

# PORTABLE VERY-BROAD-BAND TRI-AXIAL SEISMOMETER

## STS-2 "LOW-POWER"

SUBTYPE: "IRIS SPECIAL"

### MANUAL

THIS MANUAL HAS BEEN SHIPPED  
TOGETHER WITH THE STS-2  
"LOW-POWER" SEISMOMETER:

SERIAL NO. 60127

G. STRECKEISEN AG, MESSGERAETE, CH-8422 PFUNGEN, SWITZERLAND

\*\*\*\*\* CERTIFICATE OF CALIBRATION \*\*\*\*\*

Type: STS-2 Low-Power

Serial No. 60127

Date: 01-Oct-2001

The above unit has been inspected and tested in accordance with the specifications given in the accompanying manual.

All tests and calibrations checked below have been performed and passed:

Basic properties:

- ☒ Axes purity (x, y horizontal and rectangular to each other; z vertical.  
Maximal deviation  $\pm 0.6$  deg)
- ☒ Generator constants (x, y, z; value =  $1500 \pm 15$  V $\cdot$ sec/m each)
- ☒ Transfer function (each sensor)

Noise performance:

- ☒ Instrumental noise lower frequency band (0.001...0.03 Hz)
- ☒ Electronic self-noise 1...50 Hz (each sensor)
- ☐ Instrumental noise 20...50 Hz (reduced ground noise by use of a pneumatically decoupled table) \*)

Performance over temperature:

- ☒ Proper operation over temperature (ca. 30 deg Celsius temperature variation)
- ☐ Temperature coefficient of the mechanical system \*)

Miscellaneous:

- ☒ Air tightness

☐ .....

☐ .....

\*) Samples only

Signature

  
.....

Overleaf you find selected test and model data of the unit with the above serial number.

1. Internal oscillator

Frequency: 22.21 kHz

Amplitude: 5.614 Vrms

2. Generator constant and orientation of the axes U, V, and W relative to X, Y, Z

U, V, and W are the uncalibrated, oblique sensitivity axes ('cube corner' configuration)

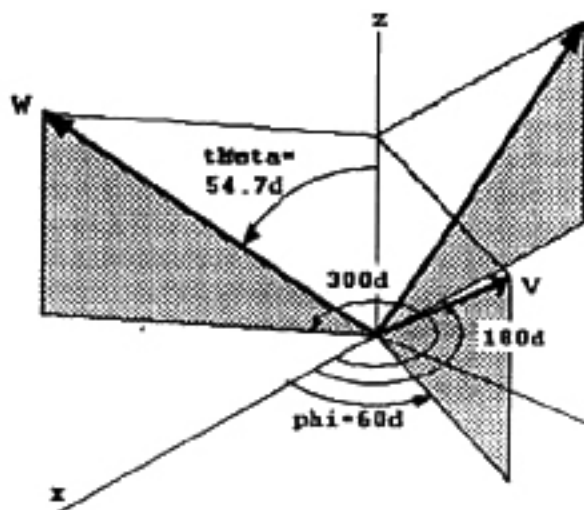
-> Naming conventions: See sketch below! <-

Sensor U:  $G/G_0 = 1.0368$   $\theta = 54.502^\circ$   $\phi = 179.79^\circ$

Sensor V:  $G/G_0 = 1.0064$   $\theta = 54.662^\circ$   $\phi = 59.908^\circ$

Sensor W:  $G/G_0 = 1.0407$   $\theta = 54.829^\circ$   $\phi = 299.81^\circ$

' $G/G_0$ ' is the normalized generator constant (actual constant divided by 1500V\*sec/m)



3. Model parameter optimization of the transfer function

a) High-frequency end (1 - 100 Hz)

Parameters partially optimized for best fitting measurement data. Model function: Linear filter function with discrete poles and zeroes at complex frequencies. Data points to be optimized:

96 complex values of the measured transfer function applying sweep signal at calibration inputs.

4 Zeroes [Hz]:

Sensor U:  $-73.50 \pm 68.29i$   $-31.77^{**}$   $-2.411$

Sensor V:  $-73.50 \pm 68.29i$   $-31.15^{**}$   $-2.411$

Sensor W:  $-73.50 \pm 68.29i$   $-30.89^{**}$   $-2.411$

9 Poles [Hz]:

Sensor U:  $-1629.7 \pm 433.7i$   $-1514.0 \pm 1825.5i$   $-72.34$   $-67.85^\circ$   $-13.85^\circ \pm 63.16i^\circ$   $-2.449^\circ$

Sensor V:  $-1629.7 \pm 433.7i$   $-1514.0 \pm 1825.5i$   $-72.34$   $-67.20^\circ$   $-13.64^\circ \pm 63.99i^\circ$   $-2.430^\circ$

Sensor W:  $-1629.7 \pm 433.7i$   $-1514.0 \pm 1825.5i$   $-72.34$   $-69.88^\circ$   $-14.74^\circ \pm 62.18i^\circ$   $-2.441^\circ$

\* = optimized, \*\* = optimized and corrected for ground motion instead of calibration coil excitation.

Notes: Values without asterisk are standard values from the theoretical model function (no optimization).

Optimization performed with MATHSOFT MATHCAD V8.01, built-in inversion algorithm 'MINERR'

b) Low-frequency end (0.00586 - 0.10547 Hz)

Model: Linear 2nd order highpass filter. Data points to be optimized: 64 complex values of the measured transfer function applying sweep signal at calibration inputs.

Parameters: 1. 2nd order corner period [sec]. 2. 2nd order damping constant. 3. Standard dev. corner period [%]. 4. Standard dev. damping constant [%]. 5. Ampl. RMS Error. 6. Phase RMS Error.

	Parameter					
	1	2	3	4	5	6
Sensor U:	120.17	0.7012	0.0693	0.0879	00.57	00.36
Sensor V:	120.20	0.7017	0.0944	0.1196	00.88	00.45
Sensor W:	120.36	0.7040	0.0734	0.0929	00.60	00.36

Note: Optimization performed with MATHSOFT MATHCAD V8.01, built-in inversion algorithm 'MINERR'

PORTABLE VERY-BROAD-BAND TRI-AXIAL SEISMOMETER STS-2 "LOW-POWER"  
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## 1) NOTICE

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***** * CAUTION * *****
*
* Inspect thoroughly for damage during transit. Each unit is
* shipped ready to operate. Do not open the seismometer.
*
*
* Application of incorrect power voltages may cause permanent
* damage. Do not apply voltages beyond rated values to any
* inputs.
*
*
* Always be sure that the sensor mass locking screws have been
* turned to the "LOCKED" position before moving the
* seismometers.
*
*
* Please note that each manual is labelled with the serial
* number of the corresponding instrument.
*
*****
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## 2) INTRODUCTION

The STS-2 "LOW-POWER" (simply STS-2 in the following text) is designed for quick and simple installation, wide temperature range of operation, and secure transport, while resolving minimum earth noise levels over the frequency range equivalent to and exceeding traditional long- and short-period instruments.

Like the STS-1, the STS-2 is an electronic force-feedback sensor that provides an output signal proportional to ground velocity over a broad range. Similarly, the STS-2 also employs the astatic leaf-spring suspension (Wielandt and Streckeisen, BSSA, 1982).

The STS-2 uses 3 identical obliquely-oriented mechanical sensors. The tri-axial design guarantees that horizontal and vertical components are matched as closely as possible. Standard vertical and horizontal outputs are derived electrically rather than mechanically.

DIFFERENCE BETWEEN "LOW-POWER" VERSION 2 (THIS ISSUE) AND "LOW-POWER" VERSION 1:

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Besides the motor control and the host-box circuit, the version 2 and version 1 electronics are different. Therefore, most circuit diagrams of the section "SCHEMATICS" have changed. Response and gain of the two versions are identical except at the upper frequency limit. The power consumption of version 2 amounts to about 3/4 of version 1. The electronic self-noise has been reduced relative to version 1.

### 3) GENERAL DESCRIPTION

#### 3)1) PHYSICAL

Three identical sensors with electronics and power conditioning are mounted in a cylindrical package approximately 235mm diameter and 260mm high. Power, logic-level control signals, and calibration signals enter the STS-2 on a single 18-conductor cable that is also used to deliver the 3-component differential output signal and single-ended mass position signals. The standard 18-conductor cable is 3 meters long, and is terminated in a "host-box". Three threaded mounting feet allow levelling of the seismometer package. A screw to actuate the transit lock of each sensor is accessible along the edge of the base ring. The top and bottom of the STS-2 have aluminum covers that are gasketed to the base plate.

The STS-2 is vacuum-tight. The construction is further designed to minimize the distortion of the package by barometric pressure changes by isolating the top and bottom covers from the massive base plate, in a way similar to the isolation of a seismograph pier from its surrounding building. The top and bottom covers are secured to the base plate with compliant O-rings, allowing the covers to compress without stressing the entire package. The sealed construction and massive metal base plate provide thermal isolation and inertia.

Since all 3 sensors are mutually aligned by mounting to a common frame and the complete package is factory-calibrated using a standardized 3-dimensional shake table, the STS-2 eliminates some common causes of installation and calibration error. It is necessary to orient and level only a single package in the field. It is not necessary to open the STS-2 package, or to individually adjust and orient each sensor.

Some physical and geometrical outlines may be seen in the figure "STS2 AXES"

#### 3)2) FEEDBACK SYSTEM

(See figure "STS-2 FEEDBACK SYSTEM")

The STS-2 feedback system is basically identical to that of the STS-1/VBB (Wielandt and Steim, Annales Geophysicae, 1986) although the feedback is stronger at short periods improving linearity and extending the high-frequency flat-velocity response. The low-frequency -3dB corner of the STS-2 is set at 120sec.

No filters are used to derive the velocity-proportional output: the STS-2 feedback system delivers velocity directly from the feedback loop. The output stage of the feedback electronics for each component provides a high-level (40V p-p, max) differential output signal, suitable for direct connection to a high-resolution A/D converter, such as the Quanterra Q52K-1 (20Hz sampling) or Q52K-80 (80Hz sampling).

### 3)3) OUTPUT SIGNALS

The raw electrical output of each of the STS-2's obliquely-mounted sensors contains both vertical and horizontal components of motion. These raw sensor signals are electrically summed within the STS-2's electronics to provide standard vertical and horizontal output signals. Cross-coupling between components is suppressed electrically, rather than by mechanical adjustments.

The summation corresponds to a coordinate transformation of the sensor frame U, V, W into the standard frame X, Y, Z (for mutual axis orientation see figure "STS2 AXES"). The theoretical transformation equations are given in section 10. Because of mechanical material and assembly tolerances, the real transformation equations differ slightly from the theoretical ones. But for on-line test purposes (e.g. discrimination of a bad sensor) the theoretical equations will be sufficient.

Three additional output lines are used to monitor either the mechanical balance or the raw broad-band output signals of the individual sensors. The broad-band output signals are selected by applying an external logic control signal.

### 3)4) ORIENTATION AND SIGNAL POLARITY

The orthogonal output signals are factory-adjusted to represent motions in the geometrical X, Y, and Z axis of the seismometer with an accuracy of 1 percent (0.6 degrees) at a period of ca. 6 sec.

Physical orientation of the STS-2 by the user requires the adjustment of only two parameters: the verticality and azimuth of the package. Each STS-2 package is equipped with an integral bubble level. To facilitate orientation, a rod is supplied with each instrument that represents the X axis when fitted into the accordingly labelled hole in the edge of the base ring.

Usually, the instrument is deployed with the X-axis pointing to the east. A positive first excursion in the signal then arises for the following ground motions:

- Step-shaped ground motion to the east at output X+ vs. X-
- Step-shaped ground motion to the north at output Y+ vs. Y-
- Step-shaped ground motion upward at output Z+ vs. Z-

Note: The POS outputs (SIGSW not asserted, see section 5)3)) and the raw sensor outputs (SIGSW asserted) show opposite polarity. For details see section 8.

### 3)5) CALIBRATION

The effective free-period and damping of each channel of every STS-2 is factory-adjusted to within  $\pm 1$  percent of the nominal values.

### 3)6) ELECTRICAL INPUTS

The STS-2 comes supplied with a 3-meter interface cable that is terminated at the sensor end in a seismometer connector and at the other end in a "host-box" with two waterproof connectors named "REMOTE" and "MONITOR". Power, control, output signals, and calibration signals are accessible at the "host-box". The "host-box" also contains DC/DC converters, input protection circuits, and other signal distribution. See the CONNECTIONS section for further details.

#### 3)6)1) CALIBRATION CURRENT INPUTS

The STS-2 provides separate inputs giving access to the calibration coils to allow individual excitation of the three sensors. The return legs of all calibration coils are tied together.

#### 3)6)2) CONTROL INPUTS

Logic-level inputs are provided on the STS-2 "host-box" to control 4 functions: monitor-signal selection (POSITION or raw sensor outputs), initialization of mass recentering, selection of low-frequency corner period, and connection or disconnection of calibration lines.

The STS-2 can automatically recenter the boom position on receipt of an autozero command or pressing the "AUTOZERO" pushbutton. The autozero cycle requires about 30 sec.

To reduce installation and mass centering or recentering time, the STS-2 has the ability on command to change its low-frequency corner period from 120sec to 1 sec and vice-versa without exciting the seismometer's impulse response that can require 10 - 20 minutes for complete decay with the 120-sec low-frequency corner. The autozero command automatically initiates switching to 1 sec corner period and returning to 120 sec after the autozero cycle has finished.

### 3)6)3) POWER

The "host-box" contains an isolating, regulated DC/DC converter. Primary power is applied through a overvoltage and false-polarity protection network consisting of a thermal current limiter and a voltage limiter. Primary DC operating voltage is 10 - 30 VDC. Power consumption is 0.55 W.

### 4) INSTALLATION

#### WARNING:

Whenever handling or moving the STS-2, be sure that the three locking screws are in the "LOCKED" position. See the section on locking/unlocking below.

#### 4)1) UNPACKING

Each STS-2 shipment contains the following:

- 1) STS-2 seismometer with internal electronics
- 2) "Host-box" with 18-conductor cable terminated in a connector that plugs into the STS-2
- 3) 1 Connector 24-pin for REMOTE port on "host-box"
- 4) Orienting rod

For a functional test of the STS-2 seismometer, install it on a flat, solid surface. Plug the 18-pin connector from the "host-box" into the STS-2. Do not apply power yet. Allow the seismometer to adjust to ambient temperature.



#### 4)2) ORIENTATION

The STS-2 may be oriented using the supplied rod. Insert the rod in the hole labelled X-AXIS and align it against a reference (usually directed to the east).

#### 4)3) LEVELLING

Level the STS-2 using the built-in bubble level. The 3 stainless steel legs of the seismometer have locking jam rings that should be loosened before attempting to rotate the legs. Loosen the rings just enough to be able to rotate the legs, otherwise tightening them may deteriorate levelling. After levelling tighten the rings again!

#### 4)4) LOCKING / UNLOCKING

After the seismometer has been oriented and levelled, the masses of the three sensors (U, V and W) may be unlocked. Turn the labelled screws counter-clockwise by 90 degrees until an audible click occurs. Do not force. The locking screws should turn with little resistance. Difficulty in operation may indicate internal damage.

The seismometer is now ready to apply power, auto-center the masses, and begin operation.

Always lock the sensors again before moving the seismometer.

#### 5) CONNECTIONS AND CONTROLS

The "host-box" gives access to the power, signal, and control lines of the miniature 18-conductor cable from the STS-2 through two connectors "REMOTE" and "MONITOR". Connections to the data acquisition system are made through the "REMOTE" connector. Its pinout is shown in schematic "STS2REMC.SCH".

The "host-box" contains optical isolation of the control inputs, a push-button for initiating an automatic mass recentering, and a DC/DC converter that supplies power to the seismometer. Control signals are transmitted to the seismometer over a single conductor from a serial encoder in the "host-box". The schematic for the "host-box" is on the sheets "STS2BOX3.SCH", "STS2BXC2.SCH" and "STS2INP2.SCH".

## 5)1) POWER

Input voltage (connector pins W and X) is wide range, 10 - 30 VDC. Typical current is 22 mA at 24 VDC when recentering is not active and the signal outputs X, Y, and Z do not exceed 100 mV. Mass recentering may draw an additional 10 - 20 mA. In the completely deteriorated state (all booms deflected to the stop) the current rises to about 80 mA.

The DC/DC-converter power-up peak current is about 250 mA. Be sure that the power source is dimensioned correspondingly! The power input is galvanically isolated from the analog and logic signals and return lines.

In the event of applying an improper supply voltage, disconnect power and wait for several minutes for the thermal current limiter to recover.

## 5)2) CONTROLS

This section refers to the REMOTE connector only.

The control inputs accept any input "high" level from 3 - 30 VDC, and require an operating current of approximately 0.5mA. The inputs are optically isolated, and require connection of the common RET line to the return of the logic signal source.

For simple operation without an external logic source, the RET may be connected to VIN -. Control signals may then be asserted by applying VIN + to the appropriate input.

The control inputs provide the following functions:

1. (R) - PERSW assertion converts the free period to 1 second for setup
2. (L) - SIGSW assertion selects raw sensor rather than mass position outputs
3. (E) - AUTZ assertion initiates automatic mass recentering  
A pulse width of 0.5 sec minimum is required.
4. (K) - CALSW assertion connects calibration coils to calibration signal inputs. When this line is de-asserted, the calibration coils are disconnected from the calibration signal inputs in order to suppress stray currents.



### 5)3) SIGNALS

The REMOTE connector provides differential signal outputs, and calibration signal inputs.

In most cases it will be favorable to connect the SHIELD (pin A) to the frame ground of your data system. In electromagnetically contaminated surroundings, where ground loops may arise, the best shield and frame ground connection must be evaluated by experience.

The SIGNAL GROUND (pin F) should be connected to your data system's input common.

The orthogonal outputs X, Y, Z (vertical) appear on the connector as follows: X+ (pin D), X- (pin J), Y+ (pin C), Y- (pin H), Z+ (pin B) and Z- (pin G). Each differential leg has a swing of  $\pm 10$ V, thus the peak-to-peak differential signal range is 40V. Connect the differential output to a differential input of your data system; unsymmetric inputs may introduce electronic noise. Use a symmetric voltage divider if your system does not accept signals as large as  $\pm 20$ V.

When the SIGSW control input is not asserted, UPOS (pin T), VPOS (pin V) and WPOS (pin U) put out the position signals.

The position signals show the mass positions of the U, V, and W sensors. A mass recentering cycle must be initiated when these signals approach the ends of the nominal range of  $\pm 10$  V. No vertical and horizontal position signals are available; therefore a "maximum gravity" adjustment of verticality as described in the STS-1 manual is not possible.

When SIGSW is asserted, the same terminals (pin T), (pin V) and (pin U) give access to the raw (unmixed) U, V, and W sensor outputs ( $\pm 10$  V output voltage swing). The single-ended signals on (pin T), (pin V) and (pin U) are provided for monitoring purposes only and cannot be used for high quality data recording.

### 5)4) RECENTERING

The automatic mass recentering cycle is initiated by depressing the "AUTOZERO" pushbutton on the "host-box" or asserting the AUTZ control input for at least 0.5 sec. During autozero, the seismometer period will be switched to one second so that the long transient response of the normal 120-second mode is not excited. Following completion of an autozero cycle, which takes about 30 seconds, the seismometer period is automatically switched back to the normal 120-second mode.

Each sensor is zeroed in sequence. In case one autozero cycle is not sufficient (one of the position signals not within  $\pm 2$  V), it may be repeated. After having levelled the instrument by means of the bubble level, it is a normal situation that more than one autozero cycle is required (see section 11)1) for more details).

## 6) SUGGESTIONS FOR OPERATION

A double styrofoam box is recommended for isolation against rapid temperature changes and air currents; it will substantially improve the long-period noise level. Satisfactory results may also be obtained with a single box. We have found that in a typical seismic vault with still air and relatively constant temperature, an STS-2 covered by a single box without special sealing can resolve minimum earth noise to about 50 sec period. Operating under these conditions, the STS-2 will produce long-period, narrow-band records (with a peak magnification at 25-35 sec) that are virtually identical to those from a properly installed set of STS-1 seismometers.

For recording with substantial gain at very long periods, the STS-2 requires some additional protection from air pressure fluctuations. We recommend in this case to provide a simple pressure jacket which needs not be air-proof for more than a few hours. Evacuation is not required and not recommended. In case of insatisfactory results see also section 11)4)

## 7) TRANSPORT AND REPACKING

Preceding any manipulation lock each sensor by actuating the locking screws.

Pack the seismometers in the original or equivalent shipping containers. Seismometers should be protected by foam rubber on all sides. The boxes should be shipped upright and clearly marked for delicate handling.

## 8) SPECIFICATIONS

### 8)1) GENERAL

Principle of operation	Force Balance
Mechanical sensors	3 identical inertial pendula in a cube-corner geometry. The mechanical free period is virtually infinite.
Seismic output signals	2 horizontal (X, Y) and vertical (Z) Broad-band velocity response
Size	Cylindrical package 235 mm dia., 260 mm high
Weight, complete with "host-box"	13 kg
Environmental protection	Vacuum-tight, low-stress construction

## 8)2) ELECTRO-MECHANICAL

Generator constant	2 * 750 V*sec/m												
Response	Ground velocity between corners 8.33 mHz (120 sec) and >50 Hz. See section 9 for details.												
Seismic signal output	+20 V differential range, 220 ohms serial resistance per line												
Auxiliary outputs	+10 V single-ended, 1 kOhm serial												
Electronic self-noise	approx. 5 dB below USGS low-noise model between 5 mHz and 1 Hz, below USGS low-noise model between 1 Hz and 10 Hz												
Clip level	+13 mm/sec ground velocity up to 20 Hz, linear derating from 20 Hz to 50 Hz down to 5.3 mm/sec at 50 Hz; equivalent to the following accelerations: <table border="0" style="margin-left: 40px;"> <tr> <td style="text-align: right;">g peak-peak</td> <td style="text-align: right;">at Hz</td> </tr> <tr> <td style="text-align: right;">0.34</td> <td style="text-align: right;">20 - 50</td> </tr> <tr> <td style="text-align: right;">0.17</td> <td style="text-align: right;">10</td> </tr> <tr> <td style="text-align: right;">0.017</td> <td style="text-align: right;">1</td> </tr> <tr> <td style="text-align: right;">0.0017</td> <td style="text-align: right;">0.1</td> </tr> <tr> <td style="text-align: right;">0.00055</td> <td style="text-align: right;">0.03</td> </tr> </table>	g peak-peak	at Hz	0.34	20 - 50	0.17	10	0.017	1	0.0017	0.1	0.00055	0.03
g peak-peak	at Hz												
0.34	20 - 50												
0.17	10												
0.017	1												
0.0017	0.1												
0.00055	0.03												
Dynamic range	see figure "STS2 SEISMOMETER NOISE AND CLIP LEVEL"												
Parasitic resonances	vertical: >140 Hz, horizontal: >80 Hz												
Power input	10 - 30 V DC, galvanically isolated												
Power consumption	Average: 0.55 W, deteriorated state: 2.0 W												
Control inputs (REMOTE connector)	"high": 3 - 30 V, 0.5 mA; "low": < 0.5 V; optically isolated												
Calibration inputs	Calibration coils 30 Ohms each, approx. 0.002 g / mA (oblique), maximal current 50 mA each												
Temperature range	+10 °C without mass recentering (see section 11)3))												
Mass centering	automatic on external command												

## 8)3) GEOMETRIC RELATIONS

Field orientation	normally: X directed to the east, Y to the north
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Seismic signal output polarity (for X = east, outputs "+" vs. "-", 1st excursion of step response)

- ground motion to E	X: pos. voltage, Y: 0V, Z: 0V
- ground motion to N	X: 0V, Y: pos. voltage, Z: 0V
- ground motion upward	X: 0V, Y: 0V, Z: pos. voltage

#### Auxiliary output polarity

- sensor boom acceleration upward	pos. voltage on UPOS, VPOS, WPOS vs. signal ground (SGND)
- sensor frame motion upward	neg. signal on raw velocity outputs U, V, W vs. signal ground (SGND)

#### Calibration input polarity

- positive current on UCAL, VCAL, WCAL vs. CCOM	downward directed force on the boom U, V, W, resp.
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### 9) RESPONSE

(See figures "STS-2 VELOCITY RESPONSE" and "STS-2 PHASE RESPONSE")

#### a) frequencies below 1 Hz

At low frequencies the STS-2 seismometer may simply be considered as a long-period, velocity-transducer, three-component seismometer with a free period of 120 sec and damping 0.707 of critical. These parameters are factory-adjusted to within 1 percent. The response of the seismometer to ground displacement at frequency  $f$  is described by the transfer function

$$T(f) = 2\pi i f S / (1 - 2i f_1 h / f - (f_1 / f)^2)$$

where

S = generator constant, 20'000 V\*sec/m  
 $f_1$  = corner frequency, 0.00833 Hz  
 $h$  = fraction of critical damping, 0.707

#### b) frequencies between 1 and 10 Hz

Between 1 and 10 Hz, the velocity response of the STS-2 is flat within  $\pm 0.15$  dB (about  $\pm 1.5\%$  in amplitude). The group delay time in this frequency range is nearly constant, about 4  $\pm 1$  msec.

## c) frequencies above 10 Hz

The velocity response of the STS-2 exhibits an amplitude peak at about 70 Hz because of the relatively low phase margin of the open-loop function. However, the overall response at high frequencies depends not only on the seismometer but also on its coupling to the ground. While coupling may influence the amplitude and the phase of the transfer function noticeably, its influence on the signal delay time is small. The group delay time observed on a shake table is a nearly constant 3  $\pm$  1 msec at frequencies between 10 and 50 Hz. The amplitude response may be expected to be constant within  $\pm$  3 dB.

A more exact transfer function than the one given above, particularly for frequencies above 10 Hz, can be extracted from the block-diagram "STS-2 FEEDBACK SYSTEM".

## 10) THEORETICAL TRANSFORMATION EQUATIONS

In order to convert the differential output signals X, Y, Z into the approximate sensor output signals U, V, W and vice versa, use the following equations:

$$\begin{aligned} U &= -\sqrt{2/3} X + \sqrt{1/3} Z \\ V &= \sqrt{1/6} X + \sqrt{1/2} Y + \sqrt{1/3} Z \\ W &= \sqrt{1/6} X - \sqrt{1/2} Y + \sqrt{1/3} Z \\ \\ X &= -\sqrt{2/3} U + \sqrt{1/6} V + \sqrt{1/6} W \\ Y &= \sqrt{1/2} V - \sqrt{1/2} W \\ Z &= \sqrt{1/3} U + \sqrt{1/3} V + \sqrt{1/3} W \end{aligned}$$

## 11) HINTS FOR INSTALLATION, OPERATION, AND TEST

## 11)1) BOOM RECENTERING DIFFICULTIES

The autozero sequence of the sensors is V, then W, then U. Note that this sequence is running twice on one command!

For being able to cover a wide range of operating site latitudes and altitudes on earth, the mass that is shifted on a recentering command must be rather heavy at the expense of the fine-adjustment accuracy. However, if centering is repeated, the boom positions converge to within  $\pm$  2 V. Be aware of the fact that a recentering cycle may not always improve the boom positions. It is therefore very important to observe the boom positions after each recentering action and not to rely on the automatic function!

Actuating the boom recentering does not disconnect the calibration lines. Be sure that no automatic or manual calibration is running while executing autozero! Otherwise it may happen that one or more sensor signals get out of range.



#### 11)2) OFFSET ON THE SIGNAL OUTPUTS

Having installed a seismometer, the temperature of the instrument is drifting towards an equilibrium temperature. Normally, the drift period lasts one day at the minimum. The characteristic of a high temperature drift is a high "offset" on the Z signal output. "Offset" means here a quasi-constant output voltage, i.e. a voltage remaining constant during many step-response settling times (about 30 minutes). Of course, an "offset" also arises, when the ambient temperature is continually changing. If this "offset" exceeds 20 mV at the differential outputs and is not remarkably diminishing during some hours, the temperature drift is very critical.

#### 11)3) OPERATING TEMPERATURE RANGE

The temperature range  $\pm 10$  degrees without recentering specified in section 8) only holds for long-term, cyclic temperature variations. Short-term variations produce noise and offset (section 11)2)), because of thermal disequilibrium inside the seismometer housing. Additionally, the temperature drift shows a non-linear behavior. As long as the temperature is fluctuating only within a specific 20 degree range no recentering is required. But if the temperature leaves this range for the first time in either direction, a substantially higher drift may be observed. Say, your vault temperature is 2 degrees Celsius in winter time at the minimum and 22 degrees in summer time at the maximum. Further suppose, you deploy the instrument in summer time. Depending on the storage temperature before the deployment, occasional recentering until the next spring time may be required. Afterwards, you do not have to recenter again. The drift caused by aging is negligible by experience. On the other hand, if you move the seismometer to a new vault with an annual temperature range of 15 to 35 degrees, you may have to recenter several times until the seismometer has reached 35 degrees for the first time.

The specifications of section 8) are guaranteed within the temperature range of 0 degrees to 40 degrees Celsius.

#### 11)4) DIFFICULTIES WITH LONG-PERIOD NOISE PERFORMANCE

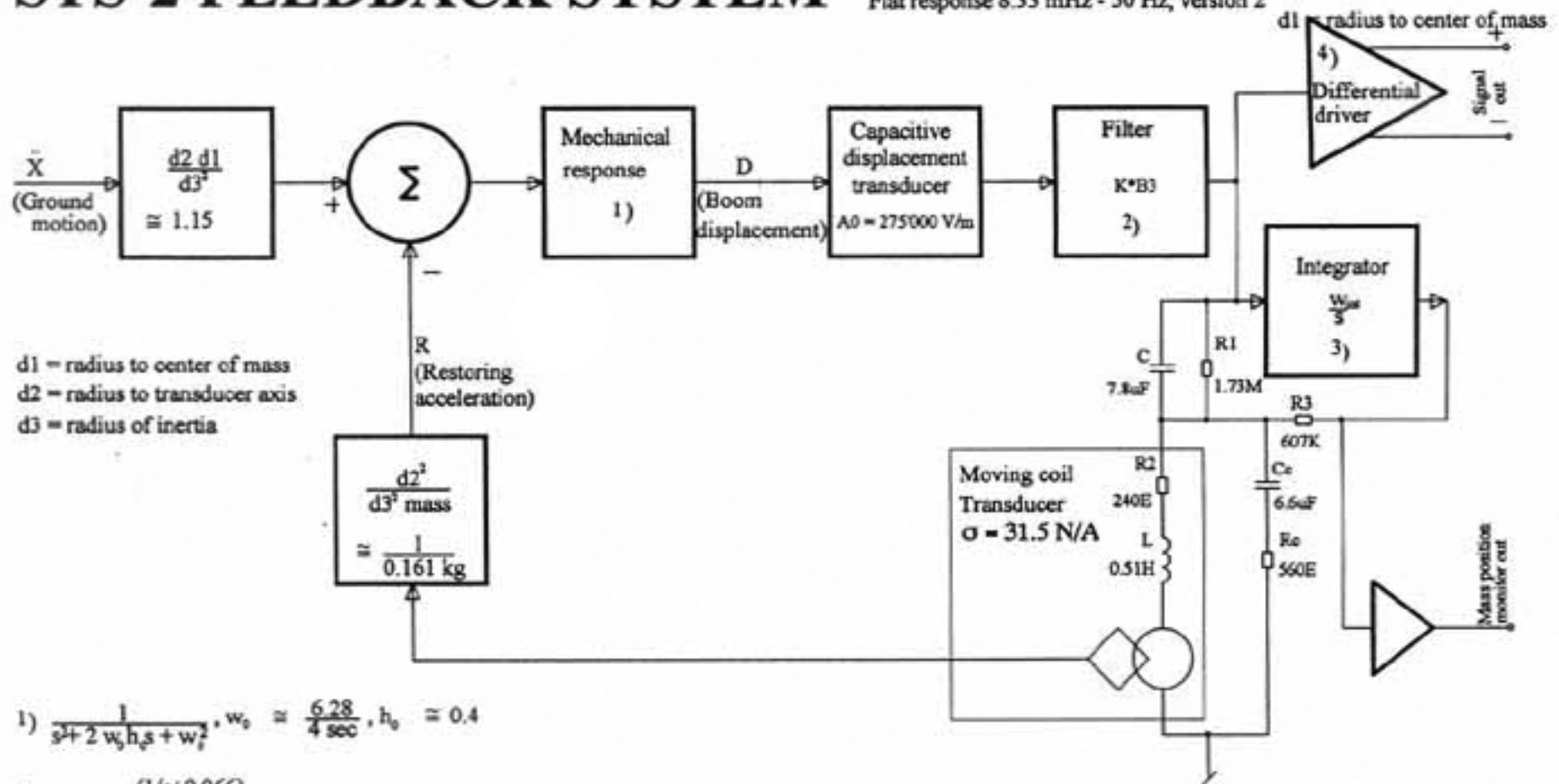
Nearly all newly installed seismometers exhibit randomly distributed step-response peaks of variable amplitude on the X, Y, and Z records because of internal and external mechanical stresses that are released at the beginning of operation. During the first few days or weeks, these peaks should diminish in frequency and amplitude and then almost vanish. If the disturbance activity remains constant over several weeks, the reason may be found among the following three possibilities:

- a) The temperature drift is relatively high (recognizable by an "offset" of several Millivolts on Z).
- b) The place of operation is mechanically unstable (e.g. corrosion phenomena, dewatering effects, etc.).
- c) A sensor mechanics part (e.g. axis hinge) has been damaged.

For a proper long-period registration it is essential to follow the advices of section 6!

# STS-2 FEEDBACK SYSTEM

Flat response 8.33 mHz - 50 Hz, version 2



$$1) \frac{1}{s^2 + 2\omega_0 h_0 s + \omega_0^2}, \omega_0 \approx \frac{6.28}{4 \text{ sec}}, h_0 \approx 0.4$$

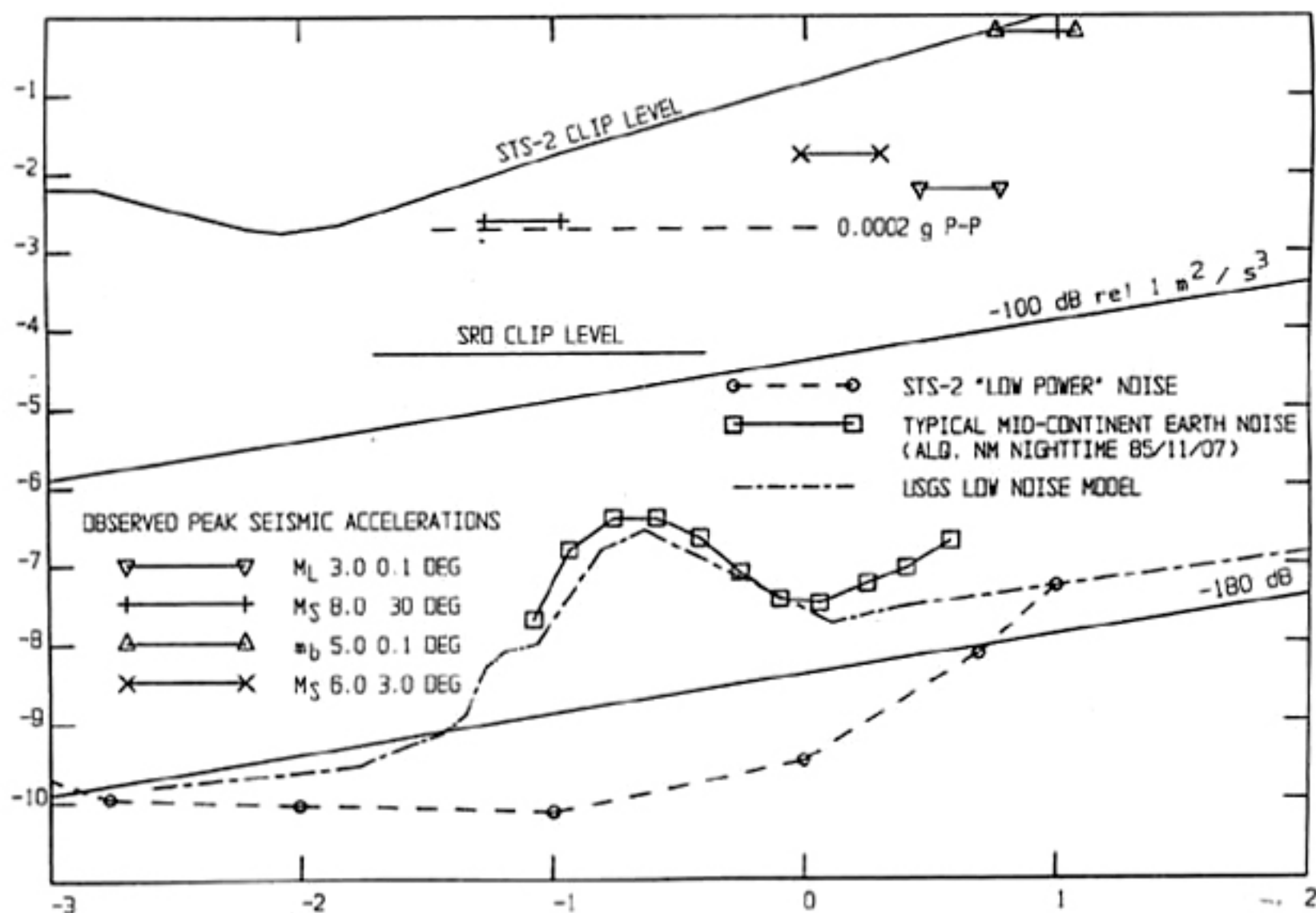
$$2) K = \frac{(1/s + 0.066)}{(1/(475s) + 0.066)} \quad (\text{Inverse filter})$$

$$B_3 = \frac{1}{(1 + 7.52e-5s)(1 + 9.94e-5s + 4.72e-9s^2)} \quad (\text{Bessel 3rd order 1600 Hz})$$

$$3) w_{int} = \frac{1}{77.1 \text{ sec}}$$

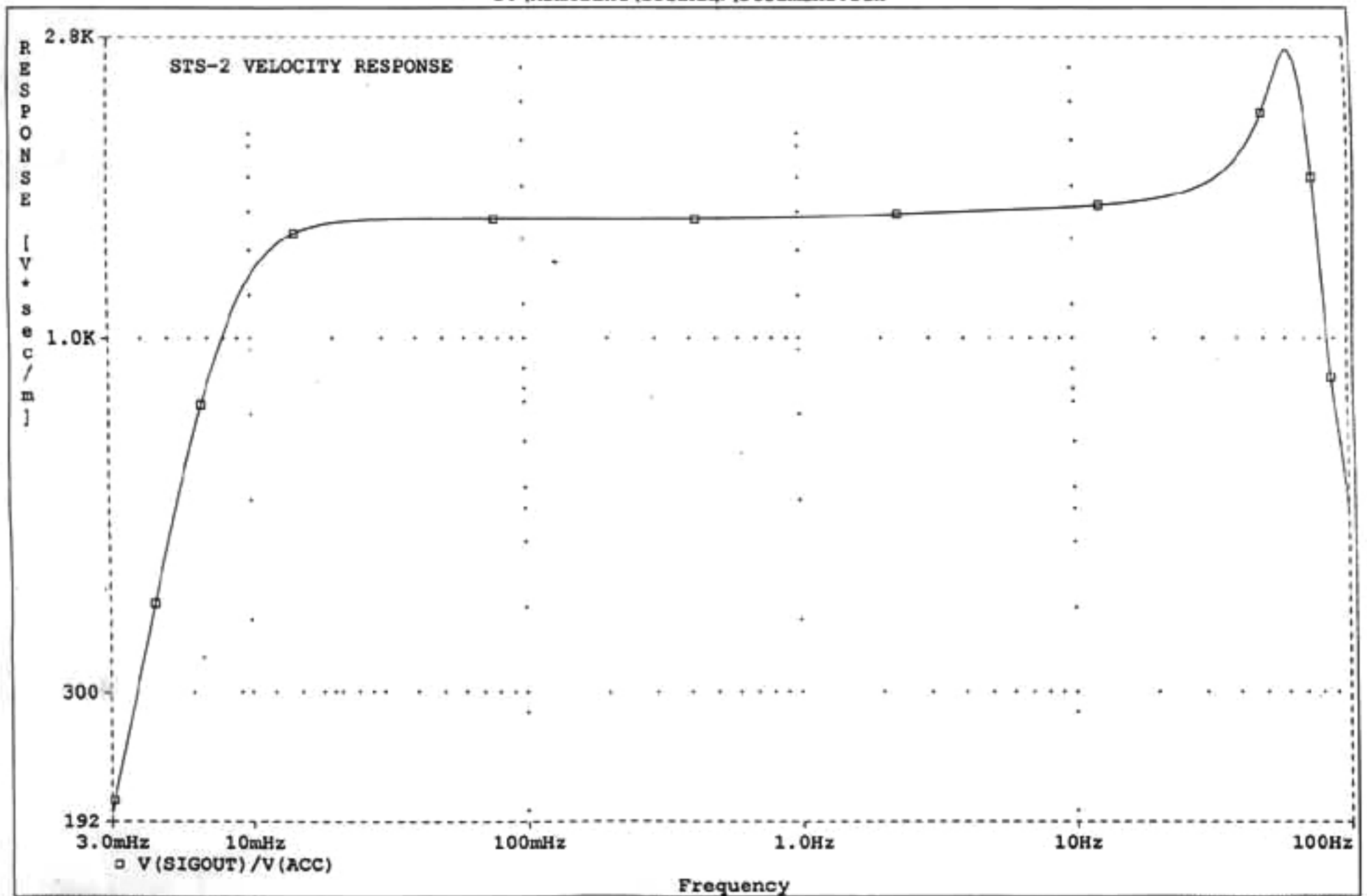
$$4) \text{ With low-pass filter: } \frac{1}{s/w_{int} + 1}, w_{int} = 6.28 \cdot 40 / \text{sec}$$

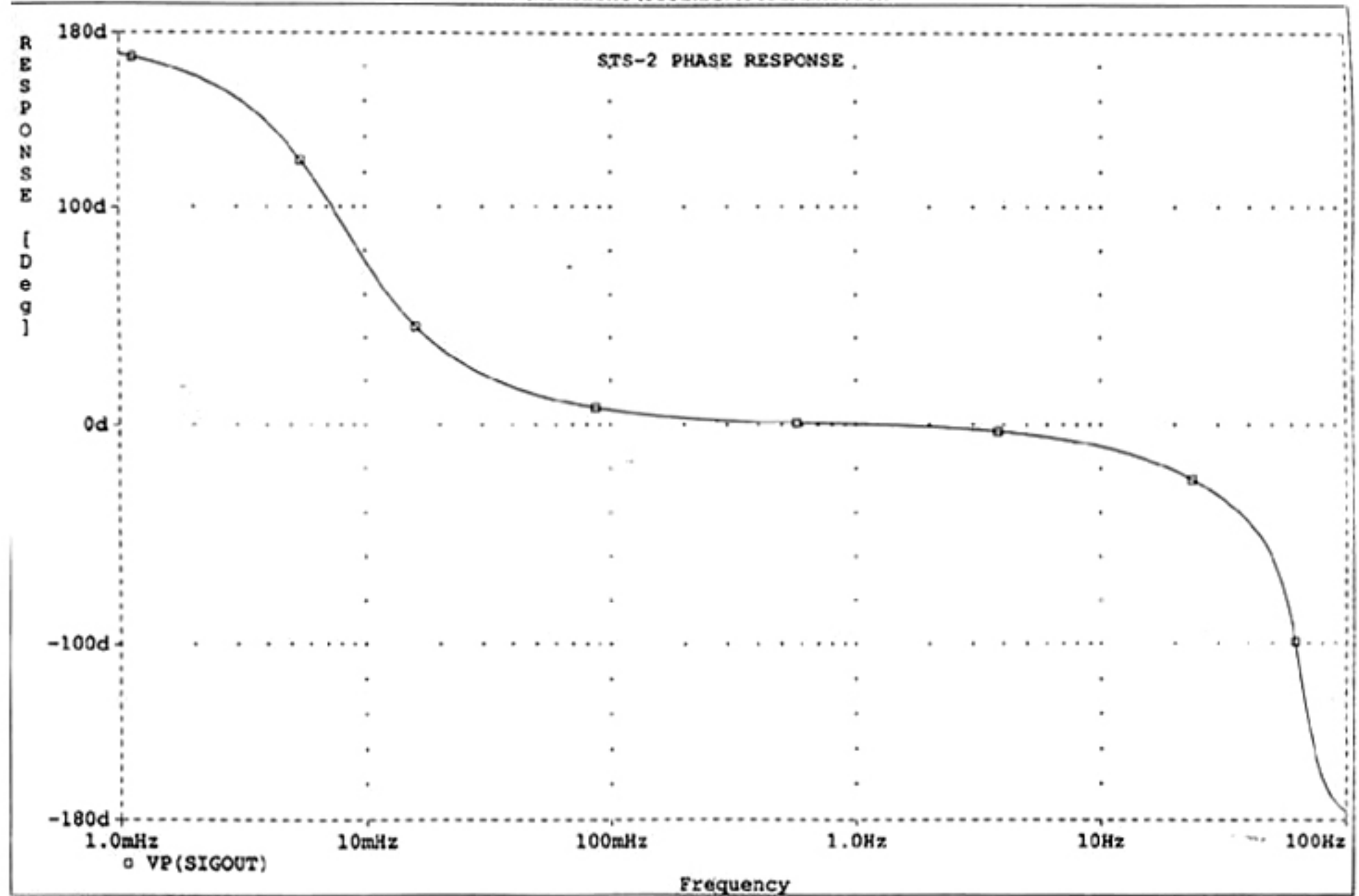
LOG (ACC P-P  $m/s^2$  1/6 decade)



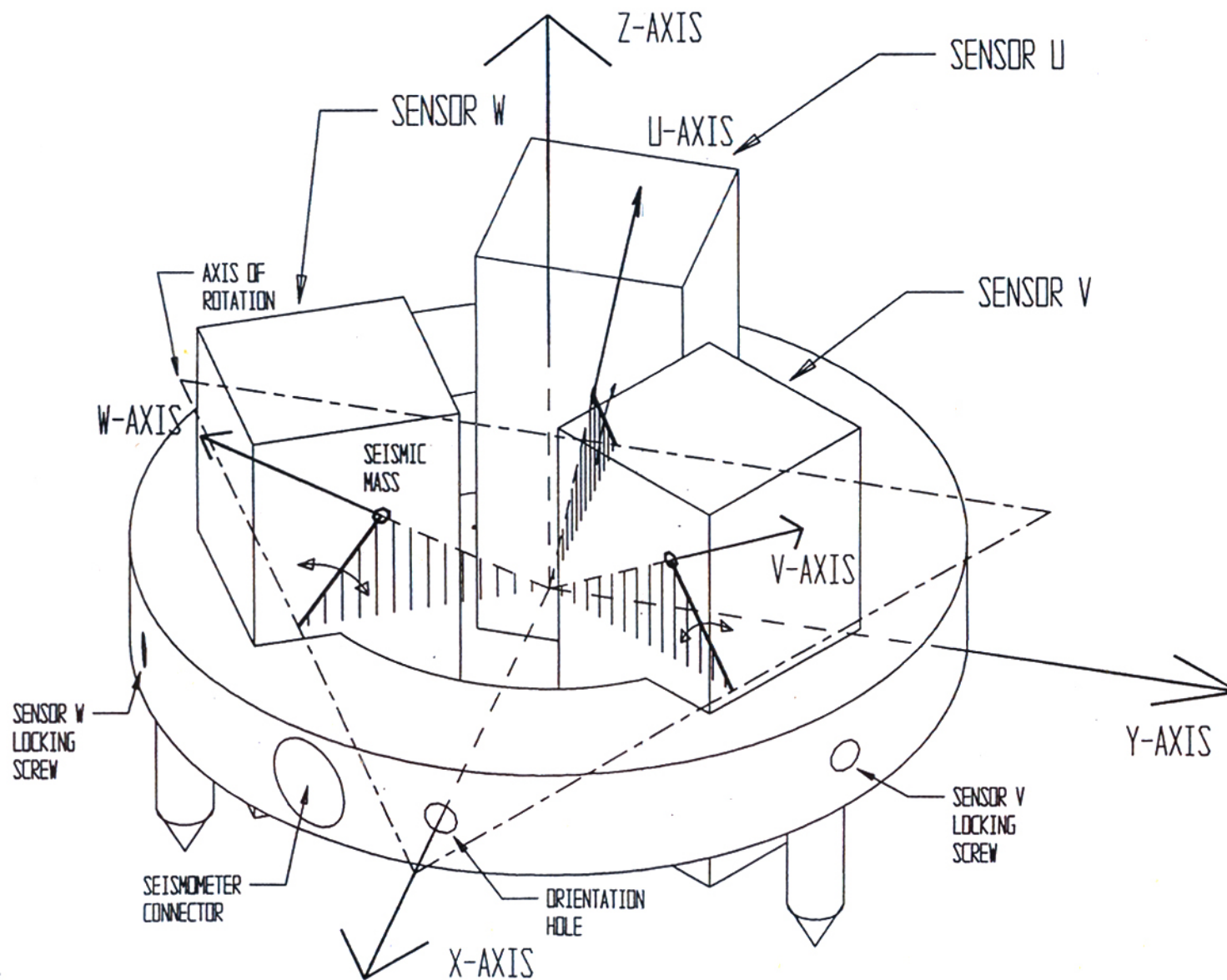
LOG (Frequency in HZ)



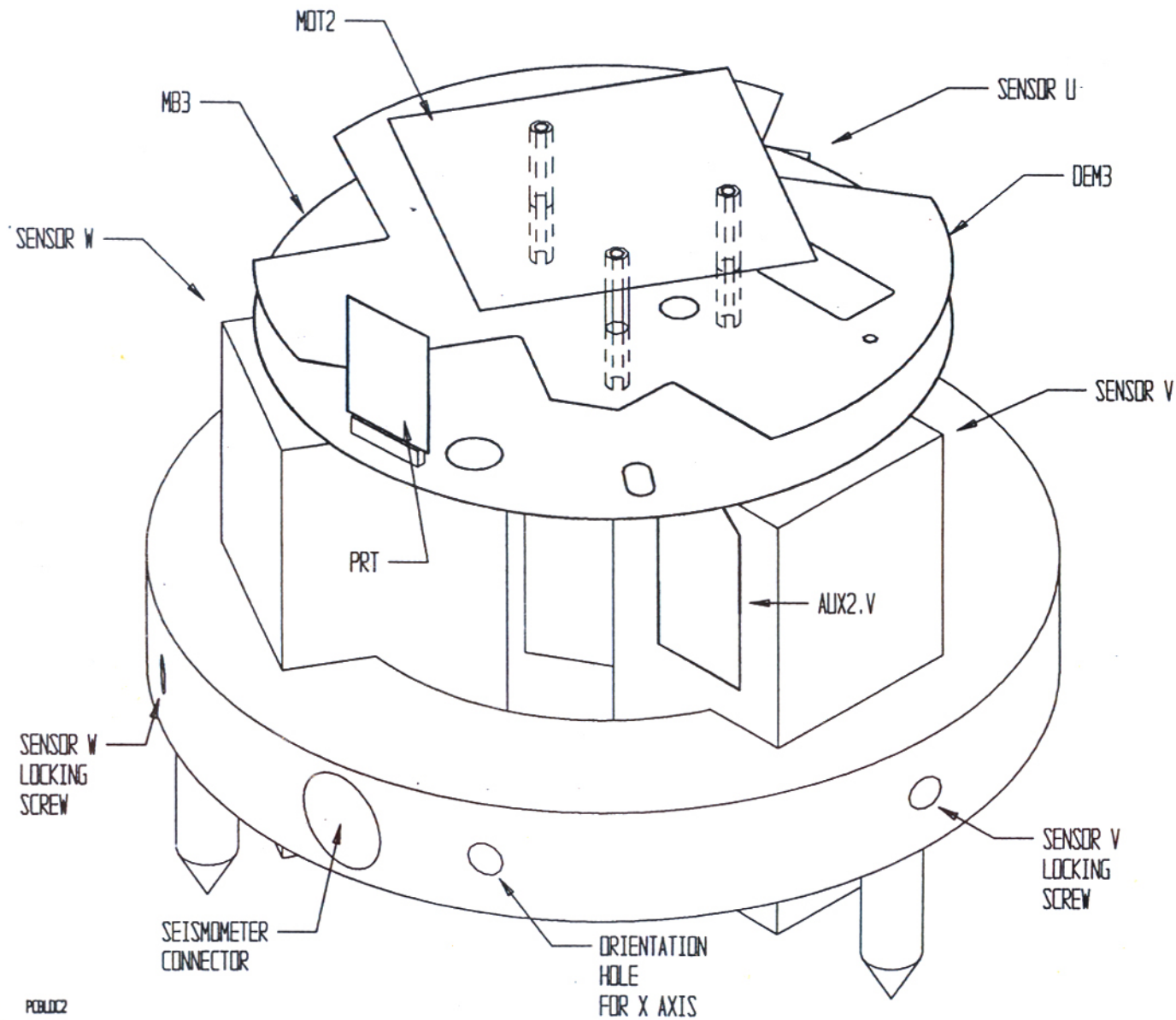




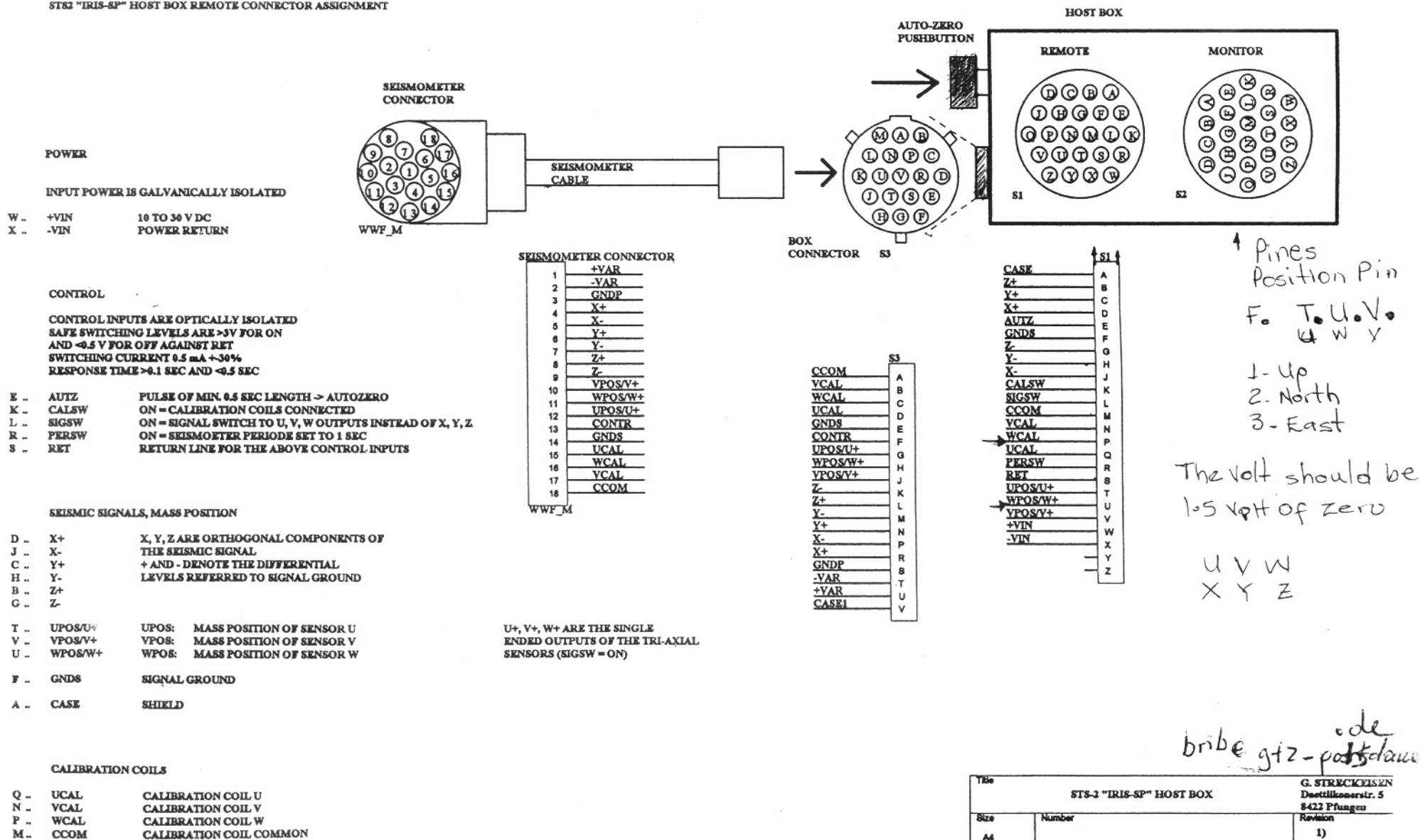
# STS2 AXES

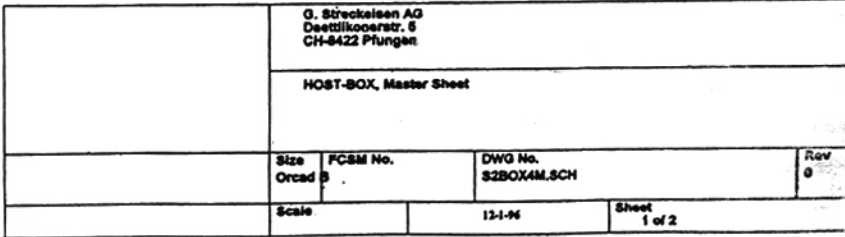


# STS2 PRINTED CIRCUIT BOARD LOCATION

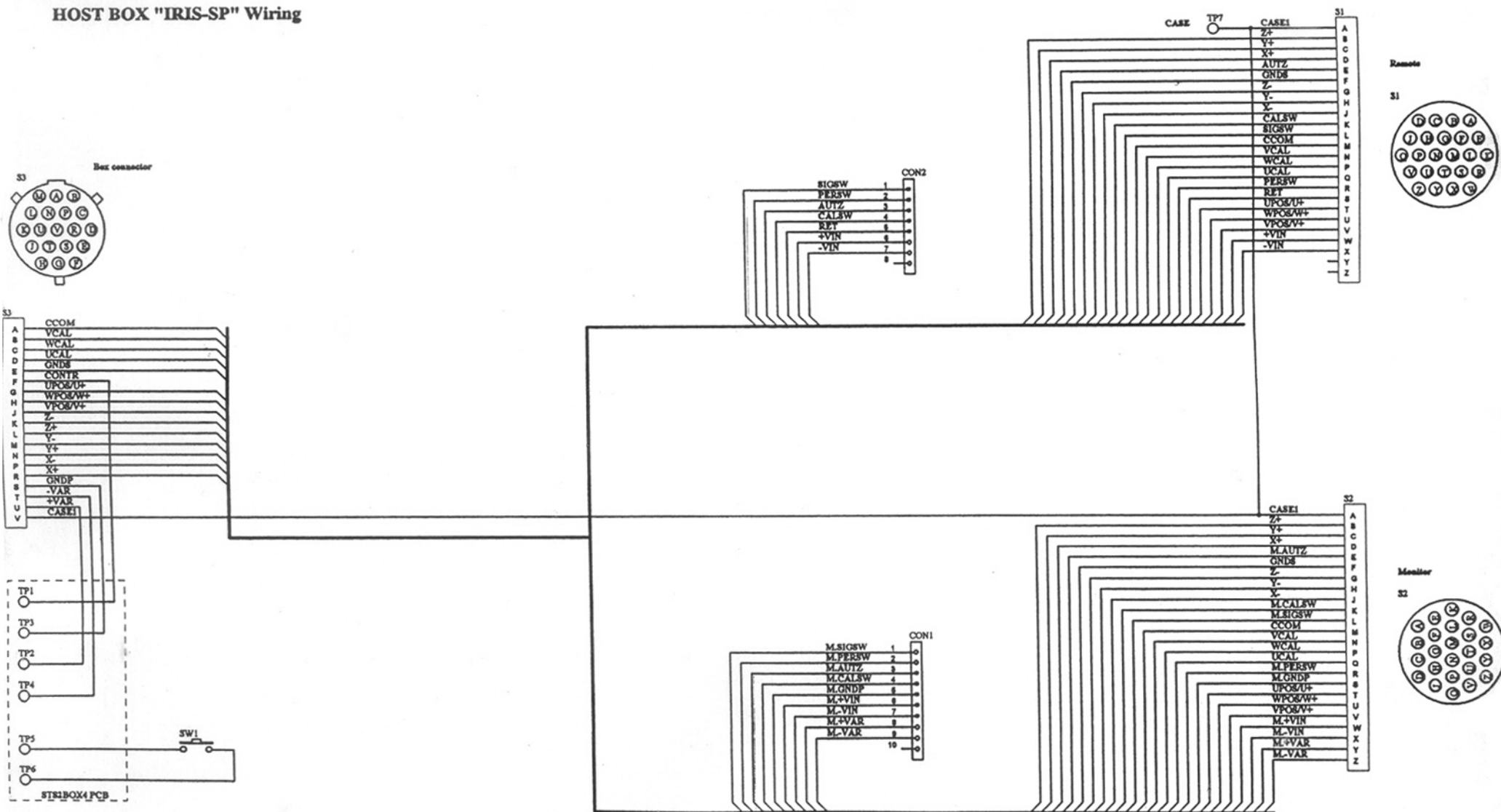


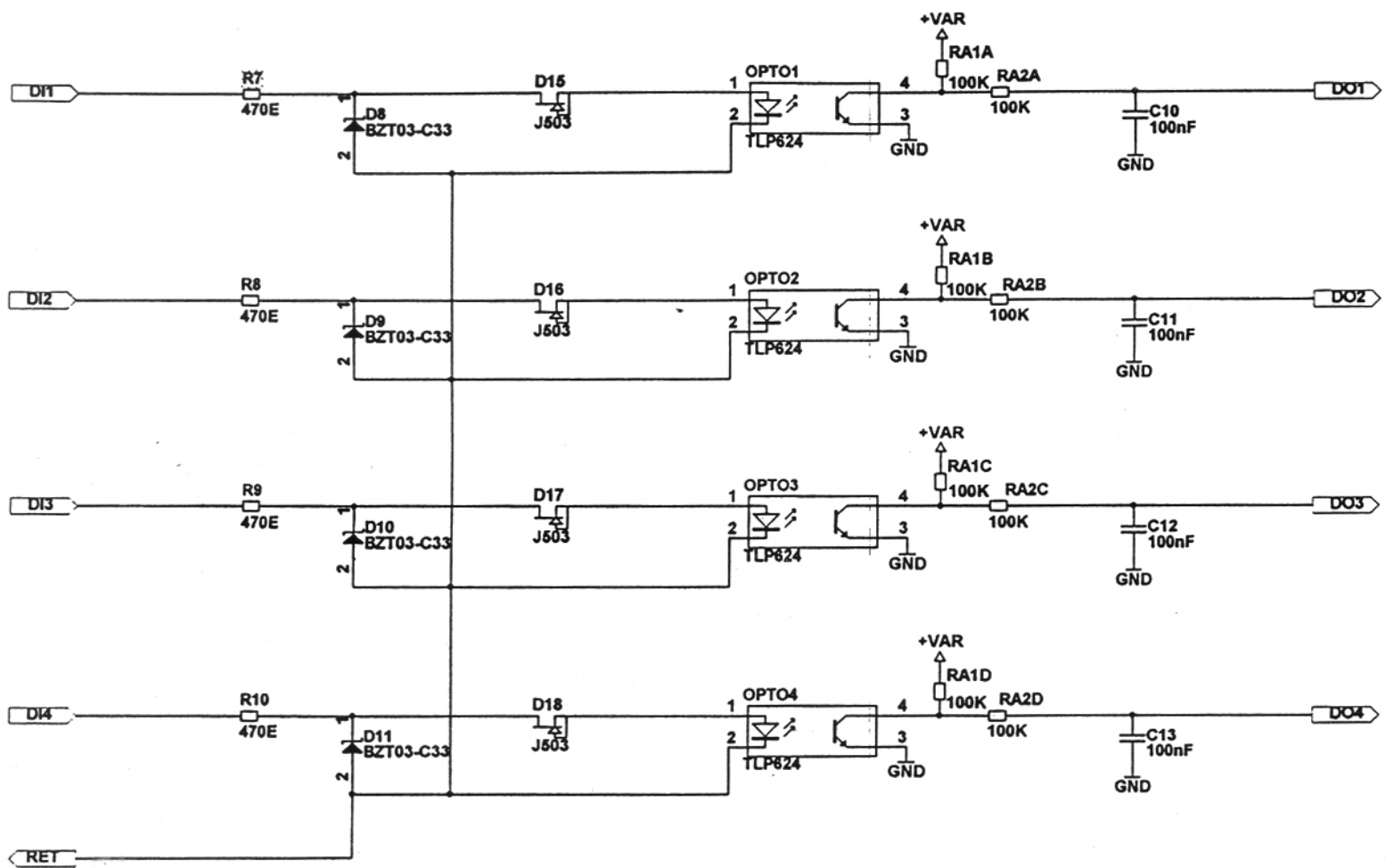
# STS2 "IRIS-SP" HOST BOX REMOTE CONNECTOR ASSIGNMENT





# HOST BOX "IRIS-SP" Wiring





G. Streckelsen AG  
Daettlikonerstr. 5  
CH-8422 Pfungen

HOST-BOX, Subsheet

Size  
Orcad A

FCSM No.

DWG No.  
INP2.SCH

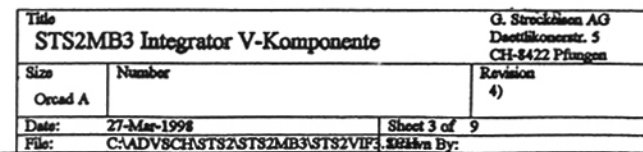
Rev  
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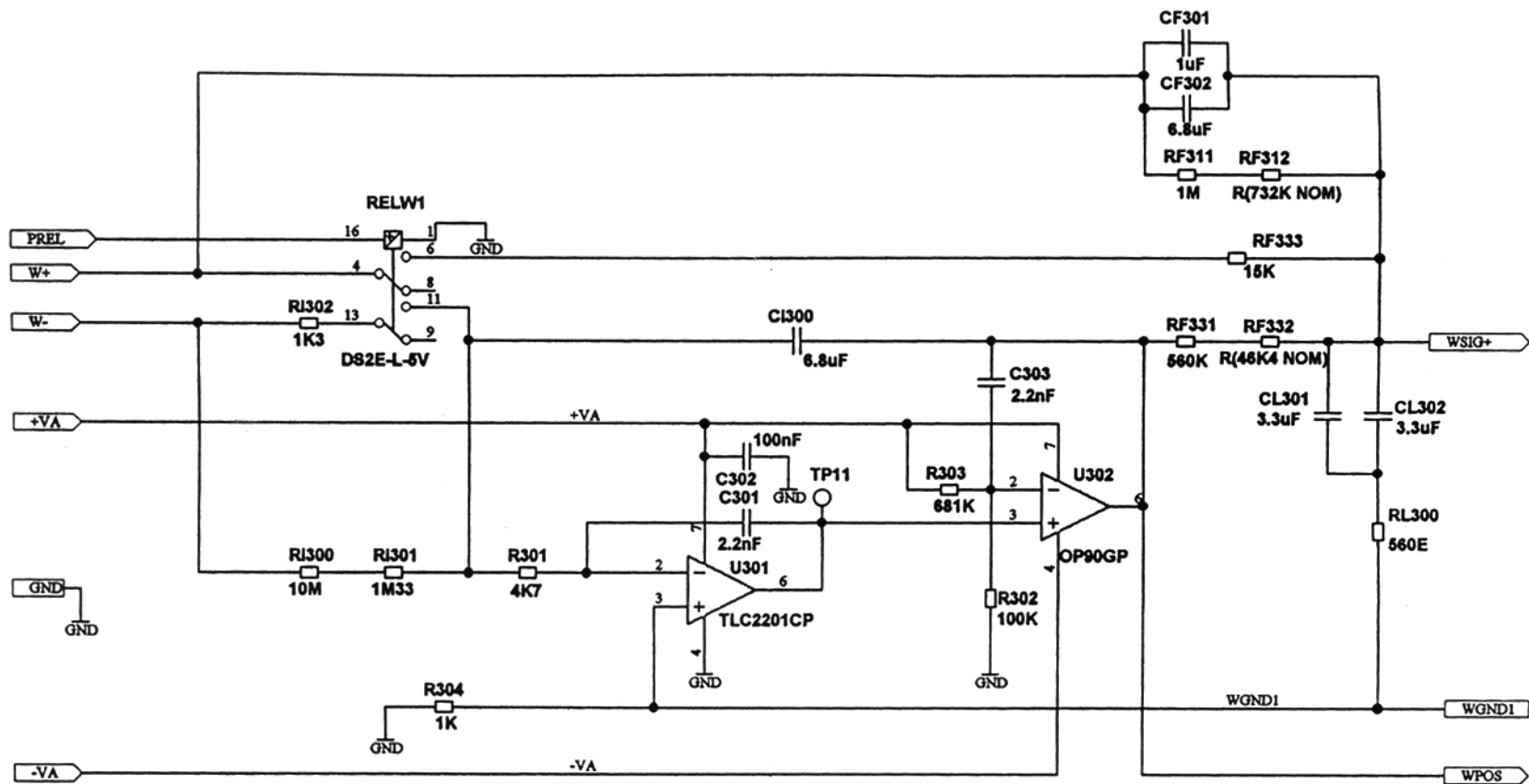
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12-1-96

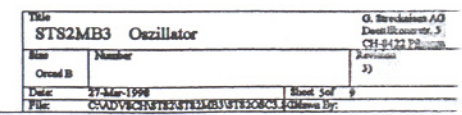
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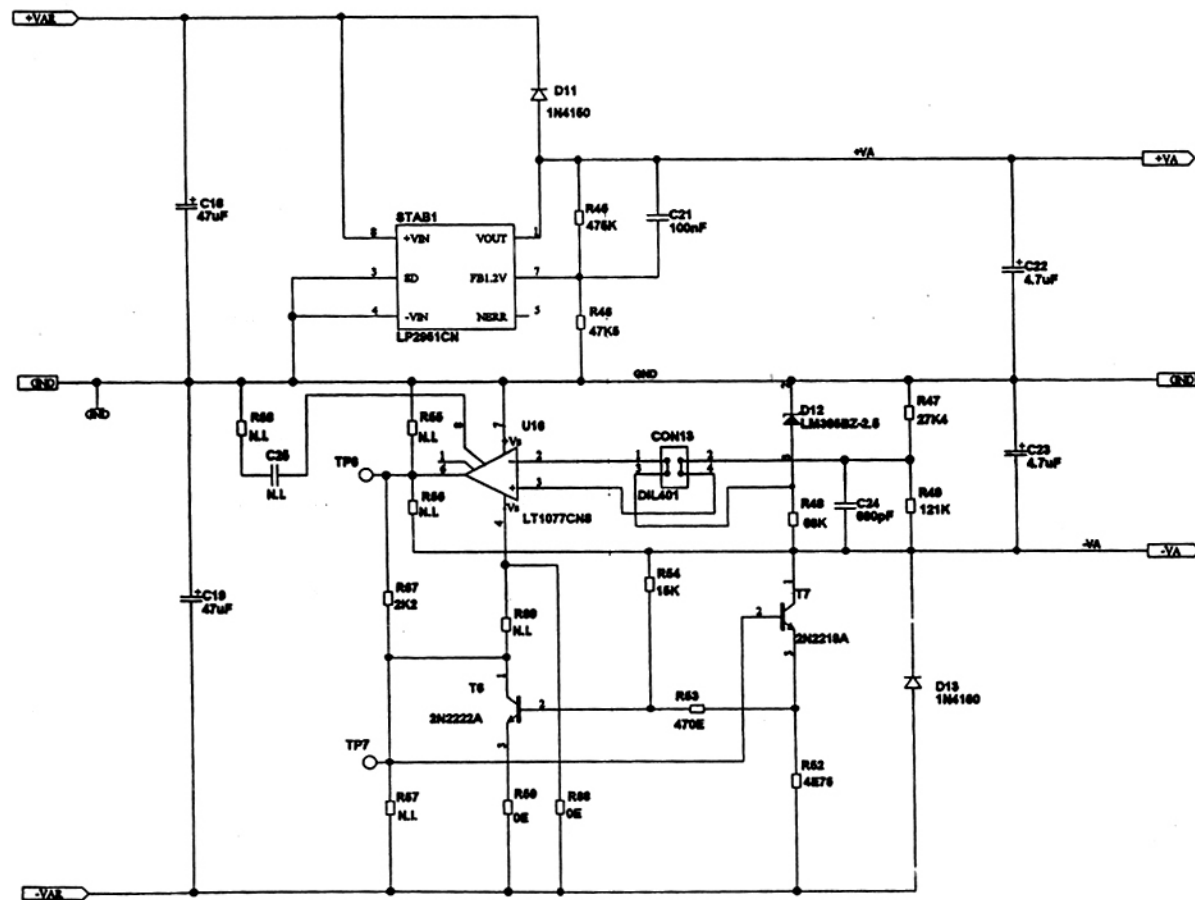


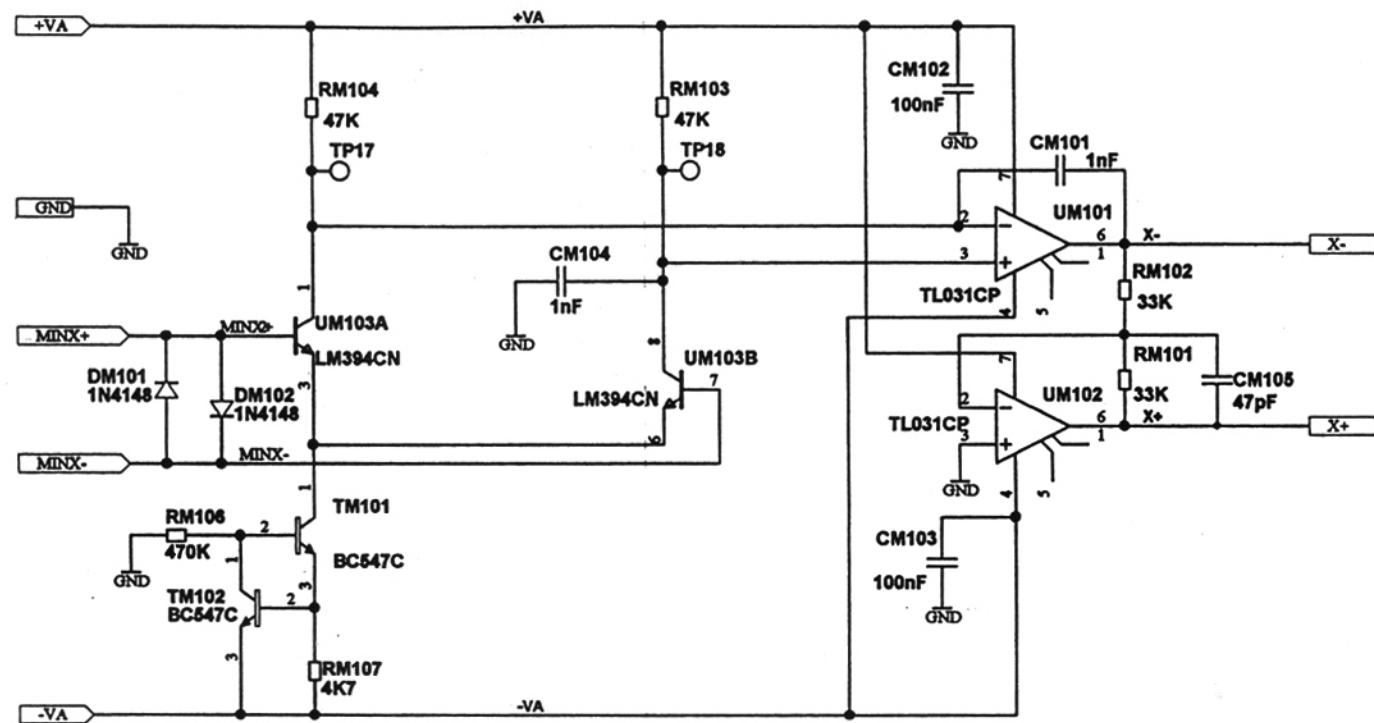




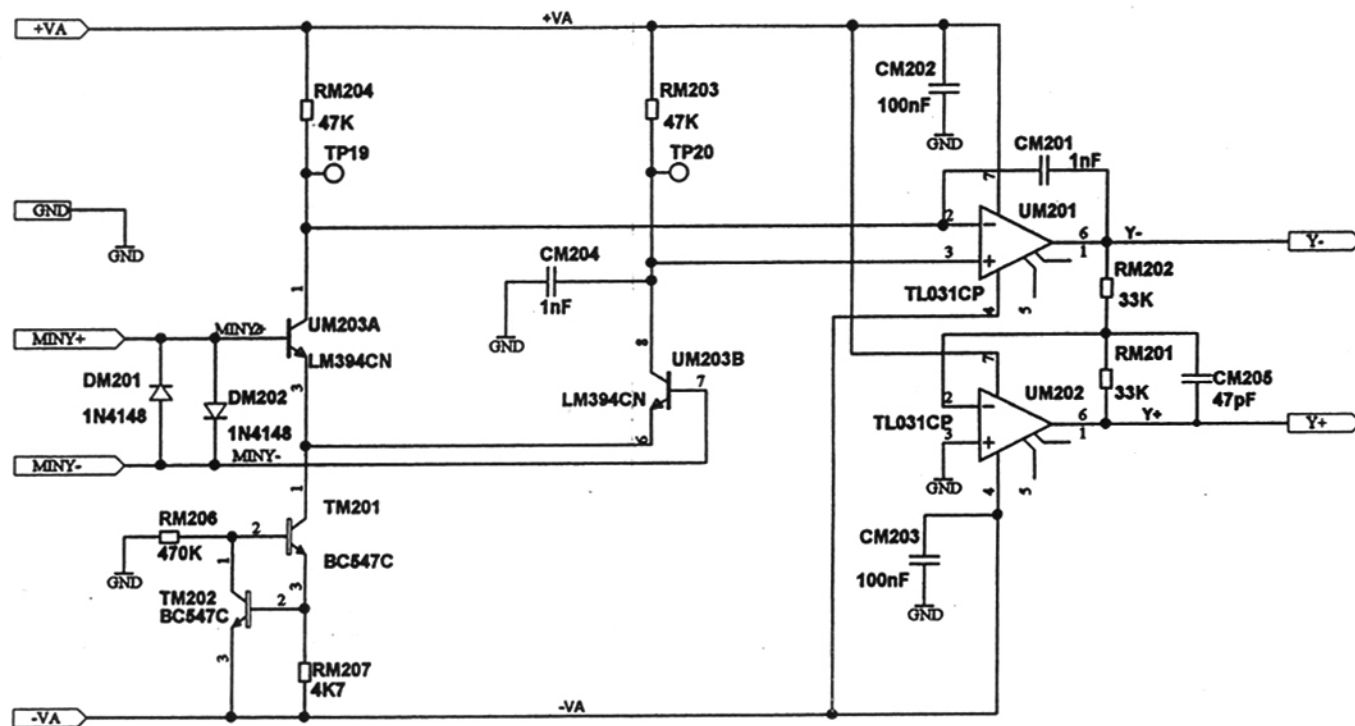
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Orcad A		Revision	
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Date:		27-Mar-1998	
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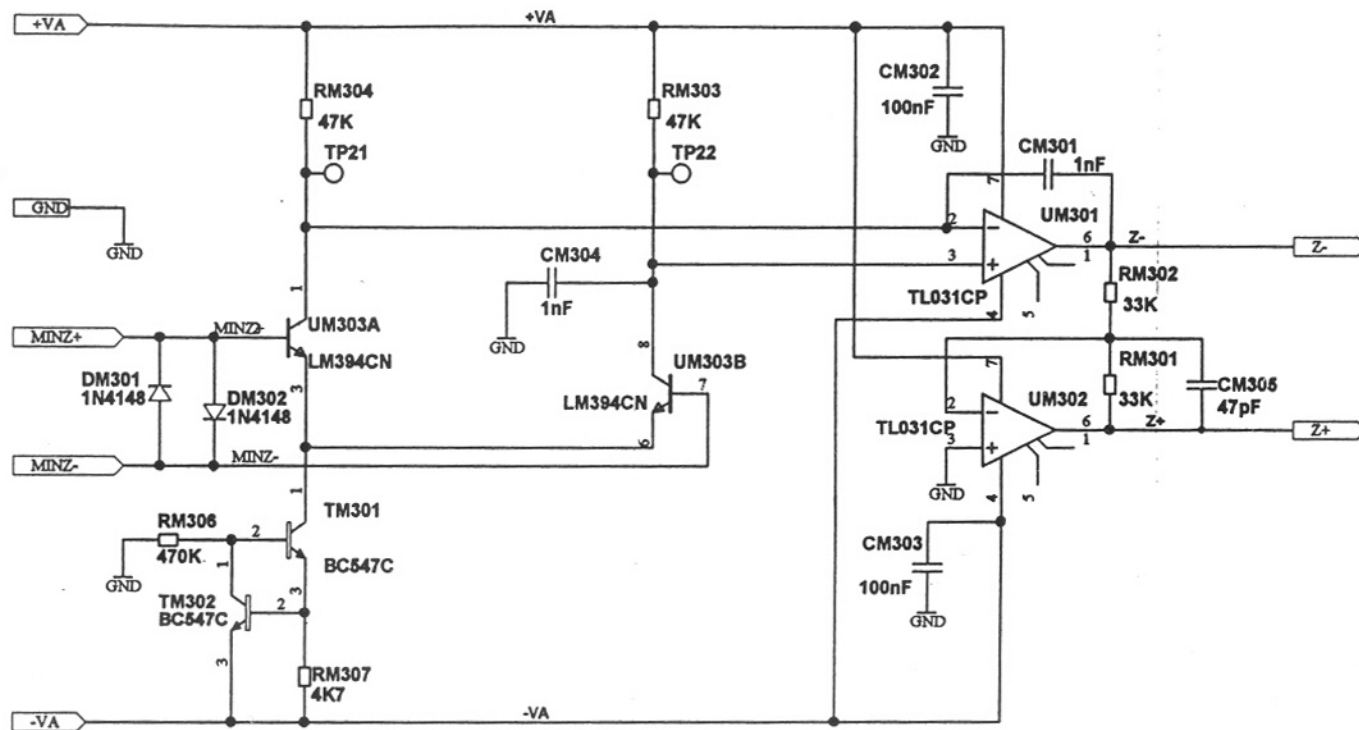




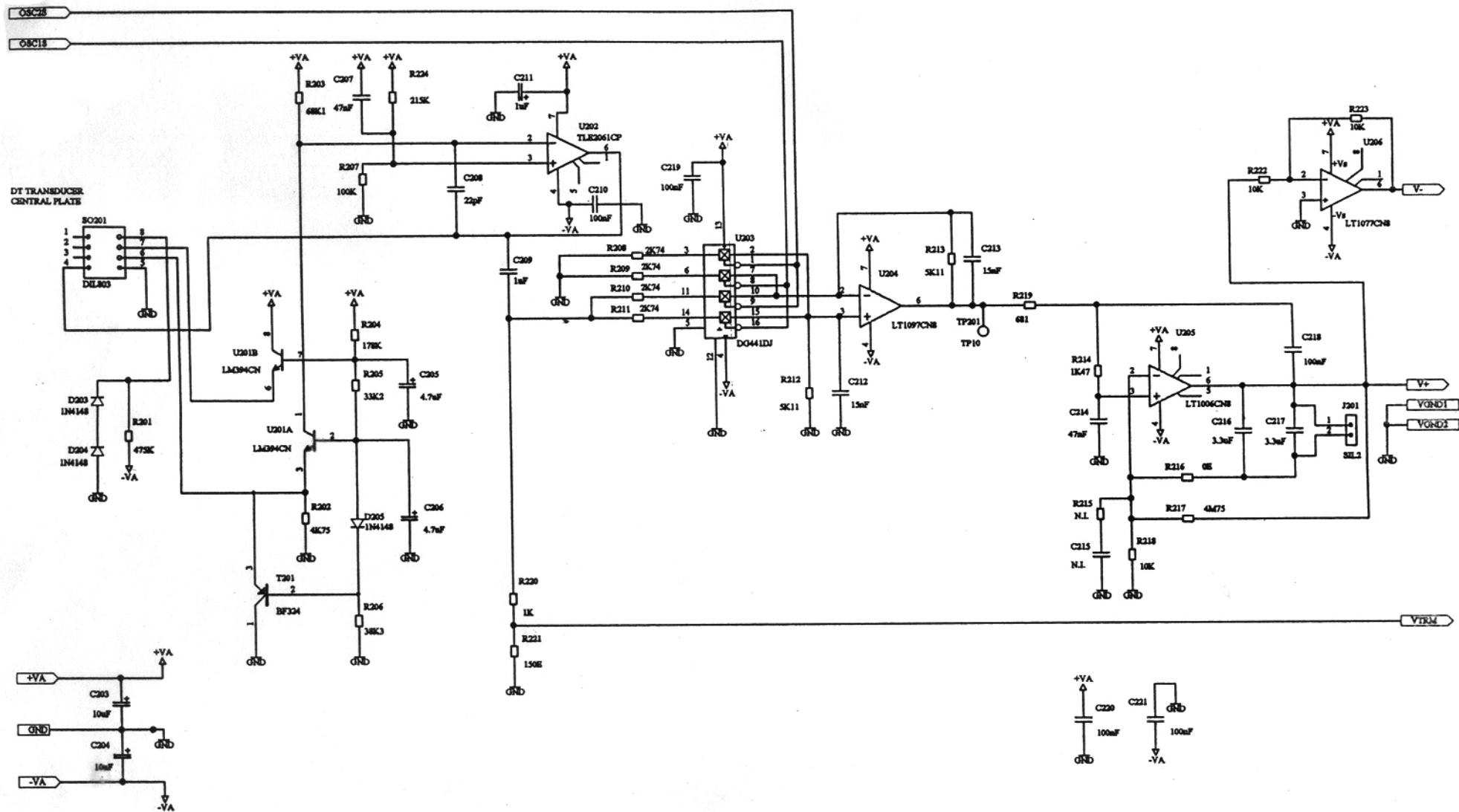
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STS2MB3 X - Mixer		Dattlikonstrasse 5
		CH-8422 Pfungen
Size	Number	Revision
Orcad A		3)
Date:	27-Mar-1998	Sheet 7 of 9
File:	C:\ADV8CH\STS2\STS2MB3\STS2MB3.DSN	



Title STS2MB3 Y - Mixer			G. Streckelsen AG Dorflikenstrasse 5 CH-8422 Pfungen		
Size Orcad A	Number		Revision 3)		
Date:	27-Mar-1998		Sheet 8 of 9		
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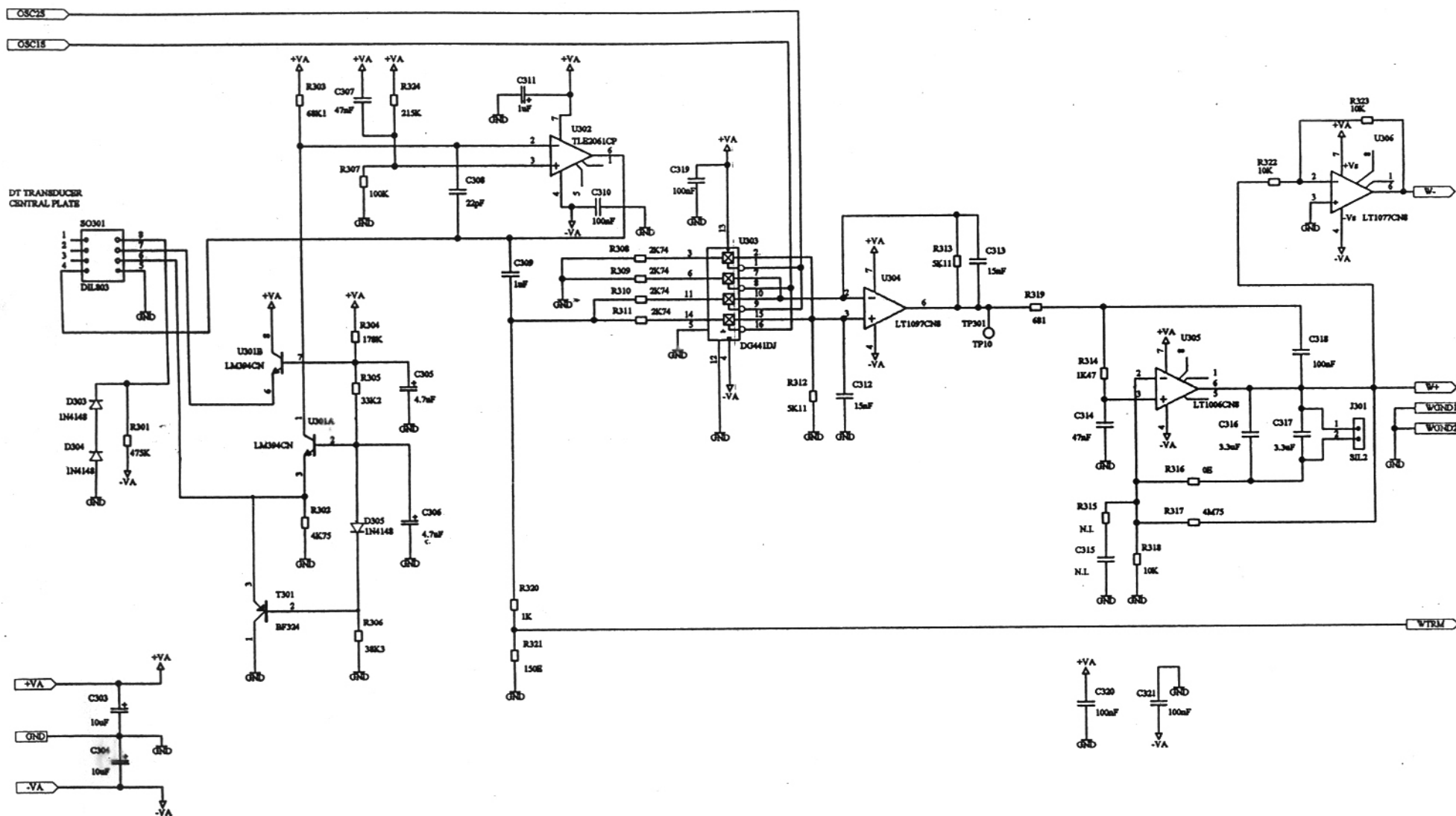


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STS2MB3 Z - Mixer		Dachstrasse 5	
Size		Revision	
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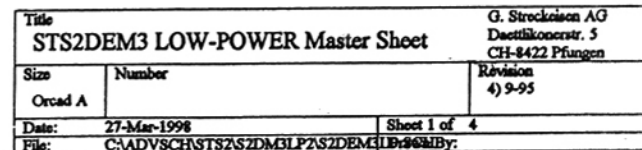


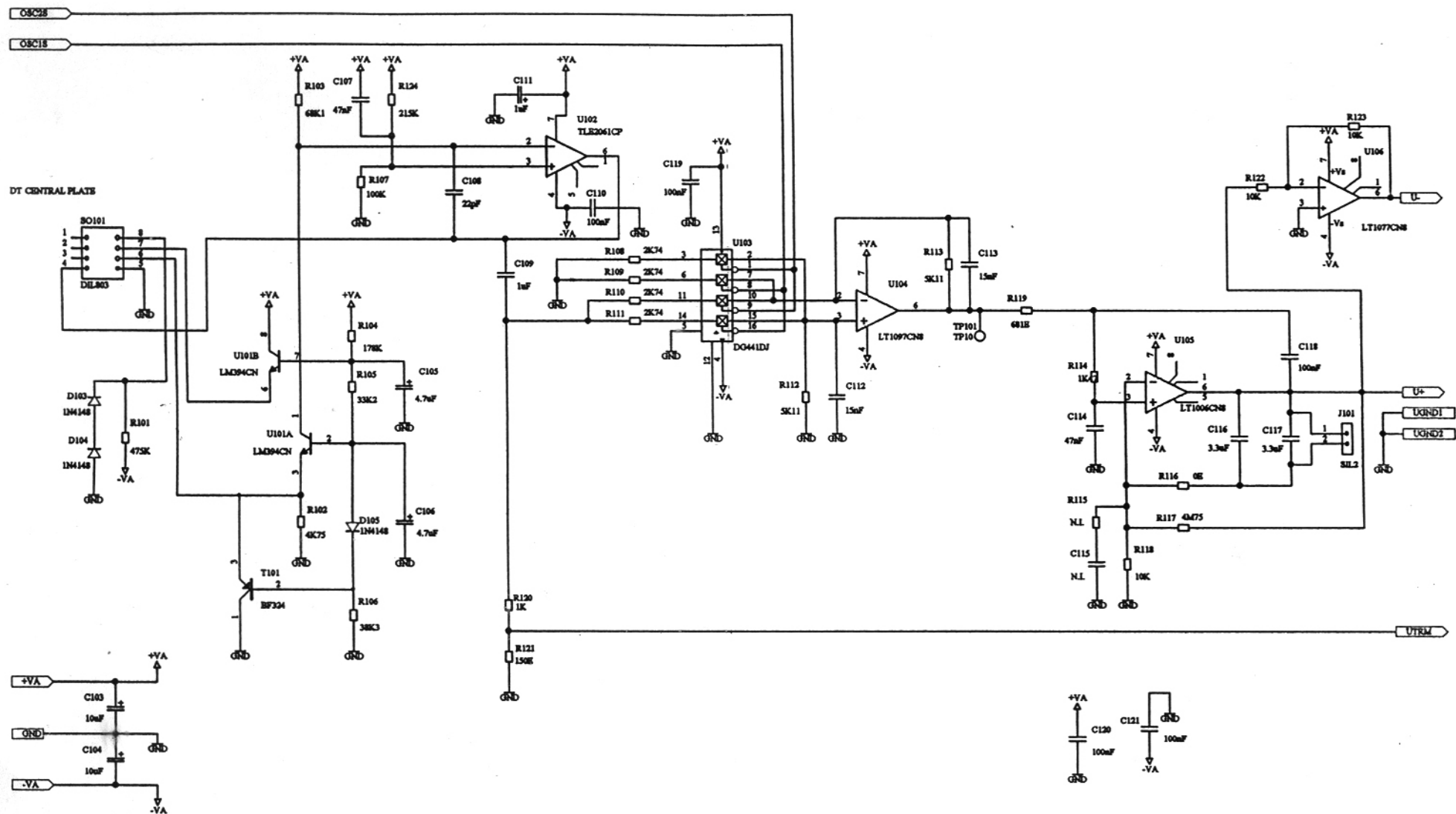
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Sim	Number	Revision	
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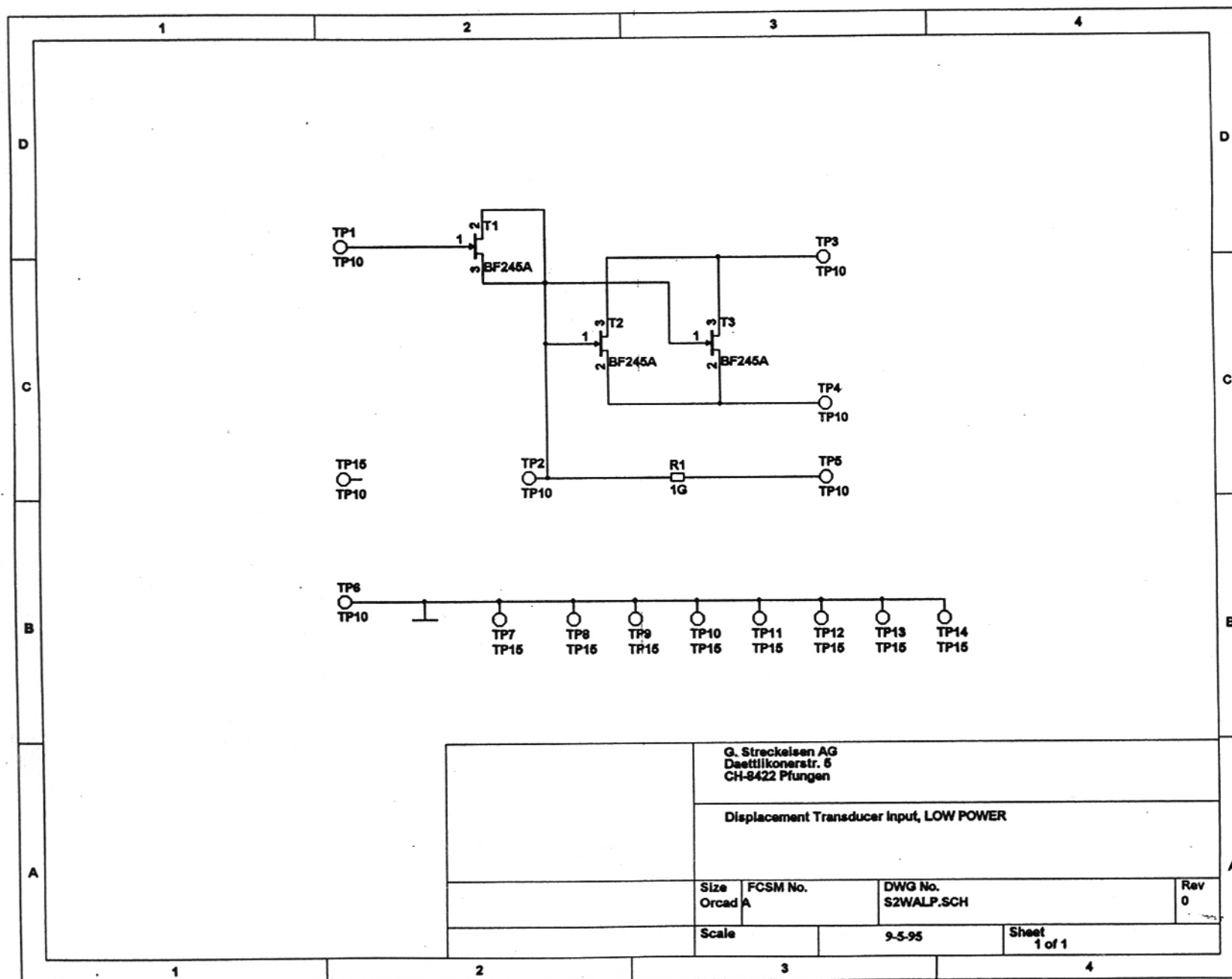


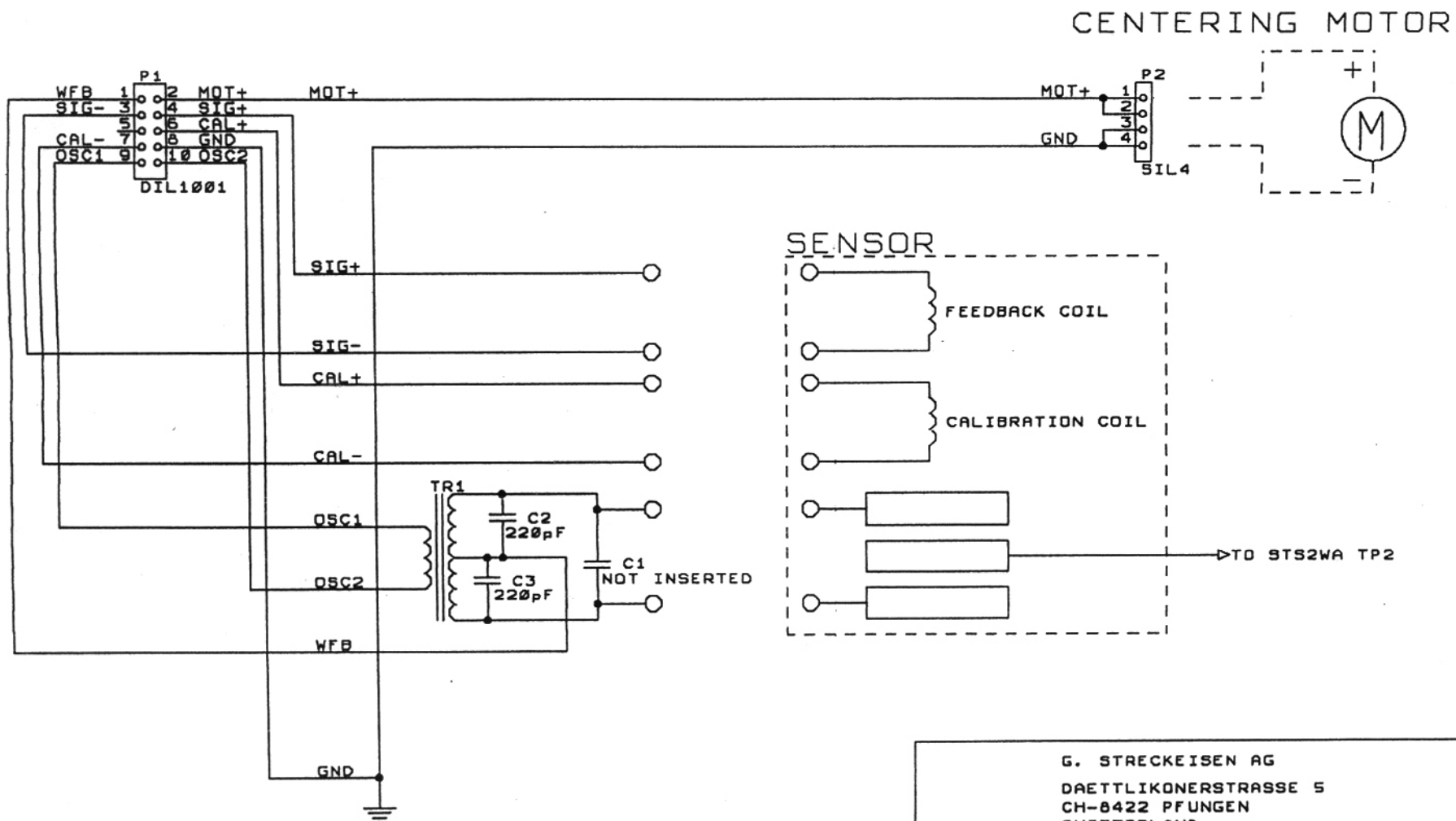


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Rev		CS-9-92 File	
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G. STRECKEISEN AG  
DAETTLIKONERSTRASSE 5  
CH-8422 PFUNGEN  
SWITZERLAND

Title

SENSORPRINT

Size Document Number

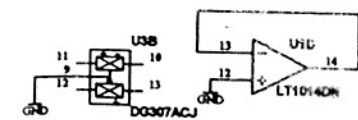
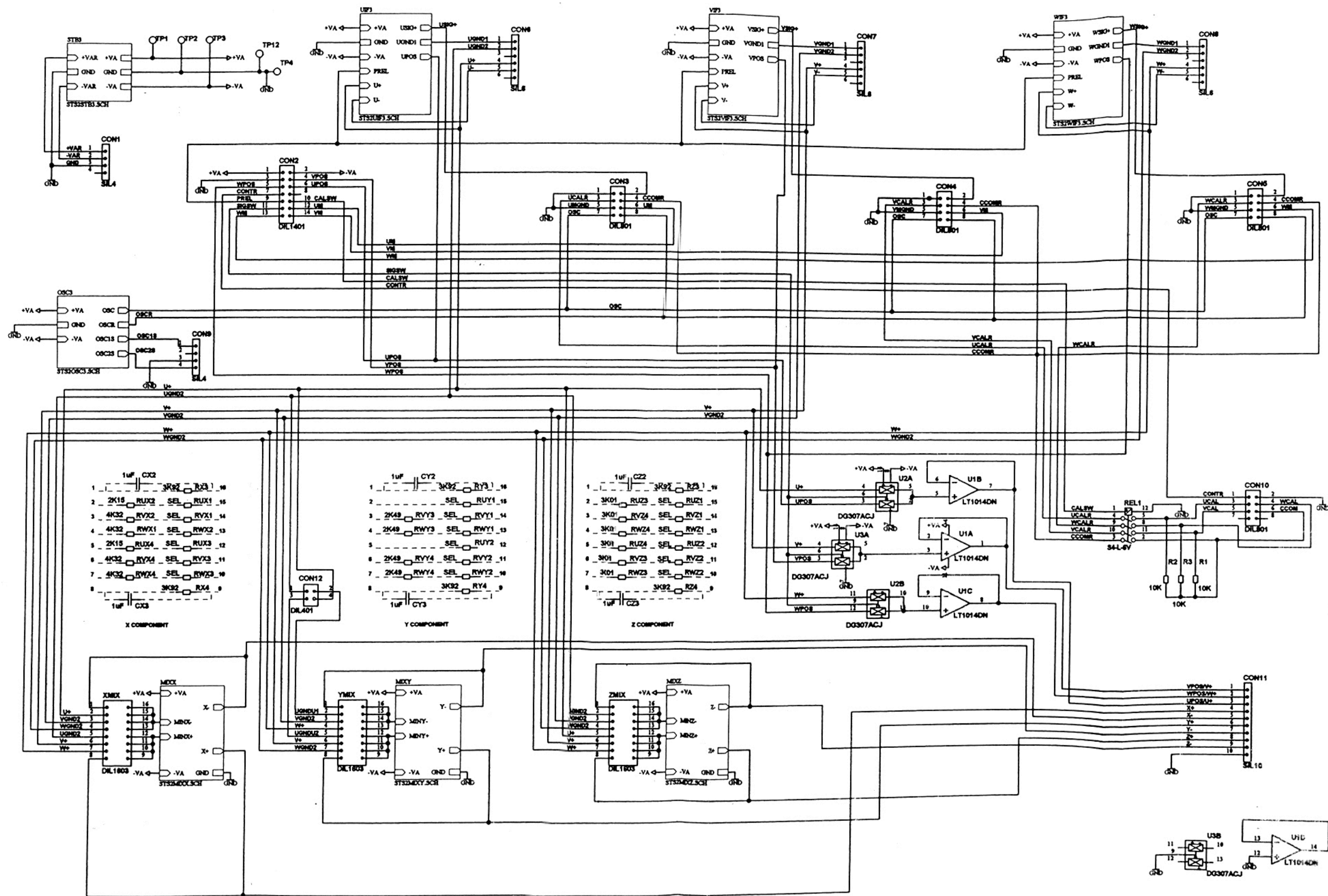
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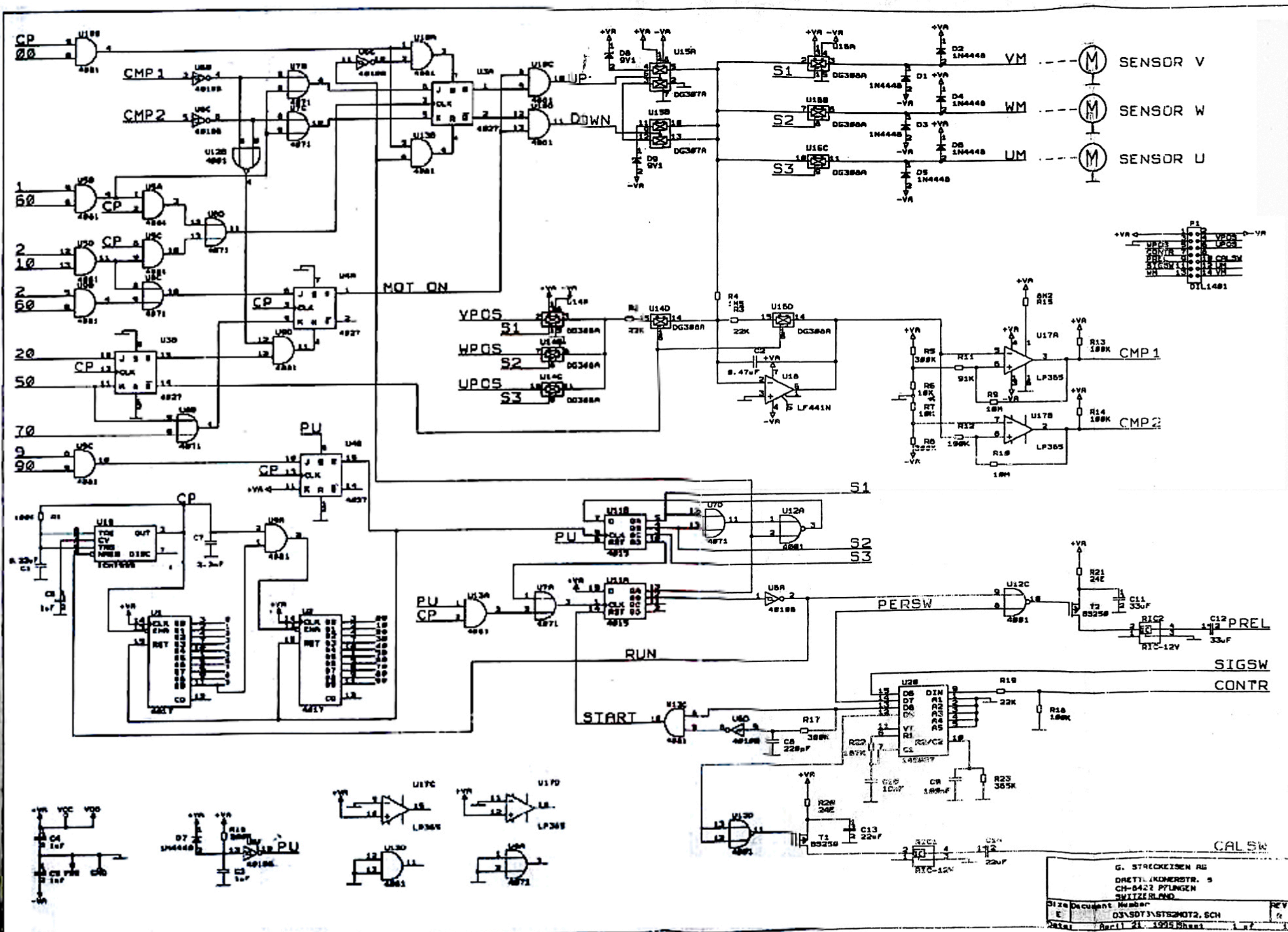
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G. STRECKEISEN AG  
DRETL. KONSTR. S  
CH-8422 PYLNGEN  
SWITZERLAND

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Date: April 21, 1995 Sheet		1 of 1