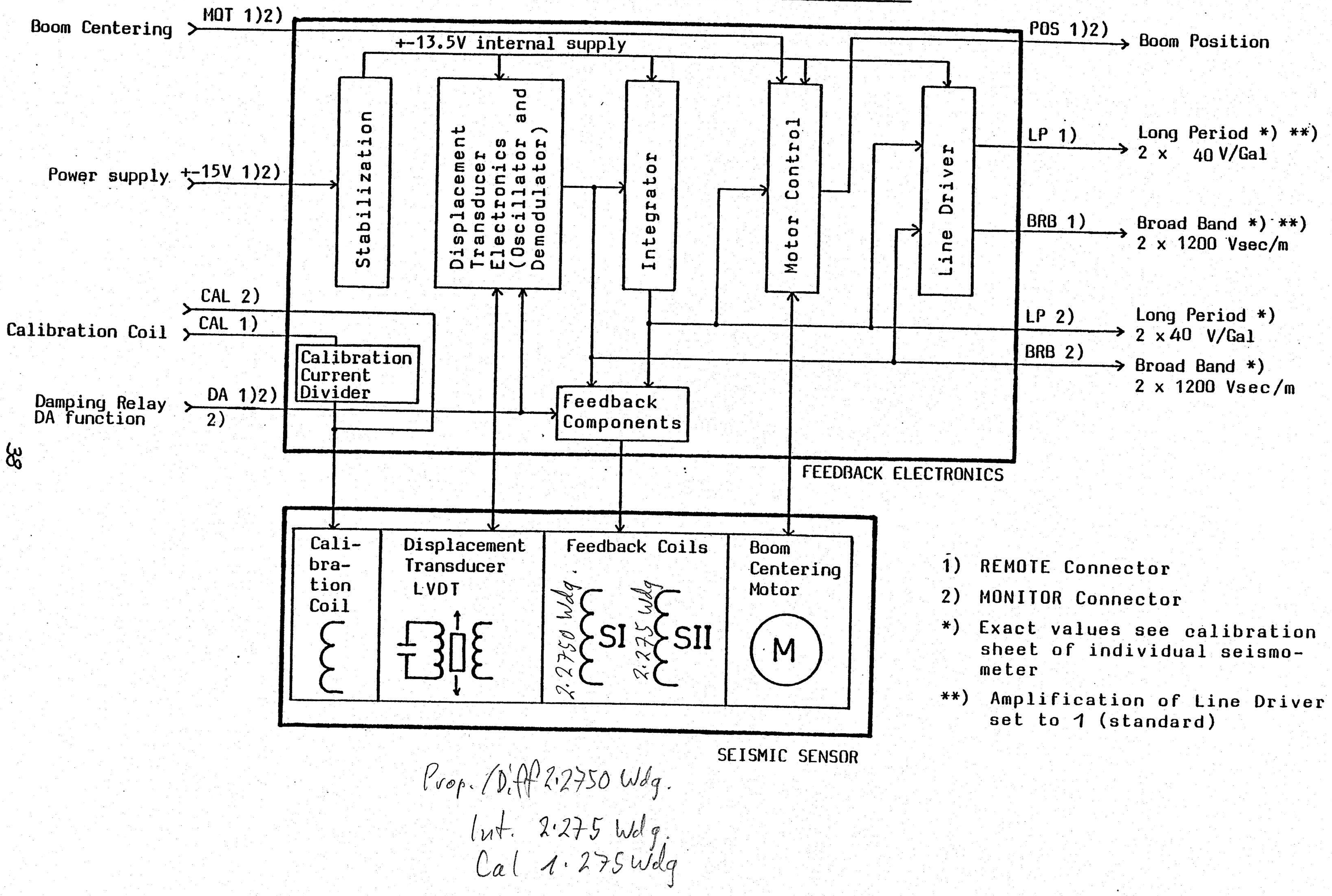


The feedback unit contains several subunits on small PC boards, namely a voltage stabilizer, oscillator and demodulator for the LVDT displacement transducer, an integrator, control circuitry for the boom centering motor, and line drivers. A few more components are directly mounted on the main PC board. We give a short description of all subunits.

ATTENTION Interchanging the feedback electronics between different instruments will result in:

- Loss of calibration (because the feedback components are matched to the mechanical sensor)
- Malfunction of the centering motor when horizontal and vertical electronics are interchanged. This can, however, be avoided when the appropriate motor control subunit is kept with each sensor, i.e. only the rest of the electronics is interchanged

STS-1V/VBB / STS-1H/VBB SEISMOMETERS - BLOCK DIAGRAM



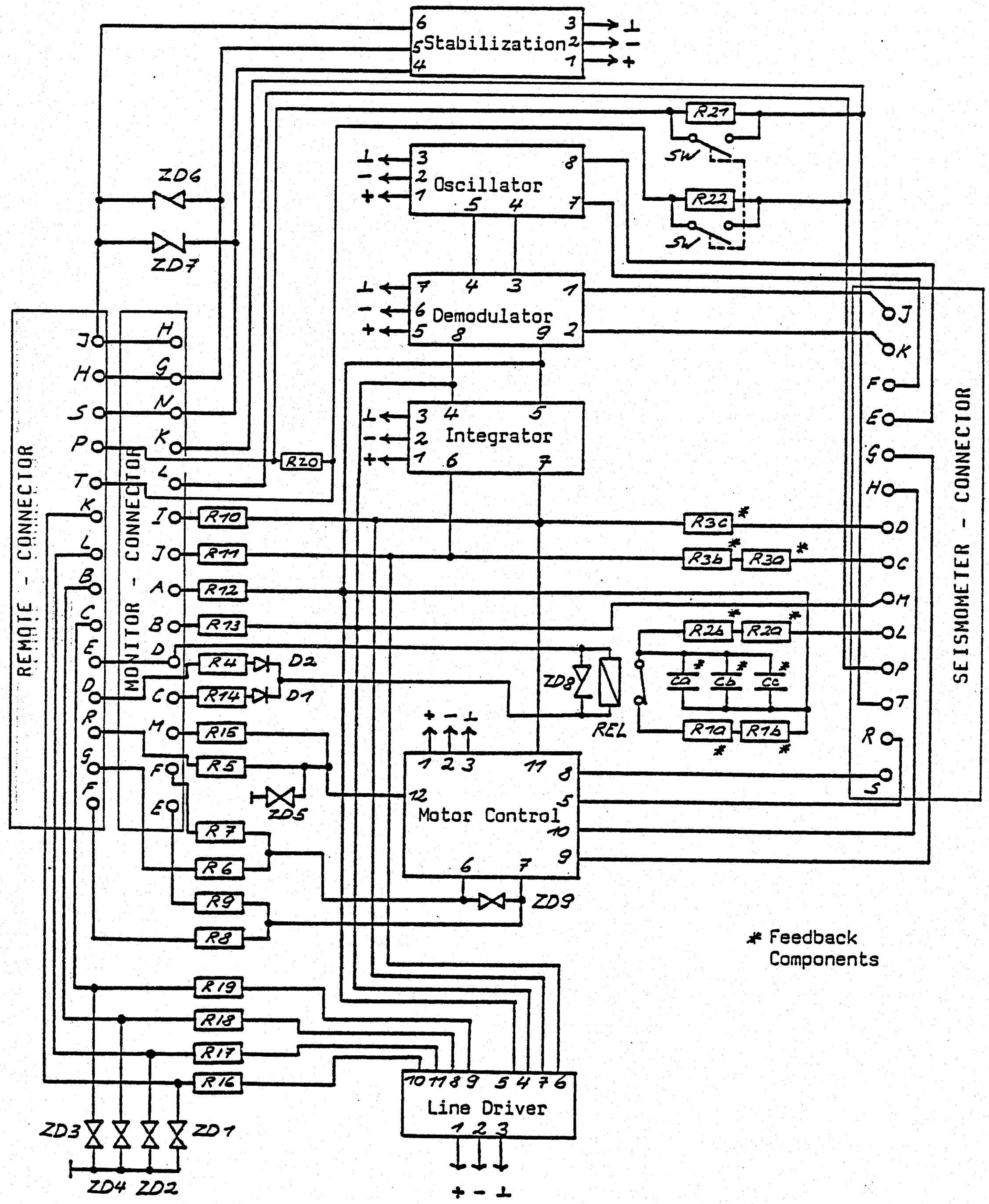
1) REMOTE Connector

2) MONITOR Connector

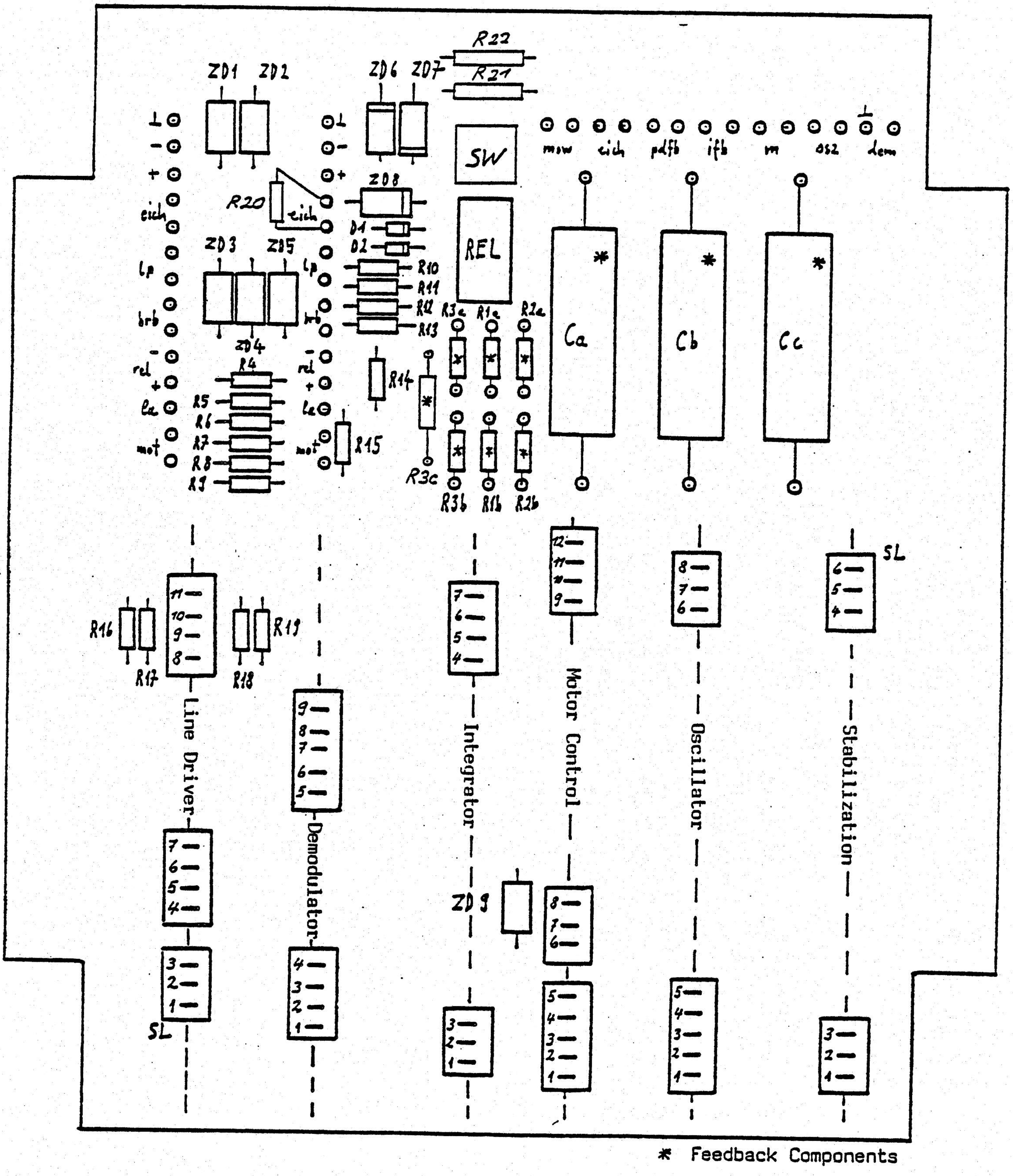
*) Exact values see calibration sheet of individual seismometer

**) Amplification of Line Driver set to 1 (standard)

SFE 481 Seismometer Feedback Electronics



* Feedback Components



SFE 481 Seismometer Feedback Electronics

Print Seismometer Feedback Electronics SFE 78

Abbreviations

brb	Broad Band
dem	Displacement Transducer Demodulator
eich	Calibration
ifb	Integral Feedback
la	Position
lp	Long Period
m	Boom Centering Motor
mot	Motor Control
msw	Micro-Switch
osc	Displacement Transducer Oscillator
pdfb	Proportional Differential Feedback
rel	Damping Relay
+ -	} Supply

Print Seismometer Feedback Electronics SFE 78

Parts List

Resistors

R1a	selected value	MR25
R1b	selected value	MR25
R2a	selected value	MR25
R2b	selected value	MR25
R3a	selected value	MR25
R3b	selected value	MR25
R3c	selected value	MR25
R4	215E	MR25
R5	1K00	MR25
R6	1K62	MR25
R7	1K62	MR25
R8	1K62	MR25
R9	1K62	MR25
R10	1K00	MR25
R11	1K00	MR25
R12	1K00	MR25
R13	1K00	MR25
R14	215E	MR25
R15	1K00	MR25
R16	1K00	MR25
R17	1K00	MR25
R18	1K00	MR25
R19	1K00	MR25
R20	1K00	MR25 } Calibration
R21	499K	MR25 } Calibration
R22	499K	MR25 } Calibration

Capacitors

Ca	selected value	ROKO
Cb	selected value	ROKO
Cc	selected value	ROKO

Diodes

D1	1N4448	
D2	1N4448	

Zener Diodes

ZD1	1.5KE18C	GSI
ZD2	1.5KE18C	GSI
ZD3	1.5KE18C	GSI
ZD4	1.5KE18C	GSI
ZD5	1.5KE18C	GSI
ZD6	ICTE15	GSI
ZD7	ICTE15	GSI
ZD8	ICTE15	GSI
ZD9	1.5KE18C	GSI

Relay

REL	RH-12V	SDS-Relais

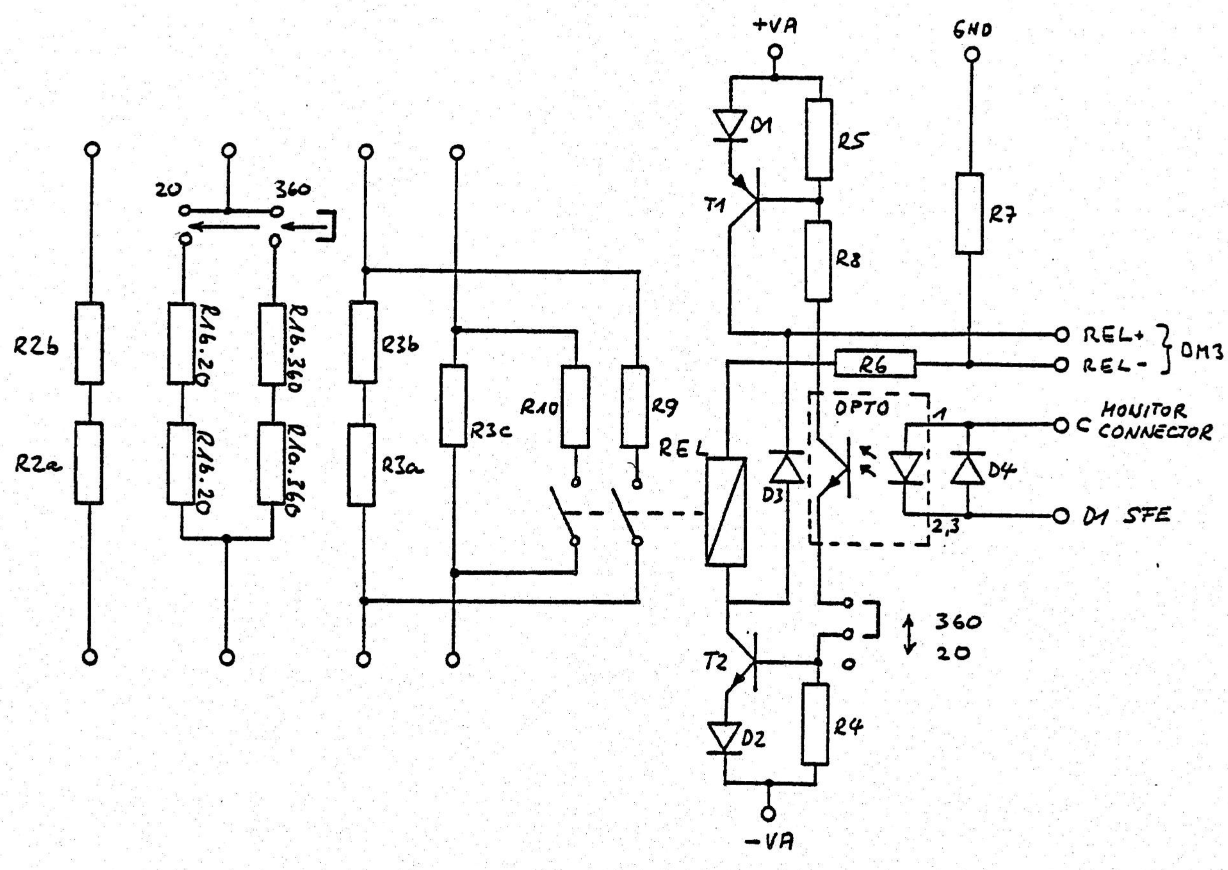
Connectors

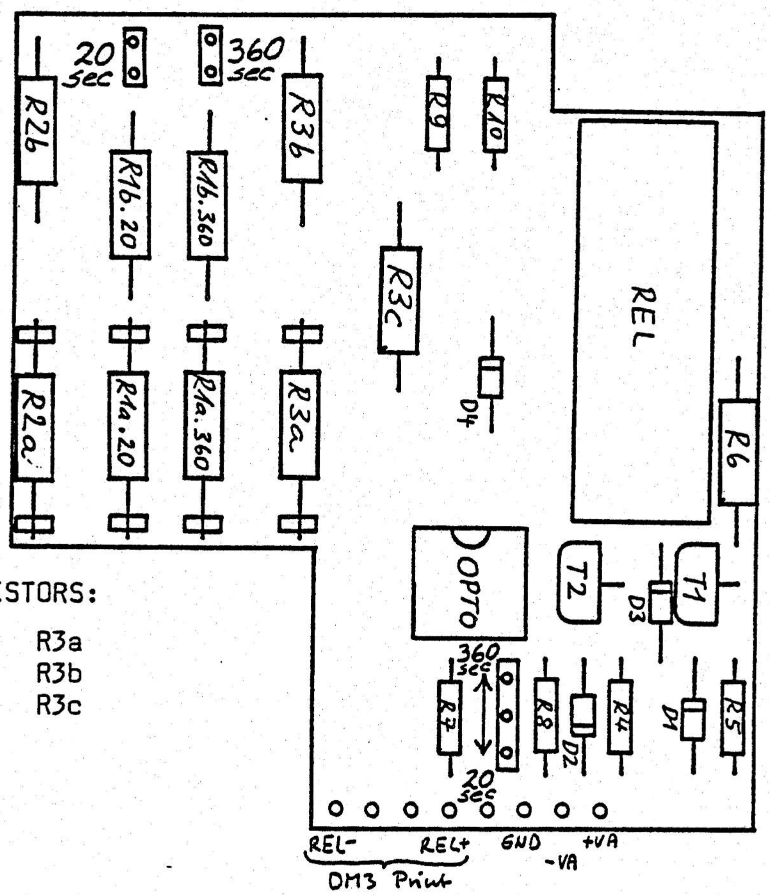
SL	ODU-3-M	Connector
	ODU-4-M	Connector
	ODU-5-M	Connector

Switch

SW	TSS21	Alko

VBB1 Auxiliary Print





FEEDBACK RESISTORS:

R1a.20	R2a	R3a
R1b.20	R2b	R3b
R1a.360		R3c
R1b.360		

Auxiliary Print VBB1

Parts List

RESISTORS

R1a.20	selected value	
R1b.20	selected value	
R1a.360	selected value	
R1b.360	selected value	
R2a	selected value	
R2b	selected value	
R3a	selected value	
R3b	selected value	
R3c	selected value	
R4	2K0	MR16
R5	2K0	MR16
R6	400E	MR25
R7	100K	MR16
R8	12K	MR16
R9	100E	MR16
R10	100E	MR16

DIODES

D1	1N4448
D2	1N4448
D3	1N4448
D4	1N4448

TRANSISTORS

T1	BC179BP
T2	BC109BP

OPTO COUPLER

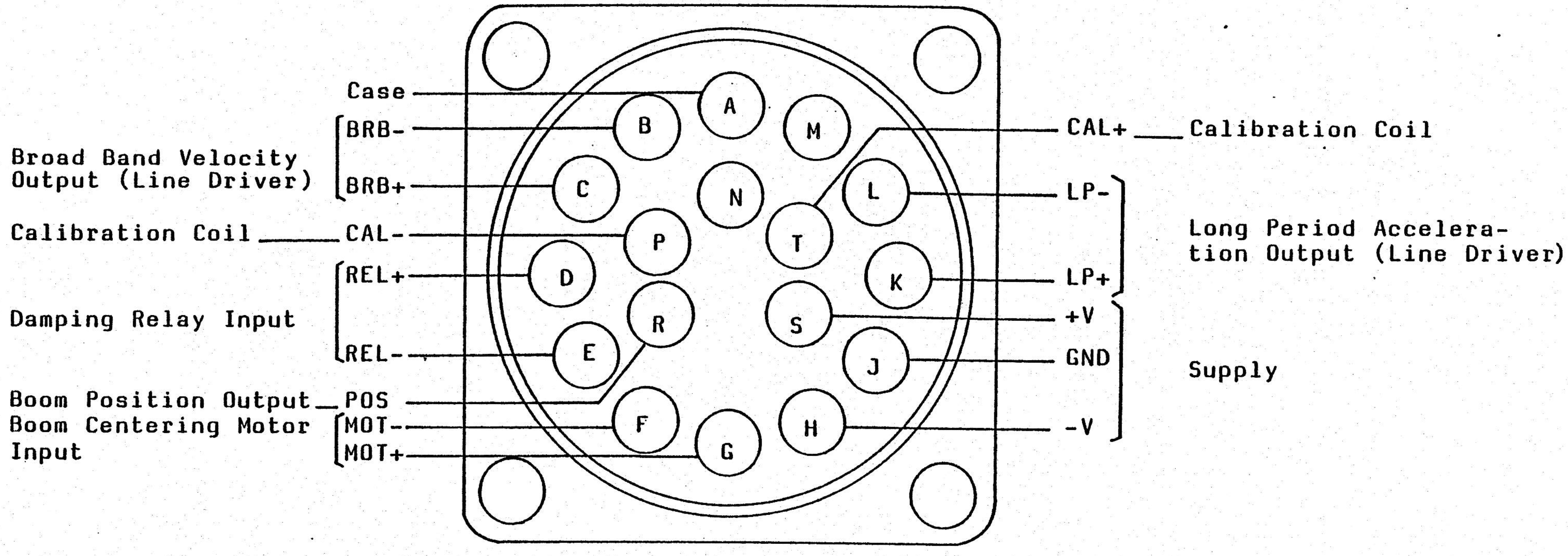
OPTO	H11A1	General Electric

RELAY

REL	S4-12V	Sauer

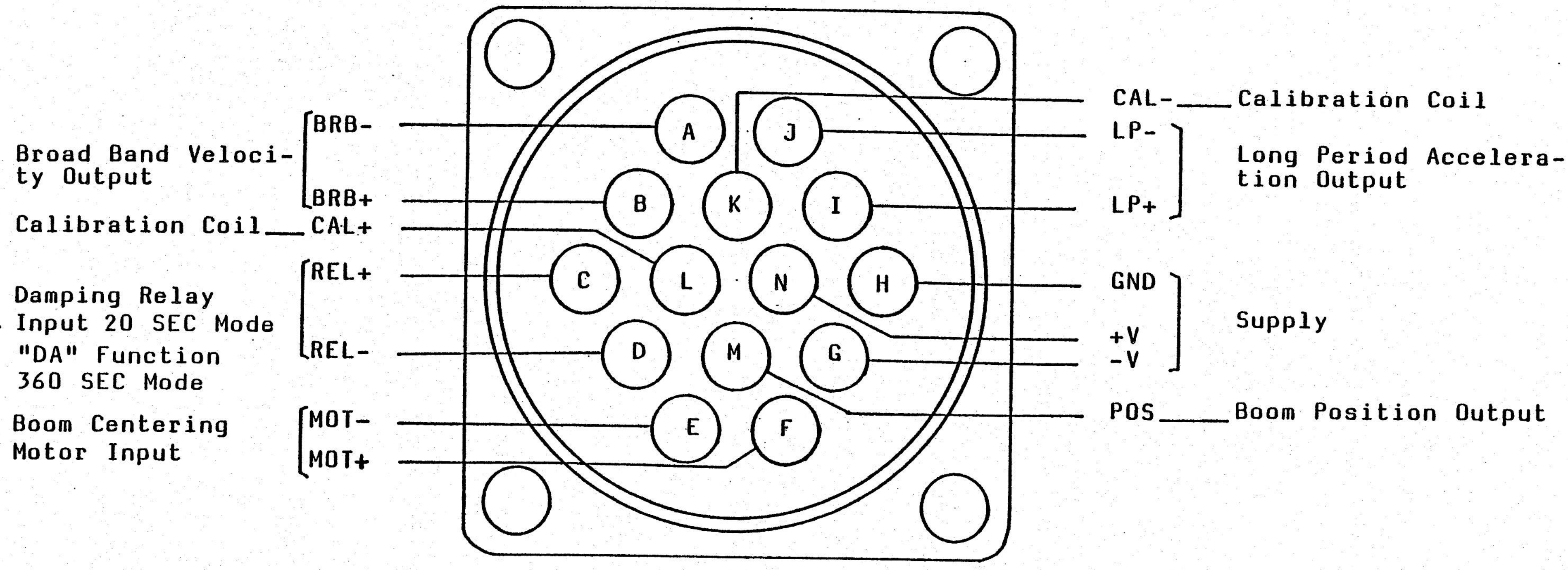
STS - 1V / STS - 1H

"Remote" Connector



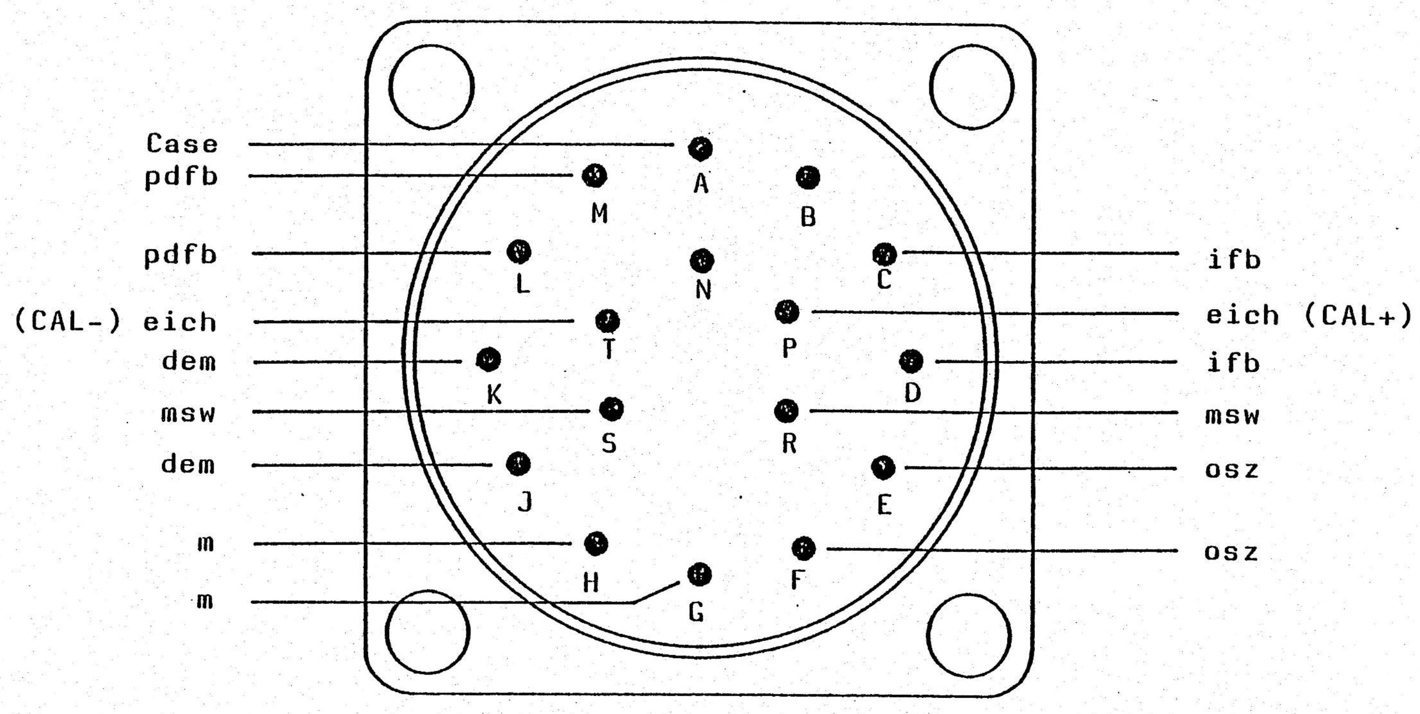
STS - 1V / STS - 1H

"Monitor" Connector



STS - 1V / STS - 1H

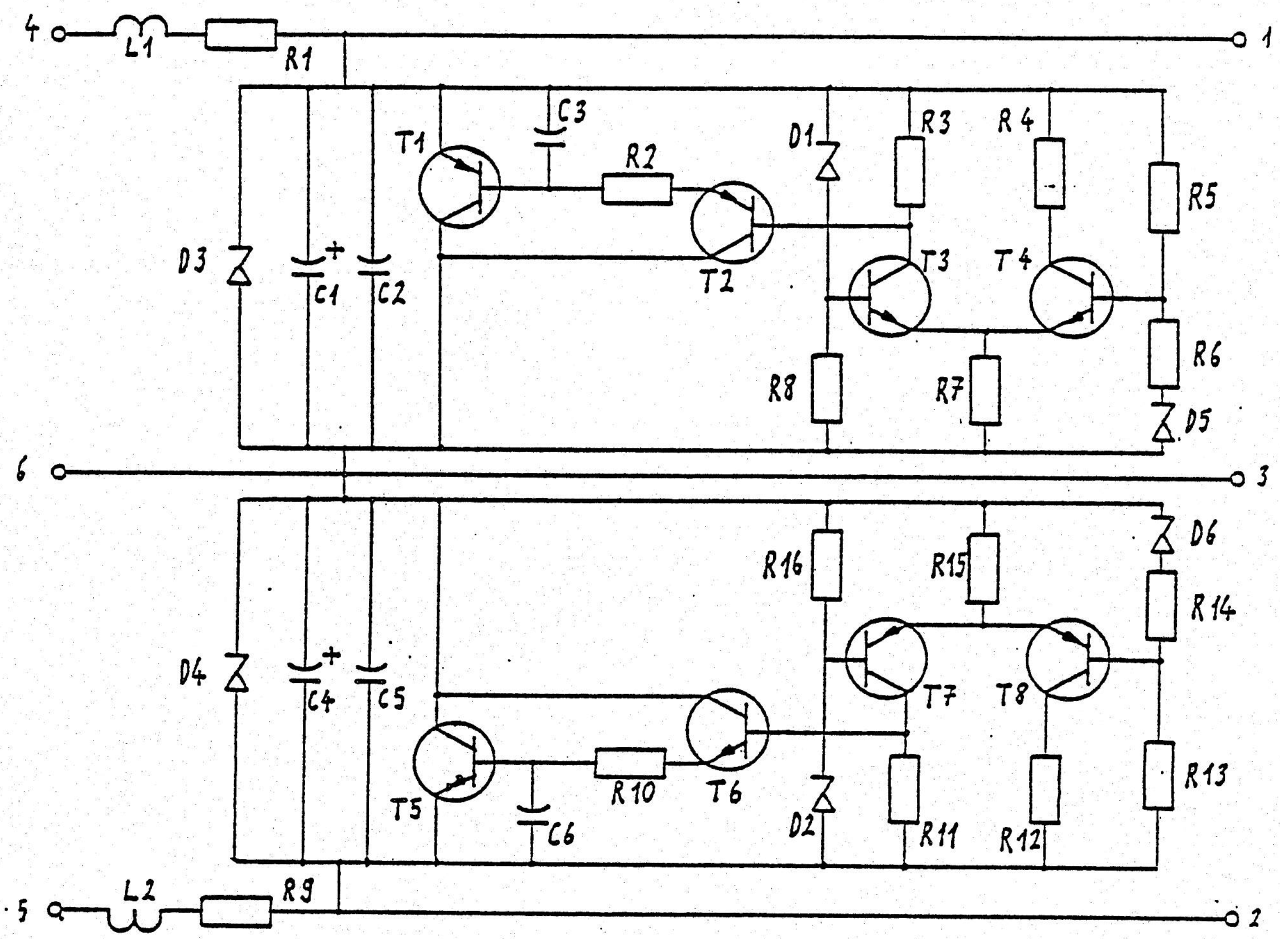
"Seismometer" Connector

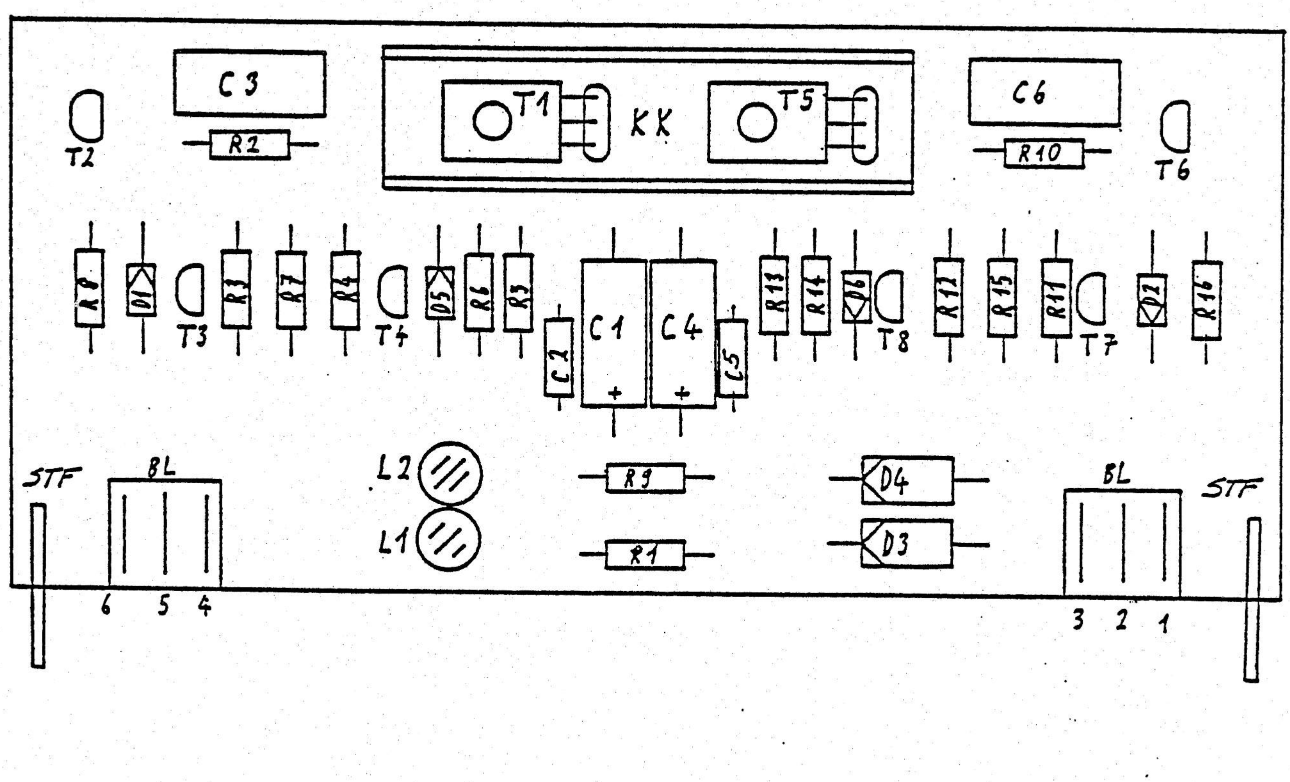


Stabilization

This is a parallel regulator that acts like a pair of Zener diodes, i. e. it takes up all the current supplied from the ST-CCU that is not used by the feedback electronics. The current is limited by the resistance of the signal cable conductors and by the series resistors R1 and R9 on the Stabilization PC board. The sum of the resistances of the signal cable conductor and of the resistance of the correspondig series resistor must be between 20 and 22 Ohms for each supply voltage. 20.3 Ohm resistors are provided on the PC board, allowing a cable resistance up to 2 Ohms per wire. (Only the resistance on the "high" side of each supply counts since no net current is returned through the "common" wire). When cable resistance is more than 2 Ohms per wire, the 20.3 Ohm resistors must be replaced by smaller values. The +-15V from the ST-CCU are reduced to +-13.5V by the parallel regulator. A constant current of 75mA is drawn from the stabilized supply in the ST-CCU and thus a constant power of about two Watts is dissipated as heat in the feedback box, providing additional protection against excessive humidity.

GSTR Stabilization





Print Stabilization

Parts List

Resistors

R1	24E	MR16
R1parallel	133E	MR25
R2	100E	MR25
R3	562E	MR25
R4	562E	MR25
R5	3K16	MR25
R6	560E	MK1
R6parallel	selected value	MR25
R7	1K33	MR25
R8	3K48	MR25
R9	24E	MR16
R9parallel	133E	MR25
R10	100E	MR25
R11	562E	MR25
R12	562E	MR25
R13	3K16	MR25
R14	560E	MK1
R14parallel	selected value	MR25
R15	1K33	MR25
R16	3K48	MR25

Capacitors

C1	TAZY	10uF/20V	Philips
C2	MIKO	0.1uF/100V	Philips
C3	NUKO	0.47uF/100V	Philips
C4	TAZY	10uF/20V	Philips
C5	MIKO	0.1uF/100V	Philips
C6	NUKO	0.47uF/100V	Philips

Print Stabilization

Parts List

Zener Diodes

D1	BZV11	Philips
D2	BZV11	Philips
D3	ICTE15	GSI
D4	ICTE15	GSI
D5	BZV11	Philips
D6	BZV11	Philips

Transistors

T1	BD138
T2	BC179B
T3	BC109B
T4	BC109B
T5	BD137
T6	BC109B
T7	BC179B
T8	BC179B

Inductance Coils

L1	Inductance Coil / 3 turns	Philips
L2	Inductance Coil / 3 turns	Philips

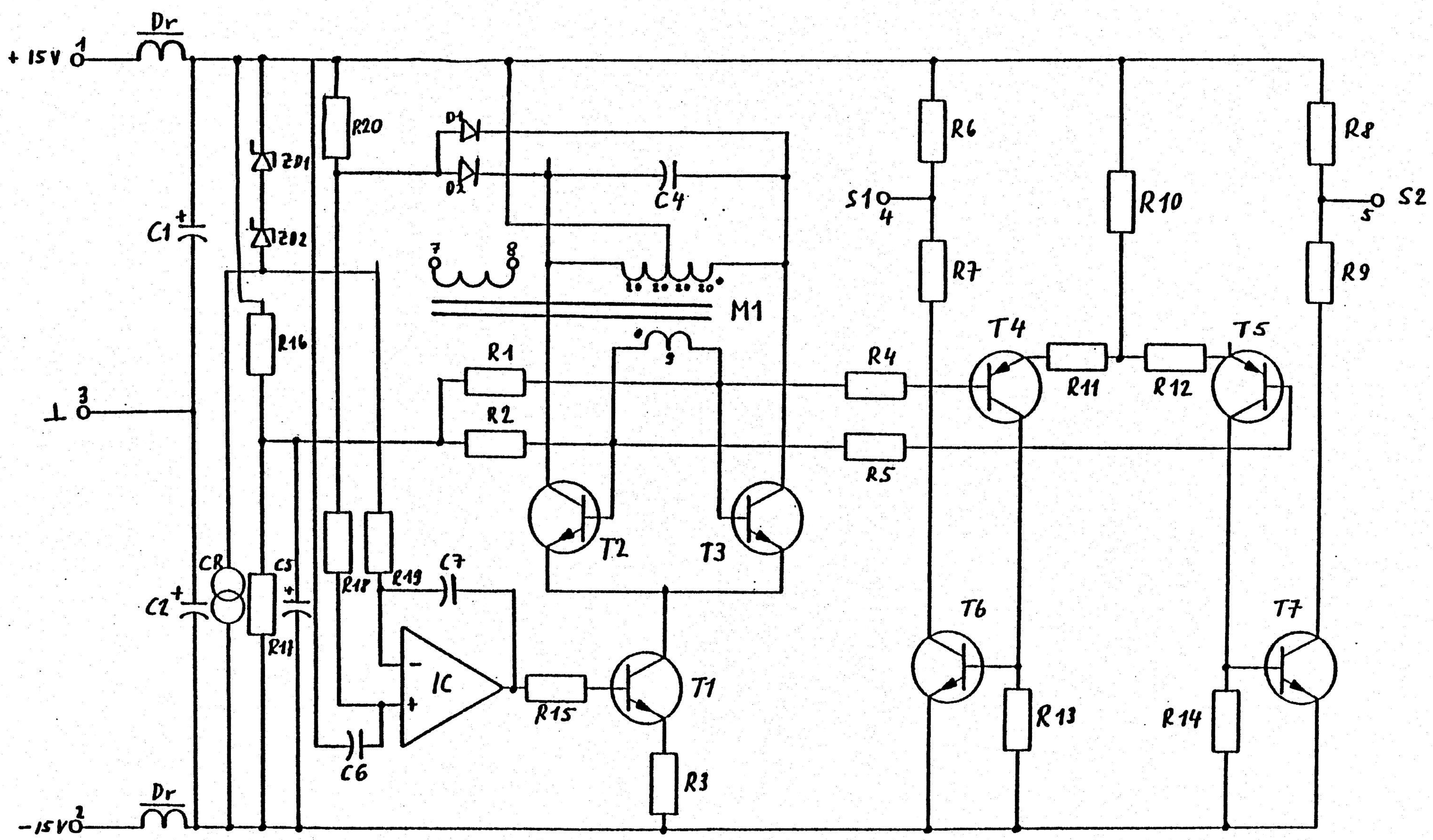
Connectors

BL	ODU-3-F	Connectors
STF	Steckfahnen	

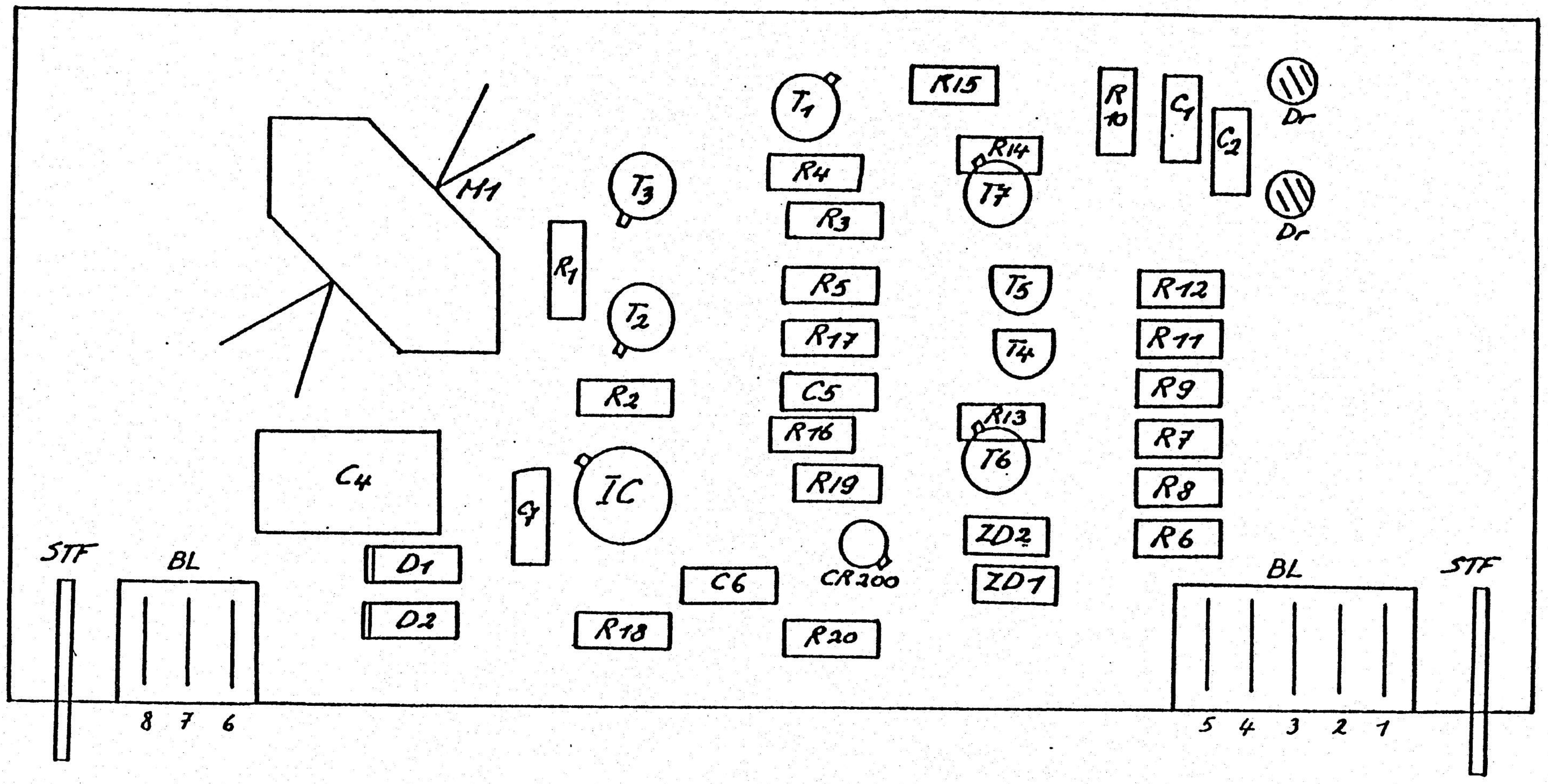
Displacement Transducer (Oscillator/Demodulator)

Oscillator and Demodulator of the LVDT displacement transducer form two of the subunits in the feedback unit. The oscillator generates a sinusoidal voltage of about 3 V rms at 28kHz that excites the LVDT. The variable secondary voltage is converted into a DC signal in the demodulator. The sensitivity to boom displacement at the demodulator output is approx. 2 x 80 V/mm.
In the 360 sec mode, a filter inverse to that of the response of the mechanical sensor follows the demodulator in order to maintain sufficient loop gain at long periods. The output signal is available at the BRB connectors of the monitor instrument and, over the line drivers, at the corresponding connectors in the ST-CCU. However, when the feedback loop is closed, this signal is not proportional to ground displacement but to ground velocity between 0.1 and 20 / 360 sec period (see Theory of Operation).

OSCILLATOR 480



OSCILLATOR 480



Print Oscillator 480

Parts List

Resistors

R1	681E	MR25
R2	681E	MR25
R3	511E	MR25
R4	1K00	MR25
R5	1K00	MR25
R6	3K48	MR25
R7	3K48	MR25
R8	3K48	MR25
R9	3K48	MR25
R10	8K25	MR25
R11	100E	MR25
R12	100E	MR25
R13	1K00	MR25
R14	1K00	MR25
R15	16K2	MR25
R16	6K81	MR25
R17	2K87	MR25
R18	619K	MR25
R19	619K	MR25
R20	31K6	MR25

Capacitors

C1	1uF/35V	TAZY	Union Carbide
C2	1uF/35V	TAZY	Union Carbide
C4	30nF/63V	POKO	Philips
C4*	2.2nF/250V	POKO	Philips
C5	1uF/35V	TAZY	Union Carbide
C6	330pF/100V	KEKO	Philips
C7	330pF/100V	KEKO	Philips

Transistors

T1	BC547
T2	BC107B
T3	BC107B
T4	2N3702
T5	2N3702
T6	2N2222
T7	2N2222

Print Oscillator 480

Parts List (Continued)

Current Regulator Diode

CR	CR200	Siliconix

Integrated Circuits

IC	LF441ACN	National

Zener Diodes (= Resistors)

ZD1	selected value	MR25
ZD2	selected value	MR25

Diodes

D1	1N4448
D2	1N4448

Inductance Coil

DR	Inductance Coil / 3 turns		Philips

Coil

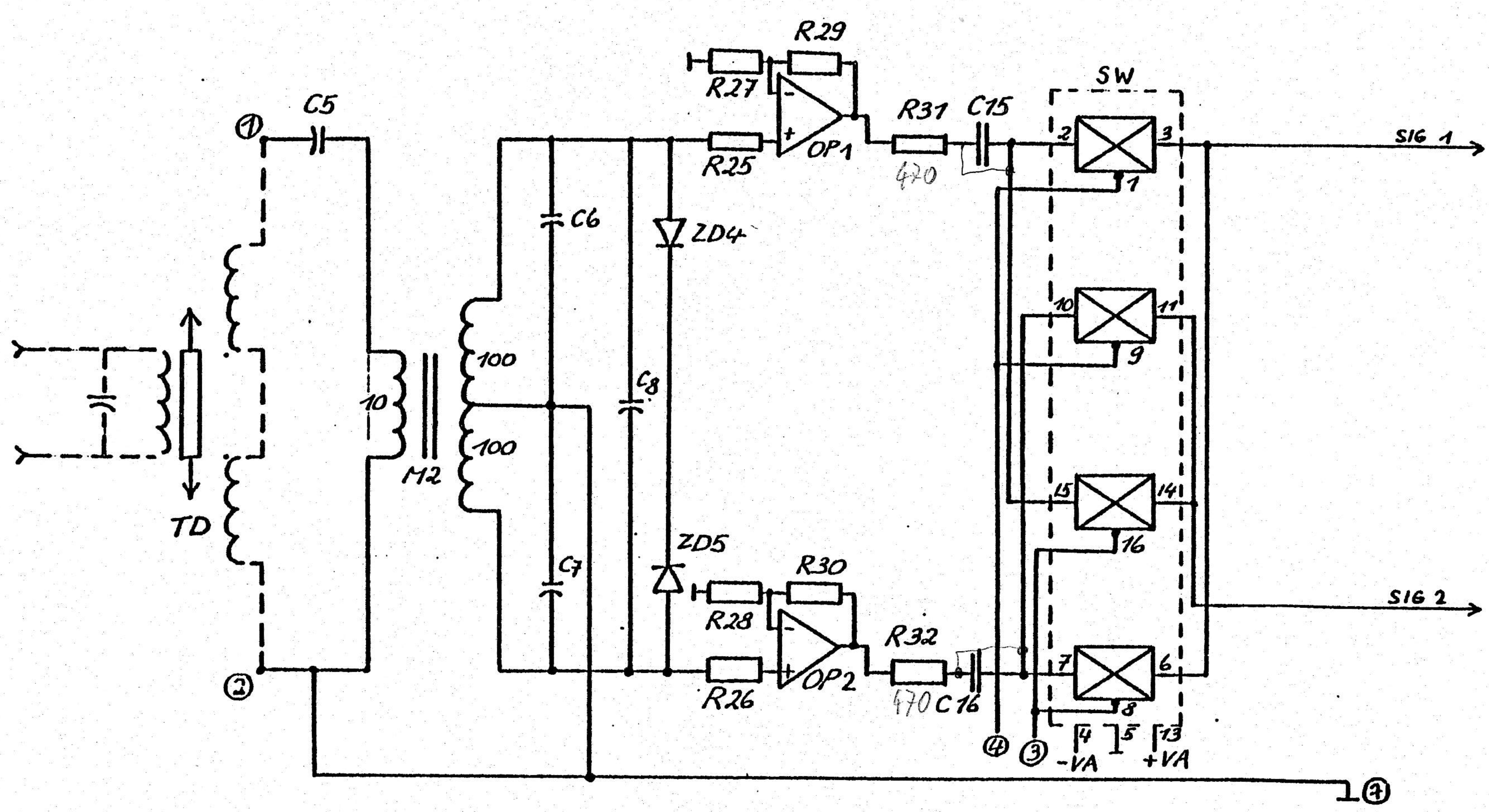
M1	Coil with plunger	AL160	Philips

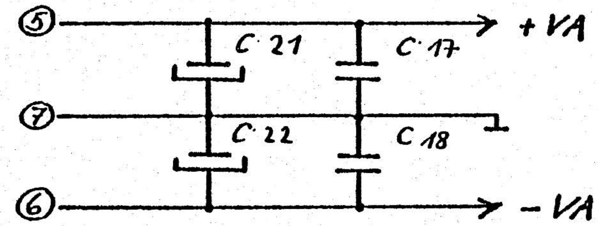
Connectors

BL	ODU-3-F	Connector
	ODU-5-F	Connector
STF	Steckfahnen	

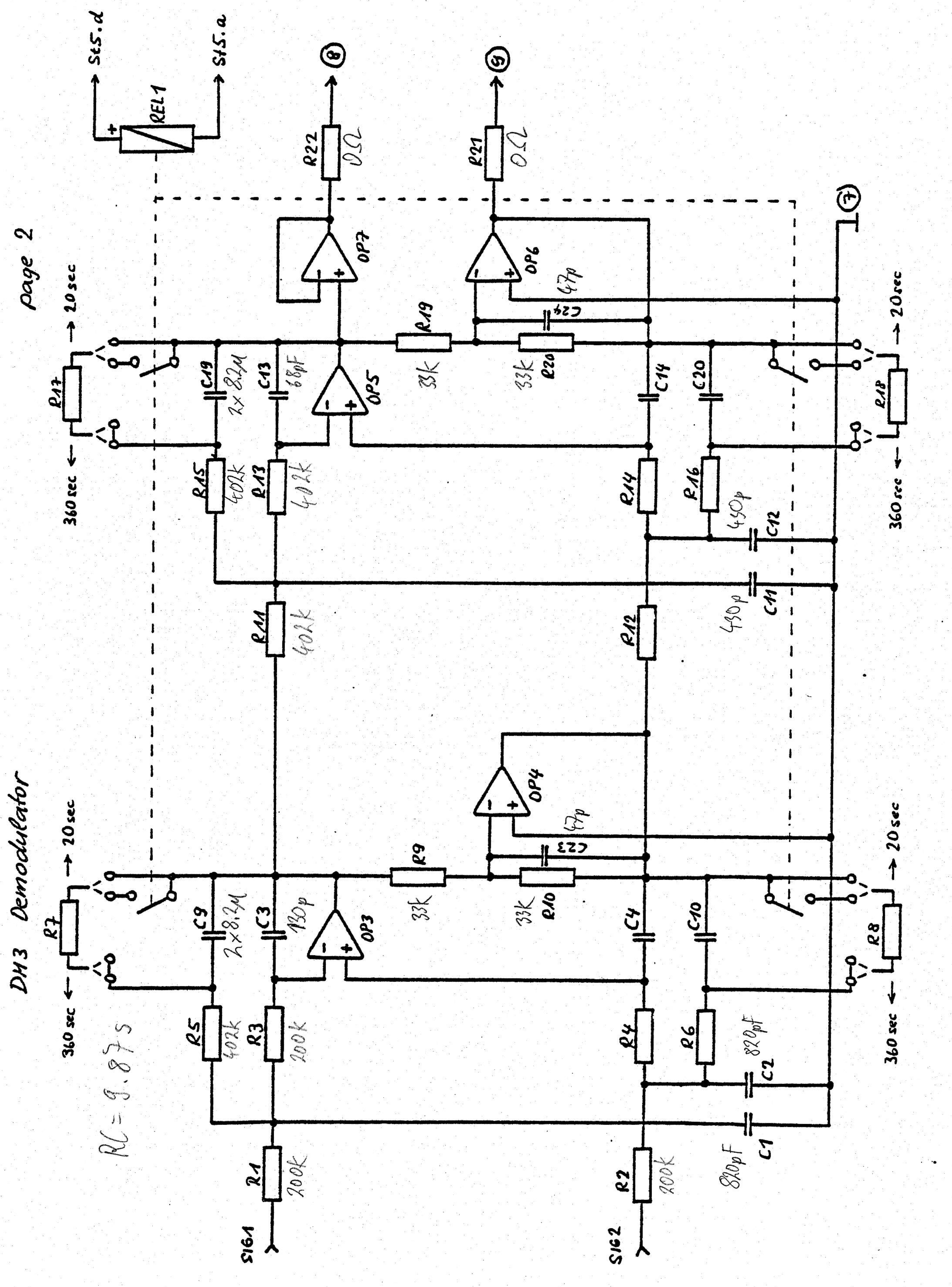
DM3-185 Demodulator

Page 1



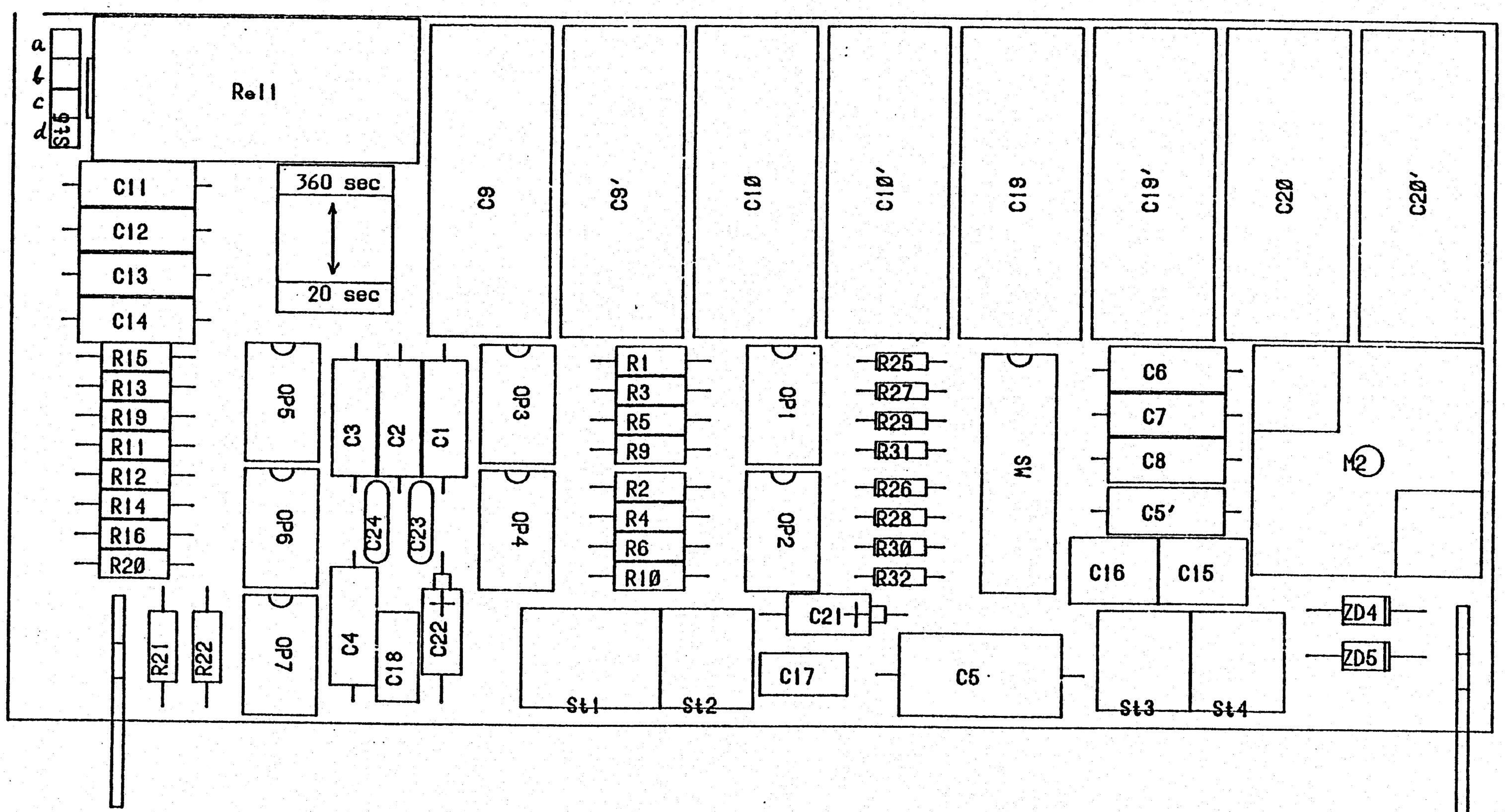


TD = Transformer of
displacement transducer



DH3 Demodulator
page 2
RC = 9.87 s
SIG1
SIG2
R1 200k
R2 200k
R3 200k
R4
R5 402k
R6
R7
R8
R9 33k
R10 33k
R11 402k
R12
R13 402k
R14
R15 402k
R16
R17
R18
R19 33k
R20 33k
R21 0Ω
R22 0Ω
C1 820pF
C2 820pF
C3 130p
C4
C9 2×8.2M
C10
C11 450p
C12 450p
C13 68pF
C14
C19 2×8.2M
C20
C23 47p
C24 47p
OP3
OP4
OP5
OP6
OP7
REL1
St5.d
St5.a
360 sec
20 sec
8
9
7

DM3 Demodulator



Print Demodulator DM3

Parts List

RESISTORS

R1	200K	MK1
R2	200K	MK1
R3	200K	MK1
R4	200K	MK1
R5	402K	MR25
R6	402K	MR25
R7	24E	MR16
R8	24E	MR16
R9	33K	MR16
R10	33K	MR16
R11	402K	MR25
R12	402K	MR25
R13	402K	MR25
R14	402K	MR25
R15	402K	MR25
R16	402K	MR25
R17	24E	MR16
R18	24E	MR16
R19	33K	MR16
R20	33K	MR16
R21	0E00	MR16
R22	0E00	MR16
R25	1K0	MR16
R26	1K0	MR16
R27	2K0	MR16
R28	2K0	MR16
R29	27K	MR16
R30	27K	MR16
R31	470E	MR16
R32	470E	MR16

CAPACITORS

C1	820pF/250V	POKO	Philips
C2	820pF/250V	POKO	
C3	130pF/500V	POKO	
C4	130pF/500V	POKO	
C5	33nF/63V	POKO	
C5'	1.2nF/250V	POKO	
C6	2.0nF/250V	POKO	
C7	2.0nF/250V	POKO	
C8	200pF/630V	POKO	
C9	8.2uF		
C9'	8.2uF		
C10	8.2uF		
C10'	8.2uF		

CAPACITORS

C11	430pF/250V	POKO	
C12	430pF/250V	POKO	
C13	68pF/500V	POKO	
C14	68pF/500V	POKO	
C15	0E00	(WIMA)	
C16	0E00	(WIMA)	
C17	100nF/63V	KEKO	Roederstein
C18	100nF/63V	KEKO	Roederstein
C19	8.2uF		
C19'	8.2uF		
C20	8.2uF		
C20'	8.2uF		
C21	1uF/35V	TAZY	Union Carbide
C22	1uF/35V	TAZY	Union Carbide
C23	47pF/100V	KEKO	
C24	47pF/100V	KEKO	

ZENERDIODES

ZD4	BZX83C/24V
ZD5	BZX83C/24V

INTEGRATED CIRCUITS

SW	DG201ACJ	Siliconix
OP1	LT1037	Linear Technology
OP2	LT1037	Linear Technology
OP3	OPA111AM	Burr Brown
OP4	LF441ACN	National Semic.
OP5	OPA111AM	Burr Brown
OP6	LF355H	National Semic.
OP7	OP07EP	Linear Technology

COIL

M2	Coil with plunger	AL630 Philips

RELAY

REL	S4-12V	Sauer-SDS

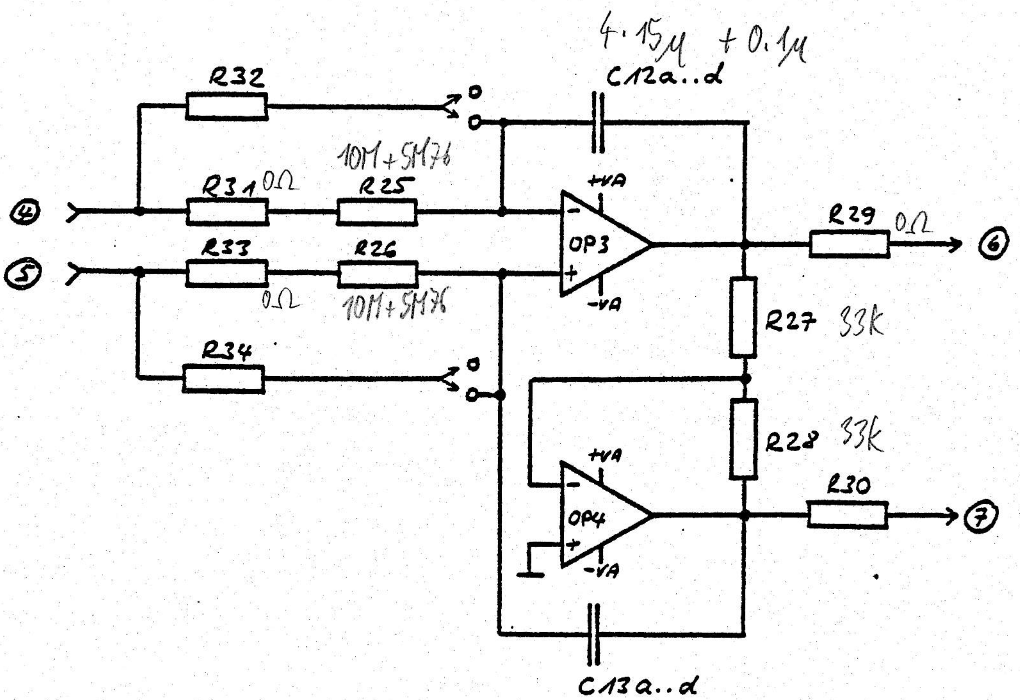
CONNECTORS

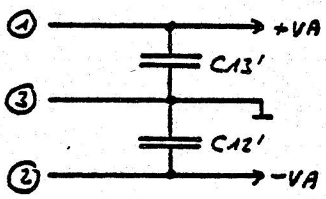
ST1+ST2	ODU-5-F	Connector
ST3+ST4	ODU-4-F	Connector
ST5	WW-M-4	
STF	Steckfahnen	

Integrator

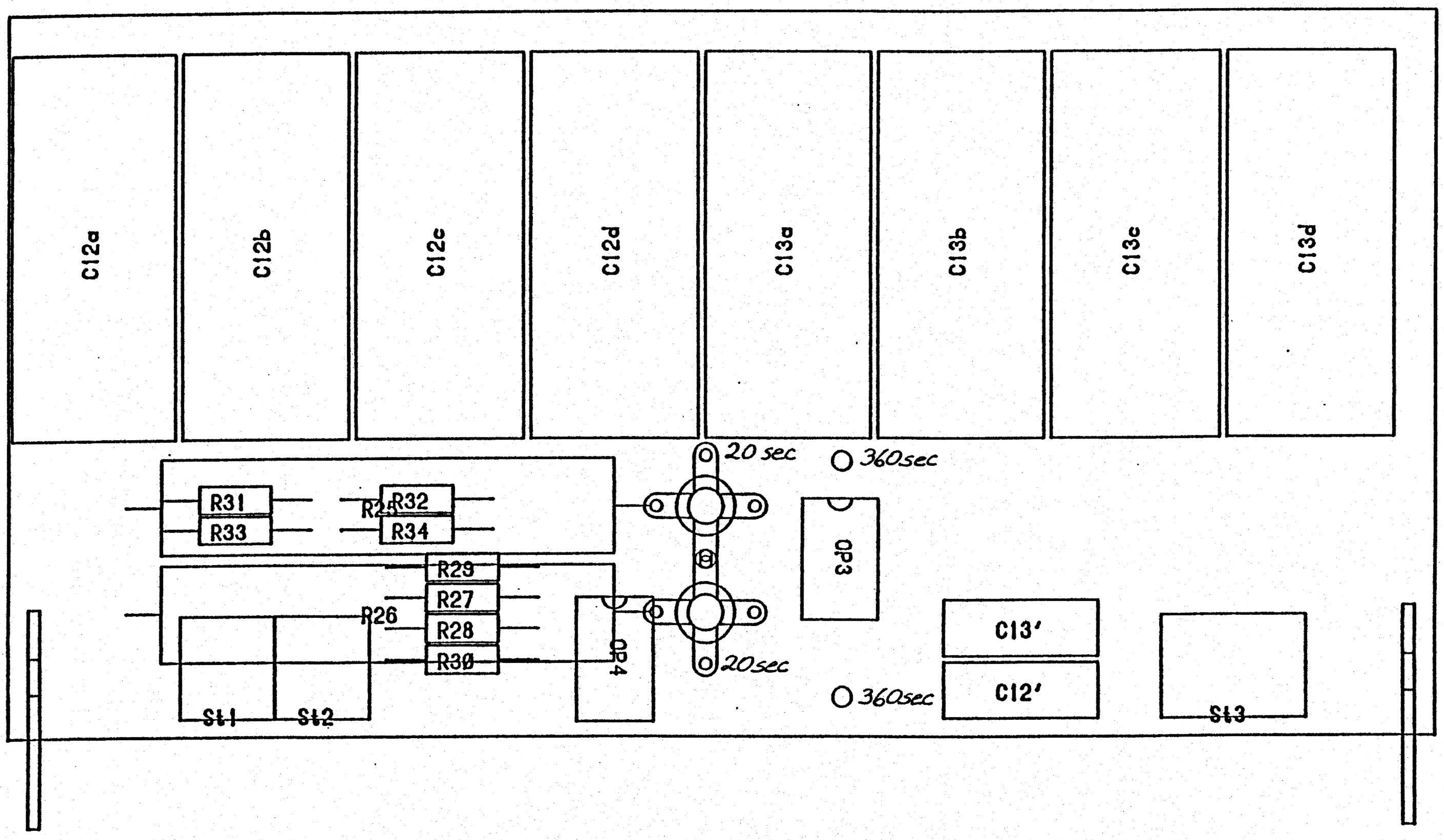
The integrator is part of the feedback circuit and provides the "LP" output signal in the 20 sec mode and the "Boom Position" signal. It integrates the output signal of the displacement transducer and feeds it back into the mechanical sensor such that the latter returns to its center position. Any permanent force that acts on the boom produces an offset at the integrator output but not a permanent offset of the boom. The integrator signal can be taken to indicate where the boom would be if the feedback were disconnected. It is therefore used as the "Boom Position" signal and as an output signal proportional to ground acceleration at long periods. The integrator signal is available at the "LP" connectors of the monitor instrument and, over line drivers, at the corresponding connectors in the ST-CCU. The LP output is not normally used in the 360 sec mode because all signals of interest are resolved in the BRB output signal.

INT 2 Integrator





INT2 Integrator



Print Integrator INT 2

Parts List

RESISTORS

R25	10M0 + 5M76	MK2
R26	10M0 + 5M76	MK2
R27	33K2	MR25
R28	33K2	MR25
R29	0E00	
R30	0E00	
R31	0E00	
R32	49K9	MR25
R33	0E00	
R34	49K9	MR25

CAPACITORS

C12a	15 uF	LSA, CF
C12b	15 uF	LSA, CF
C12c	15 uF	LSA, CF
C12d	15 uF	LSA, CF
C12'	0.1 uF	MIKO
C13a	15 uF	LSA, CF
C13b	15 uF	LSA, CF
C13c	15 uF	LSA, CF
C13d	15 uF	LSA, CF
C13'	0.1 uF	MIKO

ANALOG IC

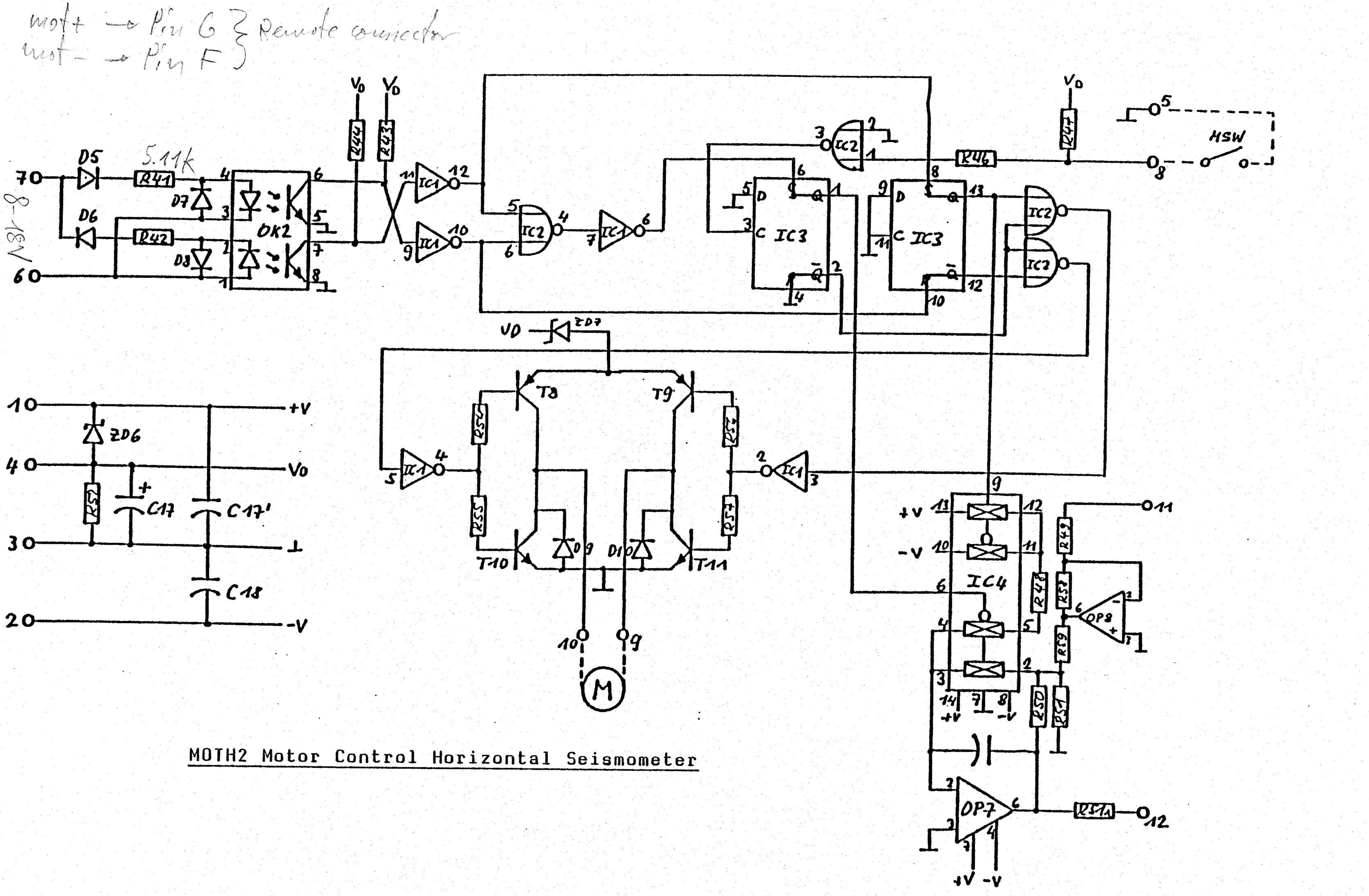
OP3	OPA 111 BM
OP4	LF 441 ACN

CONNECTORS & ACCESSORIES

ST1+ST2	ODU-4-F
ST3	ODU-3-F
STF	Steckfahnen
LSP	Loetstuetzen

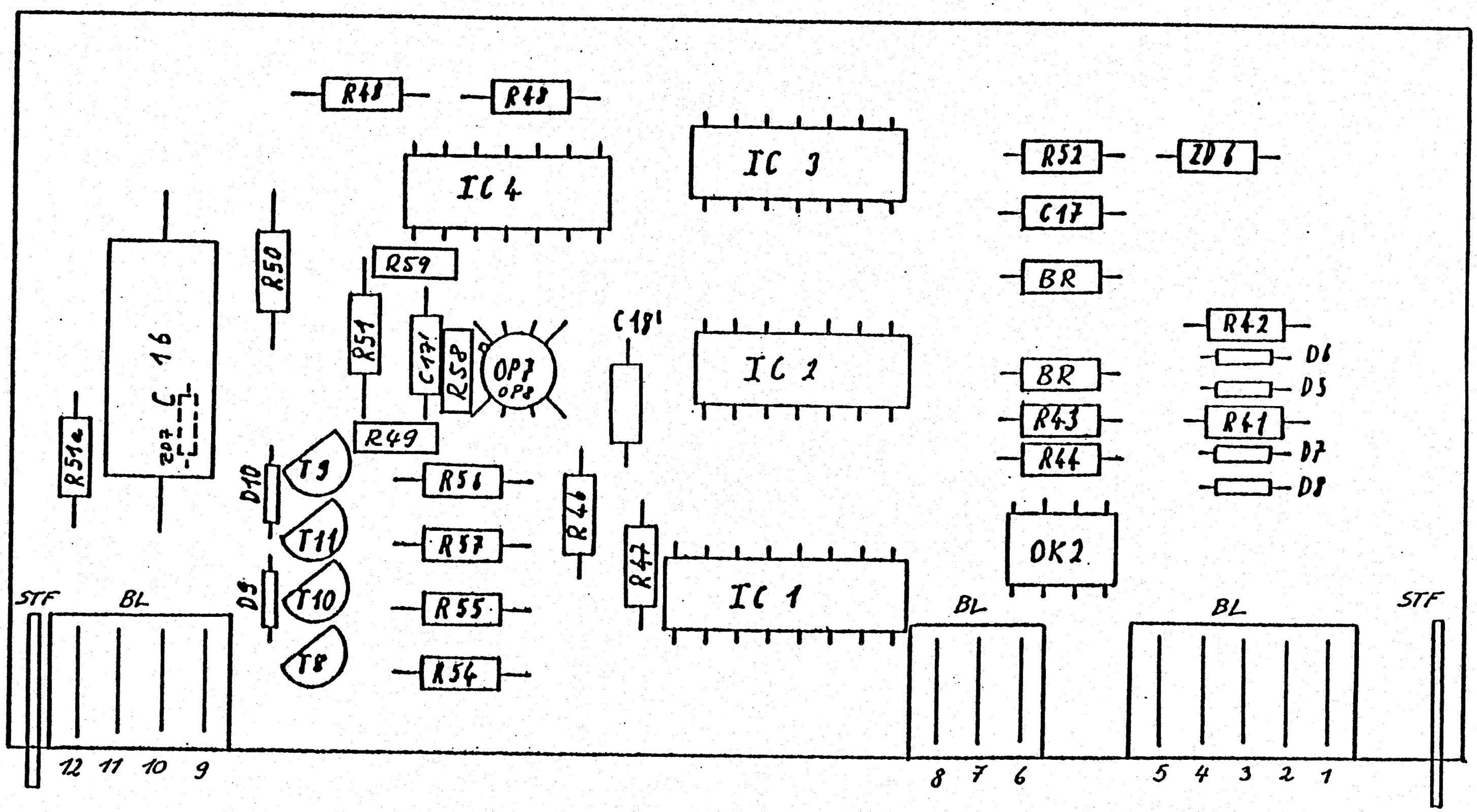
Motor Control

The motor control circuit provides remote control of the boom position over a pair of control lines that are not galvanically connected to the rest of the system; their state is sensed over optical couplers. A voltage of 8 to 18 Volts applied between the control lines will turn the boom centering motor on, the sense of rotation depending on the polarity of the voltage. The effect of the boom adjustment can be observed with the "POS" (boom position) signal. Some details of the circuit differ between horizontal and vertical sensors. Because of the slow response of the 360 sec feed-back system, and also because the boom of the vertical sensor makes irregular movements when the centering mechanism is on, the arrival at the desired position cannot be observed directly. During motor operation, an electronic circuit provides a simulated "boom position" signal that indicates where the boom will be after switching off the motor. Some irregular movements may appear in the "Boom Position" signal as soon as the motor is stopped, but then the signal should settle down close to the value which it had before the motor was stop-ped. The motor of the vertical sensor disengages itself from the boom after each complete revolution of the centering mechanism. An electro-nic circuit senses the motor position and maintains the motor voltage until the revolution is complete, such that the motor can stop only in the disengaged position. The centering mechanism can be actuated from the monitor instrument, from the ST-CCU, or remotely by a di-gital command to the ST-CCU, in addition to the possibility of apply-ing a voltage to the control lines.



MOTH2 Motor Control Horizontal Seismometer

MOTH2 Motor Control Horizontal Seismometer



Print Motor Control Horizontal Seismometer

Parts List

Resistors

R41	5K11	MR25
R42	5K11	MR25
R43	49K9	MR25
R44	49K9	MR25
R46	100K	MR25
R47	100K	MR25
R48	selected value	MR25
R49	100K	MR25
R50	100K	MR25
R51	34K8	MR25
R51a	49E9	MR25
R52	19K6	MR25
R54	20K0	MR25
R55	20K0	MR25
R56	20K0	MR25
R57	20K0	MR25
R58	100K	MR25
R59	100K	MR25
BR	0E00	

Capacitors

C16	6.8uF/63V	FOPK	Cond. Fribourg
C17	1uF/35V	TAZY	Union Carbide
C17'	0.1uF/100V	MIKO	Philips
C18'	0.1uF/100V	MIKO	Philips

Diodes

D5	1N4448
D6	1N4448
D7	1N4448
D8	1N4448
D9	1N4448
D10	1N4448

Zener Diode

ZD6	BZX83C/7V5
ZD7	BZX83C/3V3

Transistors

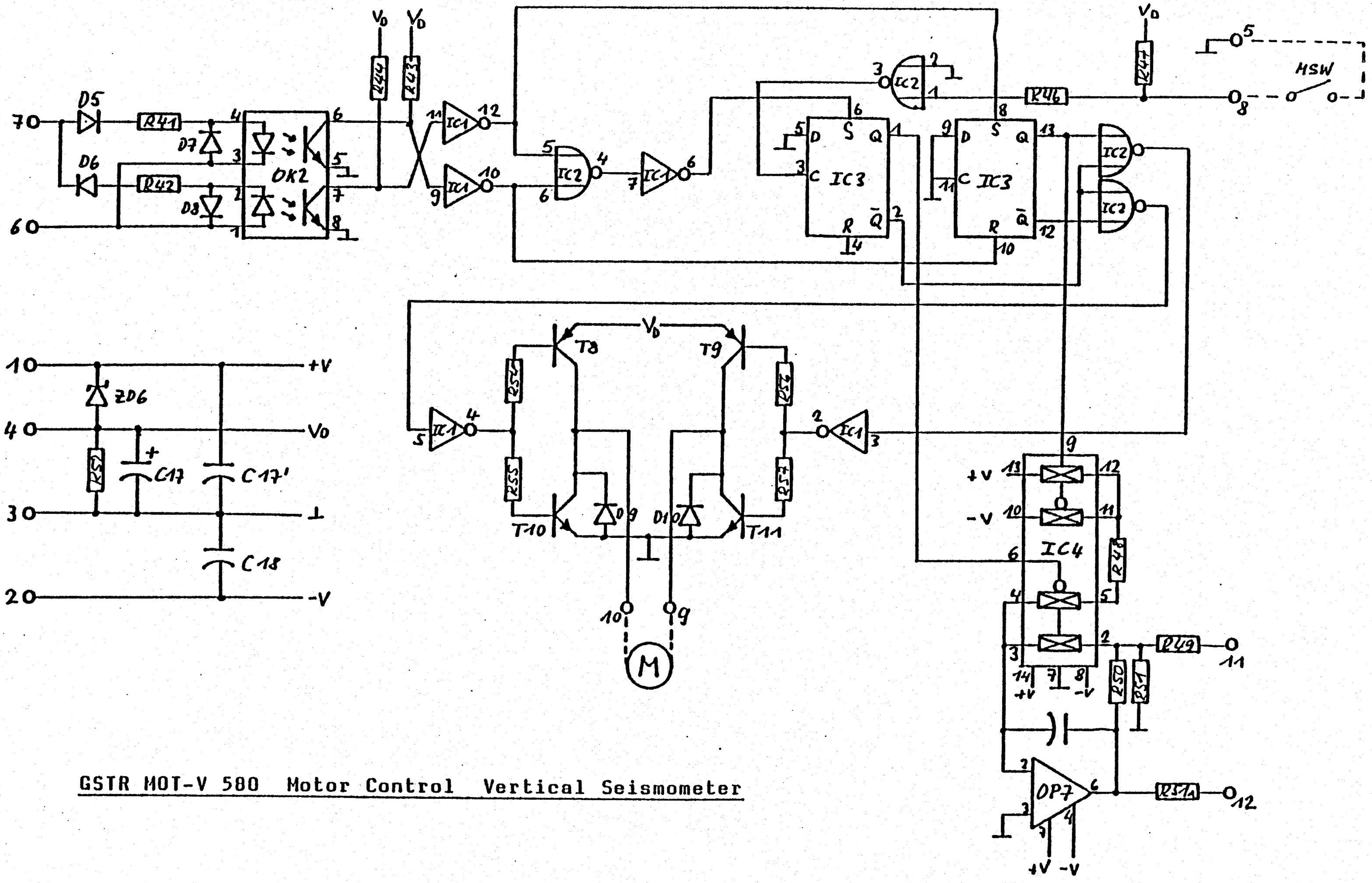
T8	BC327
T9	BC327
T10	BC337
T11	BC337

Integrated Circuits

OP7	LF441ACN	National Semicond.
OP8	LF441ACN	National Semicond.
OK2	MCT6	Optocoupler Monsanto
IC1	CD4049BE	
IC2	CD4001BE	
IC3	connected pins:	1-6, 2-4, 8-13, 10-12
IC4	DG307CJ	Siliconix

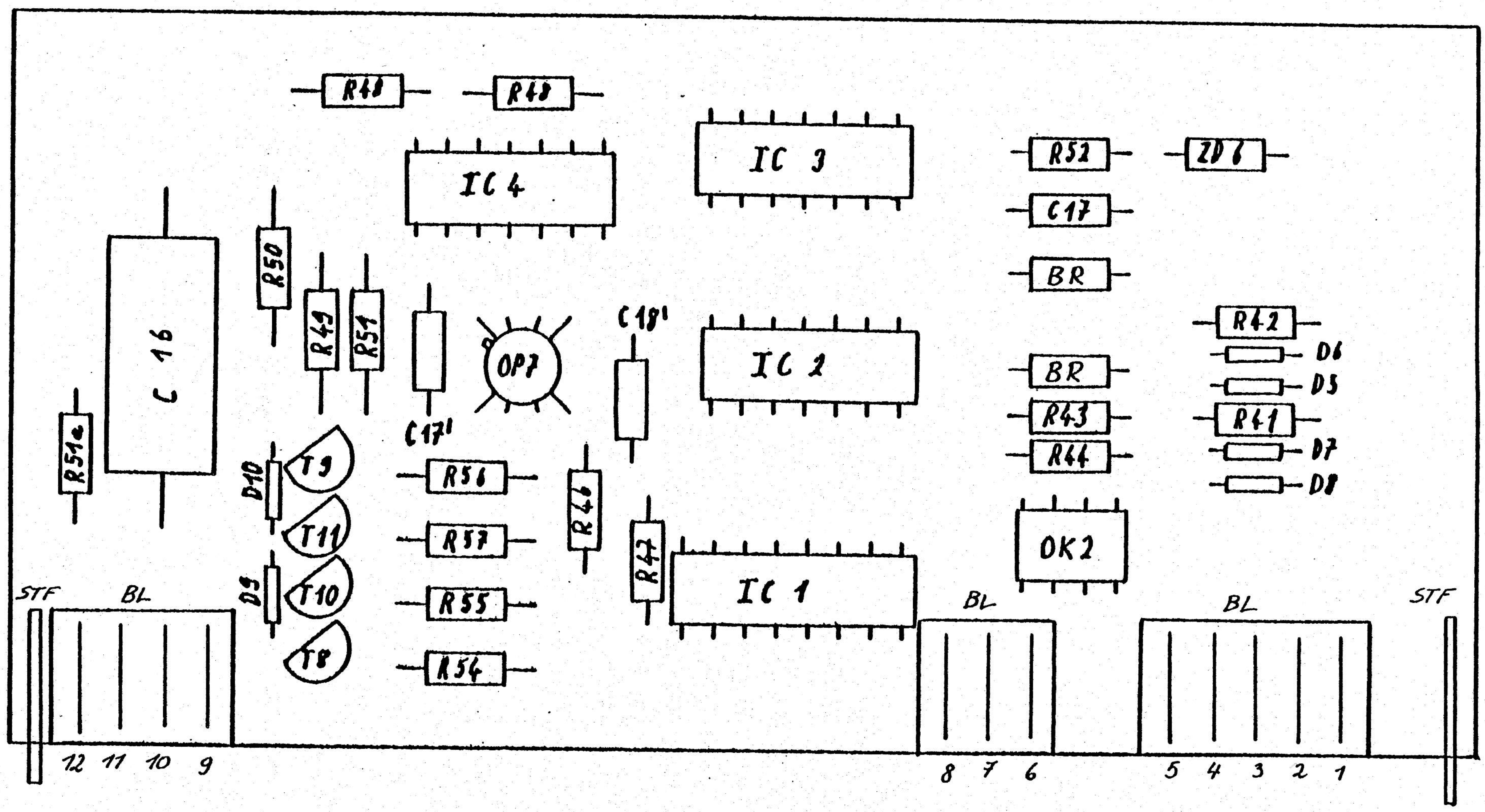
Connectors

BL	ODU-3-F	Connector
	ODU-4-F	Connector
	ODU-5-F	Connector
STF	Steckfahnen	



GSTR MOT-V 580 Motor Control Vertical Seismometer

GSTR MOT V 580 Motor Control Vertical Seismometer



Print Motor Control Vertical Seismometer MOT-V 58Ø

Parts List

Resistors

R41	5K11	MR25
R42	5K11	MR25
R43	49K9	MR25
R44	49K9	MR25
R46	1ØØK	MR25
R47	1ØØK	MR25
R48	selected value	MR25
R49	1ØØK	MR25
R5Ø	1ØØK	MR25
R51	34K8	MR25
R51a	49E9	MR25
R52	19K6	MR25
R54	2ØKØ	MR25
R55	2ØKØ	MR25
R56	2ØKØ	MR25
R57	2ØKØ	MR25
BR	ØEØØ	

Capacitors

C16	6.8uF/63V	FOPK	Cond. Fribourg
C17	1uF/35V	TAZY	Union Carbide
C17'	Ø.1uF/1ØØV	MIKO	Philips
C18'	Ø.1uF/1ØØV	MIKO	Philips

Diodes

D5	1N4448
D6	1N4448
D7	1N4448
D8	1N4448
D9	1N4448
D1Ø	1N4448

Zener Diode

ZD6	BZX83C/7V5

Transistors

T8	BC327
T9	BC327
T1Ø	BC337
T11	BC337

Integrated Circuits

OP7	LF441ACN	National Semicond.
OK2	MCT6	Optocoupler Monsanto
IC1	CD4Ø49BE	
IC2	CD4ØØ1BE	
IC3	CD4Ø13BE	
IC4	DG3Ø7CJ	Siliconix

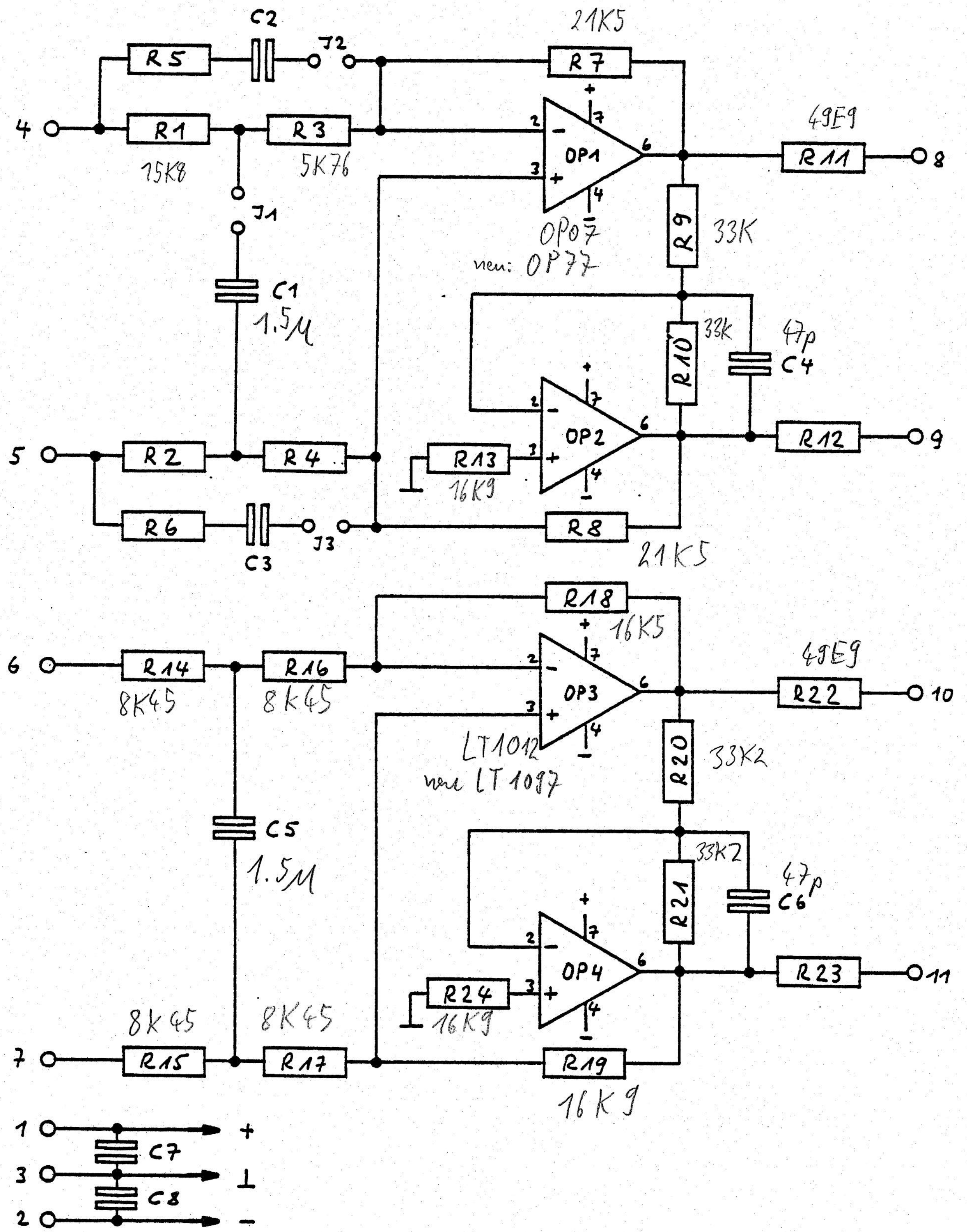
Connectors

BL	ODU-3-F	Connector
	ODU-4-F	Connector
	ODU-5-F	Connector
STF	Steckfahnen	

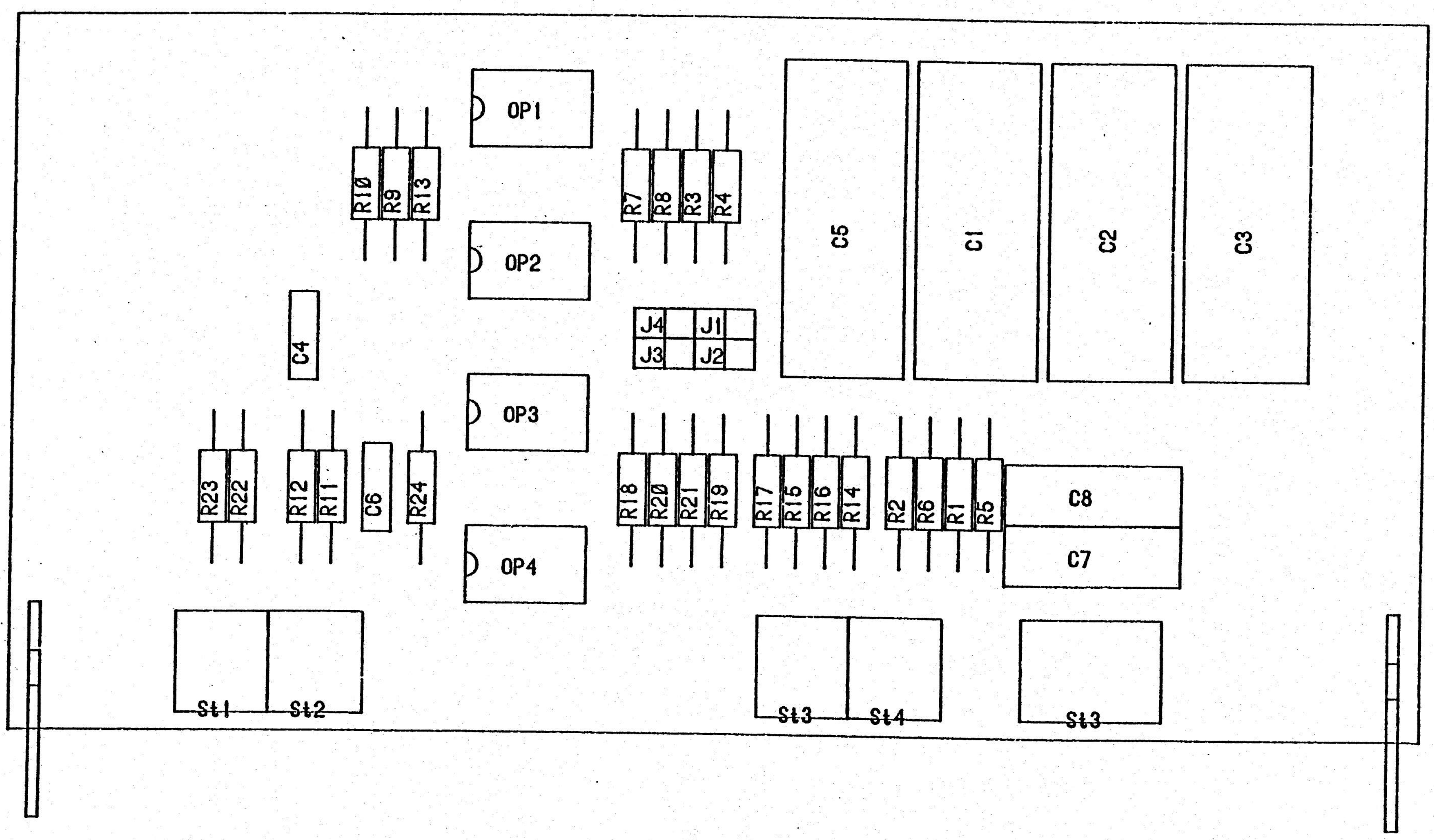
Line Drivers

The feedback circuit is decoupled from the signal cable by two pairs of line drivers. These have a gain of one when the instruments are delivered, but can be adjusted to a different gain by exchanging resistors R7 and R8 for BRB, and R18 and R19 for LP. The output impedance of BRB and LP outputs is 1 KOhm. An RC combination with a time constant of 13 msec (see page 28) is included in the Line Driver circuit.
The jumpers on the line-driver printed-circuit board must normally be in the upper position (J1/J4). At sites with an extremely small short-period noise, it may be desirable to enhance frequencies above 1 Hz in the output signal. This can be done by changing the jumpers to the lower position (J2/J3). The overall response at the BRB output will then become flat to acceleration, rather than velocity, between 1 and 10 Hz. The reasons for this modification are explained in a publication by Wielandt and Steim (Annales Geophysicae B 4, 1986, pp. 227-232).

Line Driver LDRS2



Line Driver LDRS2



Seismometer line driver LDRS2 parts list

RESISTIRS

R1	15K8	MRS25
R2	15K8	MRS25
R3	5K76	MRS25
R4	5K76	MRS25
R5	1K84	MRS25
R6	1K84	MRS25
R7	21K5	MRS25
R8	21K5	MRS25
R9	33K2	MRS25
R10	33K2	MRS25
R11	49E9	MRS25
R12	49E9	MRS25
R13	16K9	MRS25
R14	8K45	MRS25
R15	8K45	MRS25
R16	8K45	MRS25
R17	8K45	MRS25
R18	16K9	MRS25
R19	16K9	MRS25
R20	33K2	MRS25
R21	33K2	MRS25
R22	49E9	MRS25
R23	49E9	MRS25
R24	16K9	MRS25

CAPACITORS

C1	1.5uF/63V	LSA	
C2	6.8uF/63V	LSA	
C3	6.8uF/63V	LSA	
C4	47pF/100V	KEKO	2222.643.04479
C5	1.5uF/63V	LSA	
C6	47pF	KEKO	
C7	0.1uF/100V	MIKO	
C8	0.1uF/100V	MIKO	

ANALOG IC

OP1	OP07
OP2	LF441ACN
OP3	LT1012CN8
OP4	LF441ACN

CONNECTORS

ST1+ST2	ODU-4-F
SR3+ST4	ODU-4-F
ST5	ODU-3-F

Feedback Components

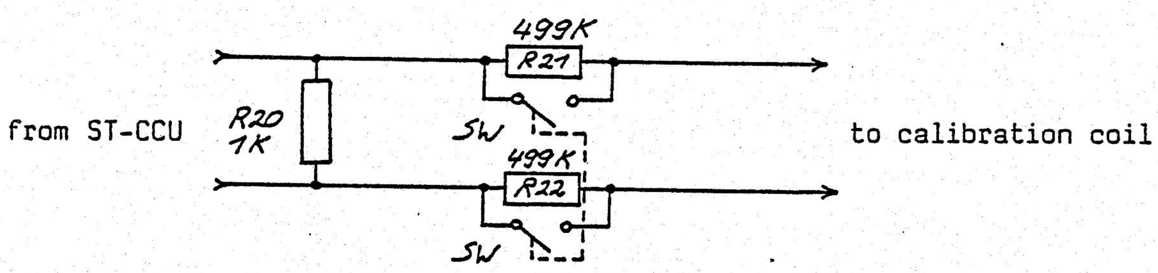
These are inserted during the calibration of the instrument and may differ from one instrument to the other. The damping resistor (R1 of feedback components) can be disconnected by a reed relay with a normally closed contact. This allows undamped electrical oscillations of the feedback system, with 20 / 360 sec nominal period, to be observed for test purposes. The relay can be actuated from the monitor instrument, in the 20 sec mode, from the ST-CCU, or remotely by a digital command to the ST-CCU.

If none of these options is available, the relay can directly be excited over the appropriate pin of the ST-CCU or monitor connector in the feedback unit.

ATTENTION The apparent free period of the system with the damping switched off (R1 disconnected) differs slightly from the nominal free period that appears in the transfer function, and is adjusted precisely to 20 or 360 sec

Calibration Current Divider

The calibration coil in the sensor is much more sensitive to calibration currents than is normally needed. It is so sensitive that leakage currents in the signal cable can produce spurious signals when they reach the calibration coil. To prevent this, a current divider has been inserted into the calibration circuit in the feedback unit. Only one part in thousand of the calibration current fed into the cable on the ST-CCU side reaches the calibration coil. If this should be too small a fraction, then the current divider can be modified or removed. The calibration coil can be accessed directly at the monitor connector, or at the Monitor Instrument's CAL jacks.



Calibration current divider in the feedback unit
(see block diagram)

Vertikal 0.25 mgal/V

LP-output:

1V am Cal-Eingang:
$0{,}00025\,\text{gal} \cdot \frac{2 \cdot 40\,\text{V}}{1\,\text{gal}} \hat{=} 20\,\text{mV}$

The transducer constant of the calibration coil without current divider is approximately 0.25gal/mA for the vertical sensor and 0.35gal/mA for the horizontal sensor. The maximum continuous current is 30mA. Actual values of the transducer constant are not specified because the calibration coil is not used (and not useful) for absolute calibration of the sensor. Due to the force-balance principle any current applied to the calibration coil is automatically compensated by an equivalent current of opposite sign in the integral feedback circuit, so the output signal obtained at the LP output depends essentially only on the feedback resistor R3, not on the absolute responsivity of the seismometer. The absolute responsivity of the LP output to acceleration is determined in a tilt-table experiment (page 29) and is specified for each instrument in the calibration sheet, so the transducer constant of the calibration coil can easily be determined by the customer when he has installed a calibration current divider according to his requirements.