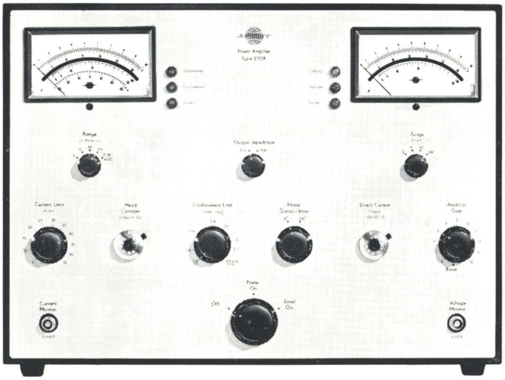
2708

Instructions and Applications



Power Amplifier
Type 2708

A 1200 VA, transistorized, low distortion, compact vibration exciter driver, with selectable output impedances, interlocked controls and giving full protection from overtesting and system component failures. Operating range extends down to DC, and a static offset current in the exciter coil can be provided.

BRÜEL & KJÆR

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POWER AMPLIFIER TYPE 2708

February 1972

CONTENTS

1. INTRODUCTION

The 2708 is a Power Amplifier designed to drive highly reactive loads, such as vibration exciters, and particularly the Exciter Body Type 4802 and the associated heads. The amplifier has a useable frequency range from DC to 100 kHz and full output (1200 VA) over the range 5 Hz – 5 kHz.

Current or voltage mode negative feedback can be used, giving a highly linear output and a selectable output impedance. The amplifier can be operated as a low output impedance voltage generator or as a high output impedance current generator.

The output is directly coupled to provide static table centring and to exclude bulky output transformers.

As well as power amplification, the 2708 provides monitoring, continuous metering and protective functions. The RMS values of the moving coil voltage and current are continuously shown on front panel meters, and the associated waveforms can be monitored using the oscilloscope connectors provided.

Fast acting protective circuitry gates off the signal input to the amplifier and triggers a warning light for the following reasons:

Temperature:	excessive transistor junction temperature
Displacement:	excessive shaker table displacement
Current:	excessive current in the shaker moving coil
Exciter:	loss of cooling in the exciter loss of exciter field disconnection of exciter head separation of exciter head from exciter body loss of one phase from the mains
Transistor:	failure of one of the transistor protection fuses

Any clipping of the output voltage, caused by too high a driving voltage, or by high output current peaks, is also indicated by a warning light.

2. CONTROLS

2.1. FRONT PANEL

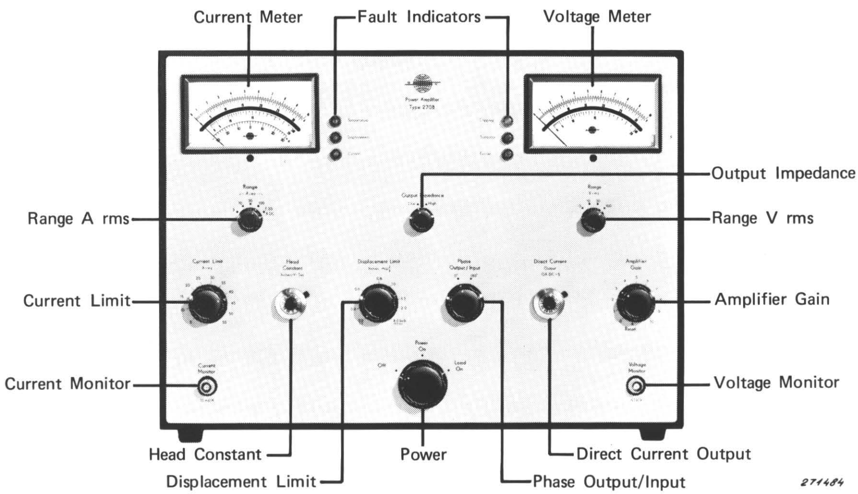


Fig. 2.1. Front Panel of 2708

RANGE A RMS

A five position switch located under the current meter. The first four positions select full scale indications of 3, 10, 30, and 100 A RMS. The fifth selects a centre-zero scale with ±30 A DC full deflection and is used when centring the moving element or when applying a static force to the test specimen.

CURRENT MONITOR

A BNC socket provides an oscilloscope display of current waveform, including the DC component. The output is short-circuit protected by a 100 Ω internal series resistor.

Output impedance is 100 Ω.
Sensitivity is 10 mV/A. A phase inversion occurs at this socket.

CURRENT LIMIT	The setting controls the RMS output current level, including the DC component, above which the CURRENT trigger circuit will fire and remove the input signal. The limit can be set anywhere in the range 5 to 55 A RMS. The current is squared and averaged with a time constant of 60 sec, matching the minimum thermal time constant of moving coils typically used with the 2708. This time constant can be reduced to 2.5 sec. as in section 3.3. The maximum current for each B & K Exciter Head is shown on a label by the connector on each head.
HEAD CONSTANT	This provides a lockable setting from 0 to 10 inches/V-sec. on a ten-turn control. The proper setting depends on the shaker head being used, and is stamped on a label by the connector on each B & K Exciter Head. This must be properly set to ensure accurate settings of the DISPLACEMENT LIMIT.
DISPLACEMENT LIMIT	The setting controls the displacement level above which the DISPLACEMENT trigger circuit fires and removes the input signal. The limit can be set anywhere between 0.2 and 4.0 inches (5.0 and 100.0 mm) peak to peak displacement.
OUTPUT IMPEDANCE	A two position switch to select the feedback mode of the amplifier. The "Low" impedance position selects voltage feedback and the "High" impedance position selects current feedback.
POWER	A three position, high current switch which first connects mains power to the amplifier and exciter field and then connects the amplifier to the exciter moving coil.

In the "Off" position power and shaker load are disconnected from the amplifier. In the "On" position the AC power (single- and three-phase) supplies are applied to the Amplifier and the Exciter Body. The single phase supply is taken to the control winding of the three phase contactor. In the "Load On" position, AC power remains applied, and the amplifier is connected to the Exciter Head moving coil. When switching from "Off" to "On" to "Load On" the POWER switch must be allowed to remain at the "On" position for a short time ($>$2 sec.).

PHASE OUTPUT/INPUT

A two position switch. Position "0^{o}" selects the output of the amplifier to be in phase with the input. Position "180^{o}" selects a phase reversal through the amplifier such that the input drive and the amplified output signal are 180^{o} out of phase.

DIRECT CURRENT

A lockable ten-turn potentiometer provides an internal DC signal for centring the exciter so that maximum displacement can be obtained with AC signals even though the test specimen may be heavy and thus statically deflect the flexures. This control could also be used to apply a static force for cyclic fatigue or other studies.
Zero Amperes DC corresponds approximately to a dial setting of 5.0.
The PHASE switch reverses the phase of the signal at the input of the amplifier and does not reverse the direction of the DC offset current.

AMPLIFIER GAIN

This is a single turn potentiometer with an approximately logarithmic characteristic. Before turning the POWER switch to the "On" position, the AMPLIFIER GAIN should be put to "Reset". Otherwise an internal electronic interlock will cause the input gate to block the input signal and turn on the

CURRENT lamp, preventing possible amplifier and/or shaker overdrive.
If the interlock is triggered, the AMPLIFIER GAIN must be turned fully anticlockwise to the "Reset" position (switch clicks) to reset the input gates. Similarly when any of the protection circuits cause the input gates to block the input to the amplifier, the amplifier must be "Reset".
Note that the centre zero current scale cannot be used when the AMPLIFIER GAIN is in position "Reset". Centring current should be measured at zero gain.

RANGE V RMS	A four position switch located under the voltmeter. The switch selects full scale indications 3, 10, 30, and 100 Volts.
VOLTAGE MONITOR	A BNC socket provides an oscilloscope display of voltage waveform, including the DC component. The output is short circuit protected and has an output impedance of approx. 500 Ω. The conversion factor is 0.1 V/V.

Six front panel indicators have also been provided. Five red lamps to indicate input cut-off conditions and a yellow lamp indication of an abnormal but not dangerous condition (thus the operator can continue or switch off at his own discretion).

TEMPERATURE	A red lamp indicating that the protection circuitry has been triggered because of excessive transistor junction temperature.
DISPLACEMENT	A red lamp which indicates the firing of the trigger circuit due to excessive shaker table displacement.
CURRENT	A red lamp which indicates the firing of the trigger circuit due to excessive moving coil current over the selected averaging time (see section 3.3).
EXCITER	A red lamp which indicates that blocking of

the input gates has occurred because of some trouble in the Exciter Body. This circuitry can also be triggered by an external trip (see section 3.6).
If the rear panel EXCITER INTERLOCK switch is in the "Bypass" position, exciter protection is removed and the EXCITER lamp will not light.

TRANSISTOR

A red lamp which indicates that the protection circuitry has been triggered by the blowing of a transistor protection fuse. Normal operation cannot be resumed again until the checks and repairs detailed in section 3.2.6 have been carried out.

CLIPPING

An amber lamp which indicates excessive voltage output with voltage clipping in the output transistor stage or current clipping in the peak current limiter. The amplifier will continue to operate. However, input level must be reduced to resume operation with a good waveform.

2.2. REAR PANEL

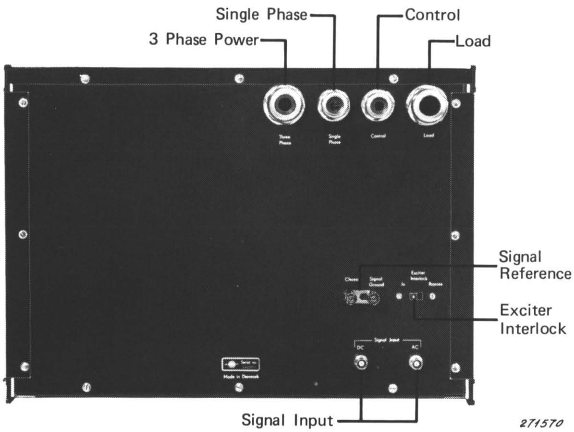


Fig.2.2. Rear Panel of 2708

SIGNAL INPUT DC	A BNC connector, insulated from the amplifier chassis, is used to give a directly coupled input. Input impedance is greater than 10 kΩ. Full output is produced by a signal of 2 Volts RMS.
SIGNAL INPUT AC	A BNC connector, insulated from the amplifier chassis, is used to give a capacitive coupled input. The low frequency cut-off is at 10 – 15 Hz, which gives an inherent displacement limiting.
SIGNAL REFERENCE	Two screw terminals linked by a removable shorting link. One terminal is connected to the "Chassis" and the other to the "Signal Ground".
EXCITER INTERLOCK	The Exciter protection is disconnected by this two position slide switch so that the 2708 can be used with non-B & K shakers or under reduced field conditions. The exciter is fully protected when the switch is in the position "In".
THREE PHASE	A cable entry carrying the single-phase AC power to the mains transformers in the amplifier.
SINGLE PHASE	A cable entry carrying the three-phase AC power to the mains transformer in the amplifier. (See power connection instruction section 3.1.3).
CONTROL	A cable entry carrying the EXCITER protection trip signal from the B & K Exciter Body Type 4802.
LOAD	A cable entry carrying the high power drive signal from the amplifier to the moving coil of the Exciter Head used.

3. OPERATION

3.1. PRELIMINARY

3.1.1. Mounting

The Power Amplifier Type 2708 can be used free standing (cabinet Type A), or rack mounted (19" standard racks, cabinet Type C). When rack mounted, care must be taken that the ventilation air stream (Induction – left side, front; Exhaust – right side), is not blocked.

The EXCITER protection circuitry relies on the Head/Body connection completing an earth loop back to the amplifier. If the Head is removed from the Body this loop is broken and the EXCITER trip operates. To preserve the integrity of this protective function care must be taken in use that this is the only earth path from the Head back to the Amplifier. Isolated studs, and mica washers should be used under all accelerometers to prevent the screen of the accelerometer cable providing an alternative path.

Single Phase Voltage	Connections on TERMINAL BOARD 1	
	Red wire from Fuse to Terminal	Link between Terminals
100	5	5 and 9 6 and 10
120	4	4 and 8 6 and 10
127	3	3 and 7 6 and 10
200	5	6 and 9
220	4	6 and 9
227	5	6 and 7
240	4	6 and 8
247	4	6 and 7
257	3	6 and 7

Table 3.1. Connection of terminal board I for various mains voltages

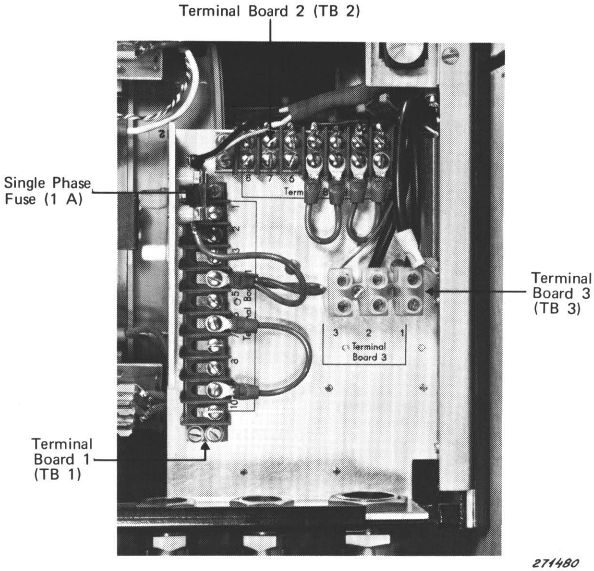
Three Phase Voltage (Line to Line)		Connect Input from Three Phase Mains to Terminals			Link these Terminal Pairs					
		A	B	C	A	B	B	C	C	A
Delta	198	3	3	3	4	3	4	3	4	3
	207	3	3	3	5	3	5	3	5	3
	220	2	2	2	4	2	4	2	4	2
	230	2	2	2	5	2	5	2	5	2
	240	2	2	2	6	2	6	2	6	2
					to		to		to	
Star	343	3	3	3	4	4	4	4	4	4
	360	3	3	3	5	5	5	5	5	5
	380	2	2	2	4	4	4	4	4	4
	397	2	2	2	5	5	5	5	5	5
	415	2	2	2	6	6	6	6	6	6
	442	1	1	1	4	4	4	4	4	4
	459	1	1	1	5	5	5	5	5	5
	477	1	1	1	6	6	6	6	6	6

Table 3.2. Connection of Three Phase transformers

3.1.2. Initial Adjustments

The Amplifier is supplied with the single phase mains transformer connected for 220 V RMS 50 – 60 Hz operation. The three phase power transformer is connected for 380 V RMS line to line 50 – 60 Hz operation. If the Amplifier is to be used on mains supplies other than these the transformer connections must be changed in accordance with Tables 3.1 and 3.2. The photographs (Fig.3.1(a) and (b)) show the transformer connector blocks as supplied. The connector block for the three phase transformer in the Exciter Body Type 4802 can also be connected according to Table 3.2.

The time constant of the CURRENT trip circuitry is set for 60 seconds.



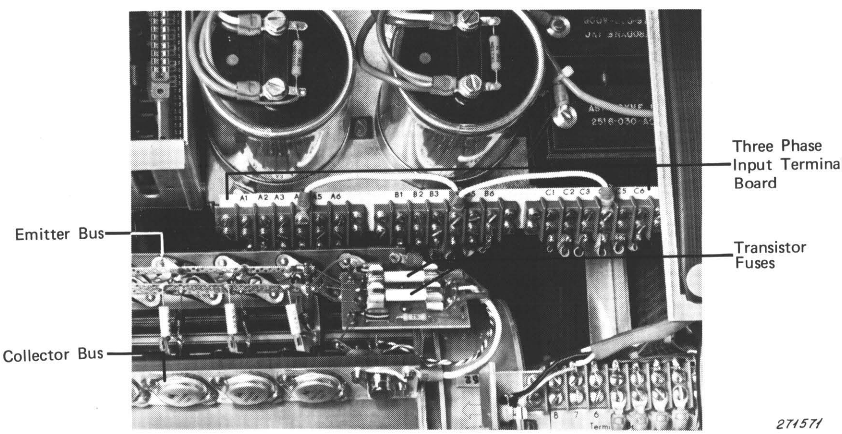


Fig.3.1. (a) Terminal Boards
(b) Three Phase Transformer Connection Block

3.1.3. System Interconnection

The system is connected as shown in Fig.3.2 and details are given in the wiring diagram Fig.3.3 and the photographs Fig.3.1(a) and 3.1(b). The contactor box is not supplied by B & K and must be made up to suit the requirements of each installation. The contactor box must be capable of handling a minimum of 7 kVA and have a coil voltage the same as the line voltage. Connection is as shown in Fig.3.3. One type which is suitable is the LK NES Type MV2 272 C4031, which complies with Danish safety standards. Local safety regulations should be consulted for each application.

Connections to the Exciter Body 4802 are shown in Fig.3.4. For use with shakers other than Type 4802, the manufacturer's wiring requirements must be followed. When so used the EXCITER INTERLOCK switch must be in the "Bypass" position.

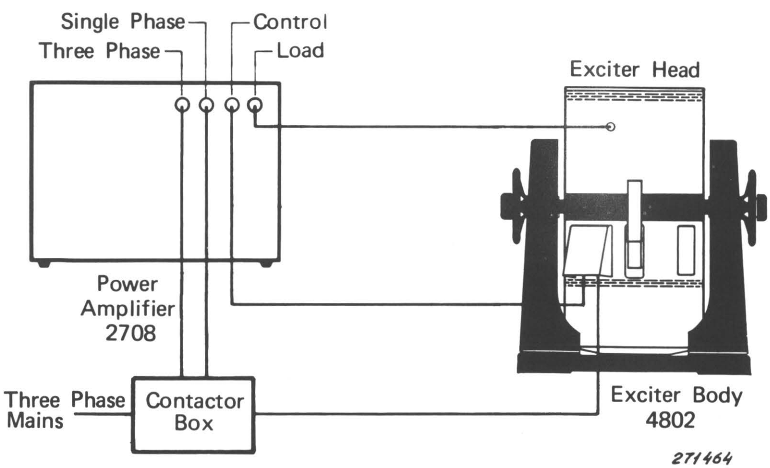


Fig.3.2. System Interconnection

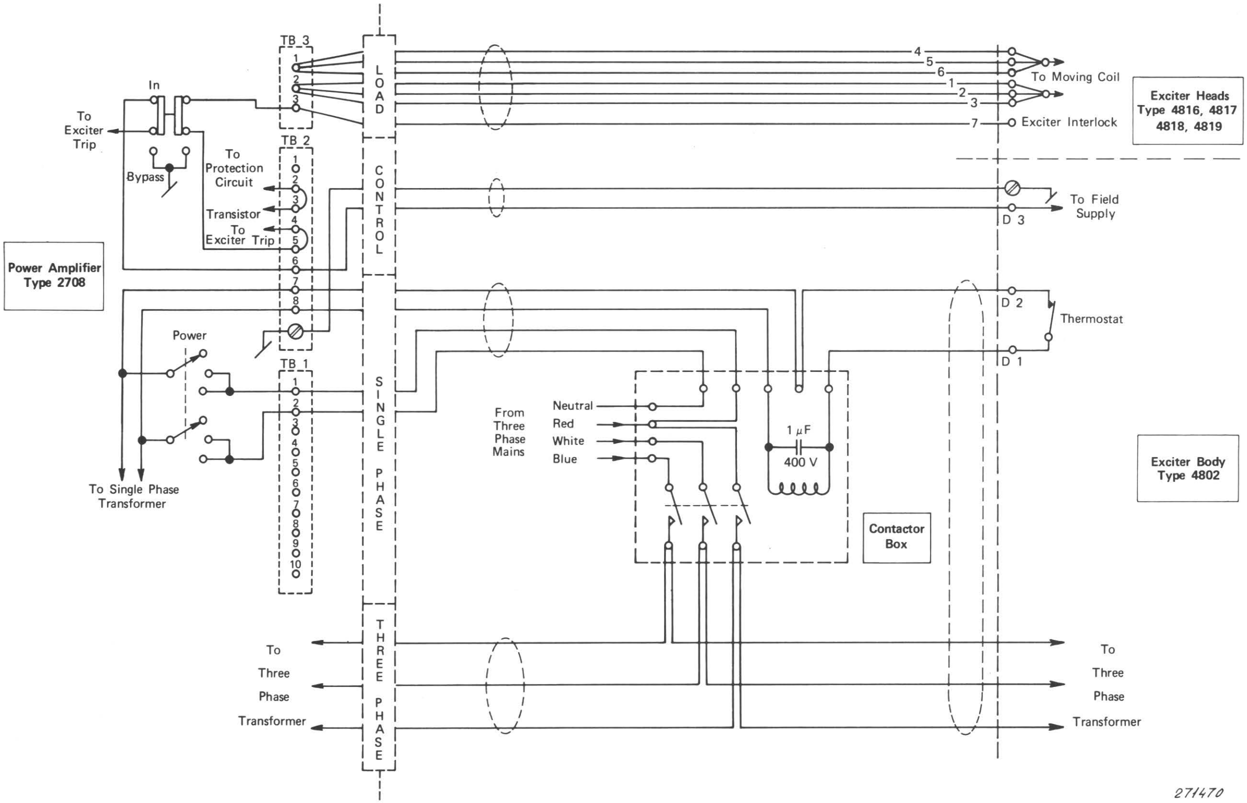


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Fig.3.3. Wiring

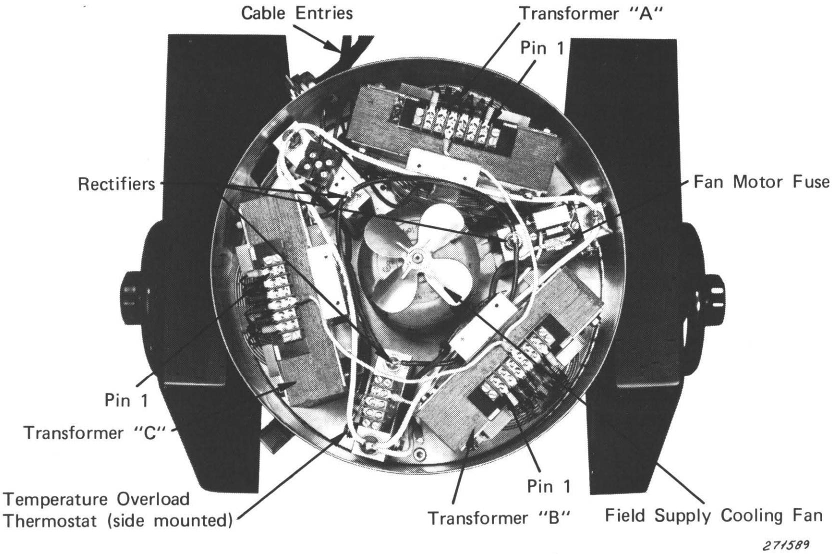

Fig.3.4. Bottom view of Exciter Body 4802 (Cover plate removed)

3.2. NORMAL OPERATION

3.2.1. Set-up

After connecting the complete system, and before applying power from the mains, make the following preset adjustments.

Set

POWER	"Off"
AMPLIFIER GAIN	"Reset"
CURRENT LIMIT	The setting given on the plate fixed to each B & K Exciter Head. (Note 1).
HEAD CONSTANT	The setting given on the plate fixed to each B & K Exciter Head. This control should then be locked. (Note 2).

DISPLACEMENT LIMIT	Twice the expected test maximum, but not greater than the Exciter's displacement capability. (Note 3).
OUTPUT IMPEDANCE	"High" or "Low" as required. (Note 4).
PHASE	0^o or 180^o as required.
DIRECT CURRENT OUTPUT	5.0 or as previously determined. (Note 5).
EXCITER INTERLOCK (rear panel)	"In" for the B & K Type 4802 or 4801 system and "Bypass" for any other manufacturer's shaker. The EXCITER INTERLOCK should also be in "Bypass" when the 4802 is used with reduced field supply (see section 3.8).
SIGNAL REFERENCE	Connect the link as required. Normally this will be broken and the "Chassis" taken directly to a good earth.

Notes:

1. The CURRENT LIMIT circuitry operates with a 60 second time constant. This can be reduced to 2.5 seconds by removing an internal shorting link from the printed circuit card ZL 0033 (Section 3.3).

   For non-B & K shakers the allowable moving coil RMS current must be ascertained from the relevant manufacturer and the CURRENT LIMIT control set accordingly, so that full protection is available.

2. The DISPLACEMENT protection circuitry of the 2708 uses the back emf across the coil as the analogue of velocity, from which integration provides an analogue of displacement.

   This emf is dependent on the physical constants of the shaker used (field strength and coil length) and thus is different for the different exciter head types used. The HEAD CONSTANT control is the calibration control for the displacement protection circuitry.

When used with non-B & K shakers the simplest way to calibrate the displacement circuitry is to set the HEAD CONSTANT at 0 and drive the shaker at a known displacement. Set the DISPLACEMENT LIMIT control for this displacement and slowly increase the HEAD CONSTANT control until the displacement trip circuitry operates. Fine adjust the reading obtained by repeating the operation at other displacements and frequencies in the range 5 to 50 Hz, where correct calibration of the circuitry is important.

Under blocked table operation (or nearly blocked table, as when driving heavy loads at low frequencies) the portion of the back emf due to the IR drop in the coil may cause some inaccuracies in the setting of the HEAD CONSTANT. This results in a trip of the DISPLACEMENT circuitry before the preset DISPLACEMENT LIMIT is reached.

3. The DISPLACEMENT LIMIT control can be used in either of two ways. It can be set to slightly greater that the test specification maximum, and thus act as a specimen overtest protection OR it can be set to the maximum displacement capability of the Exciter Head in use and thus act as shaker protection. Accuracy of the circuit is not better than ± 10%.

4. Operation in the "High" impedance mode keeps the generated force unchanged when changes occur in the test object, and therefore is particularly useful whenever the test is force related. As examples, the single exciter fatigue testing of sample bars usually requires constant force, although the bar is deteriorating during the test. Also, when using more than one exciter to determine the resonant mode of a structure, constant forces of known phase and magnitude, which are insensitive to changes in the structure, are required.

   The "Low" impedance mode keeps the voltage applied to the exciter independent of test object changes. The "Low" impedance mode provides the best acceleration waveform and is therefore preferable for most single exciter applications. "Low" impedance mode operation is useful for multiple exciters at low frequencies, if the same motion is desired from each exciter, such as the use of one exciter to push and another to pull on a model structure.

5. The direct current in the moving coil can be monitored on the centre zero position of the current meter. The position 5.0 of the DIRECT OUTPUT CURRENT control corresponds to 0 Amperes (approx.).

   After setting, this control should be locked.

3.2.2. Switch-on

Set

POWER	"On" Wait a few seconds. The POWER switch controls the single phase mains which, in position "On", is applied to the three phase contactor. In the first few seconds after switching on, the exciter body field builds up to its nominal value. During this build-up the coil should not be connected to the amplifier or else a severe mechanical transient will be experienced. The amplifier and exciter body cooling fans are energised and the scale lamps of the 2708 are lit.
AMPLIFIER GAIN	To fully anti-clockwise. If the amplifier is connected to an oscillator ensure that the oscillator output is zeroed.
POWER	"Load On" The moving coil of the Exciter is now connected to the output of the amplifier. The meter indications of AC quantities will still be zero.
RANGE A RMS	To the centre zero range ± 30 A DC.

AMPLIFIER GAIN	Turn up slowly to the required level (normally fully clockwise for servo controlled tests).
DIRECT CURRENT OUTPUT	Adjust for zero indication on the current meter or to centre the table in its vertical travel.
RANGE A RMS	To the relevant range for the test.

To commence testing increase the output of the oscillator until the table vibration levels are as required. For automatic sweep testing full instructions can be obtained from the relevant instruction manuals.

3.2.3. Warning lights

If the DISPLACEMENT LIMIT is set at less than twice the maximum test level, check that the displacement circuitry does not trip at low frequencies. Adjust the DISPLACEMENT LIMIT as necessary.

In the event of a trip the front panel red warning lamp will light and the input drive signal will be removed by a FET gate. To restore the system to full operation once more, determine the cause of the trip and remedy the situation. Turn down the drive output from the oscillator in use. Return the AMPLIFIER GAIN control to the "Reset" position (switch clicks) and back to its full gain position. Restore the drive from the oscillator until the required levels are achieved.

However, if the trip is due to a blown transistor protection fuse (TRANSISTOR lamp lights), then the test must be discontinued and the offending fuse replaced before recommencing. The procedure for this and the subsequent method of checking the power transistors is given in section 3.2.6.

Should the CLIPPING lamp light, the output signal level must be reduced until the light is extinguished. Full output current is available from 5 Hz and the output voltage decreases in inverse proportion to frequency between 5 kHz and 100 kHz.

3.2.4. Stand-by and Test Shut Down

The amplifier can be left in a stand-by condition during the course of a test by switching the AMPLIFIER GAIN control to "Reset" and the POWER switch to "Power On". Note that it is not possible to remove the Head of a B & K Exciter when at stand-by because of the high standing magnetic field generated by the field windings.

At the end of a test the Amplifier is switched off by turning the POWER switch to "Power Off" with the AMPLIFIER GAIN in the "Reset" position.

3.2.5. Fault Indicator Triggering

In the event of one of the protection circuits triggering and shutting down the test the list of Probable Faults in Table 3.3 will be of some assistance in establishing the cause of the trip.

Fault Indicator	Mains supply on and 3 phase contactor activated	Probable Fault
DISPLACEMENT	Yes	Preset Limit exceeded
	Yes	Incorrectly set HEAD CONSTANT
CURRENT	Yes	Preset Limit exceeded
	Yes	Attempted switch on without setting AMPLIFIER GAIN to "Reset"
	Yes	Moving OUTPUT IMPEDANCE switch without setting AMPLIFIER GAIN to "Reset"
TEMPERATURE	No	Power transistor junction temperature excessive (Over running at low frequencies)
	No	Power transistor heat sink thermostat closed (Loss of heat sink cooling fan, blocked airstream, etc.)
TRANSISTOR	No	Power transistor protection fuse blown
	No	Damaged power transistor (very rarely)
EXCITER	Yes	Exciter fuse failure (consequently loss of field and cooling)
	Yes	Attempted operation of Head separate from Body
	Yes	Loss of a Phase
	Yes	Opening of an external pair of contacts across TB2 Terminals 4 and 5
	No	Exciter Body thermostat activated
	No	Closing of external pair of contacts shorting TB2 Terminal 1 to Signal Ground

Table 3.3. Fault detection

3.2.6. TRANSISTOR failure and rectification

The 56 NPN power transistors (2 N 4348) are mounted in banks of seven on each of the eight radiator fins of the heat sink. The cooling air stream is directed down the centre of this structure (Fig.3.4). To gain access to the heat sink remove the top and bottom panels.

The fuses protecting each of two banks of transistors are mounted close together (Fig.3.1(a)). These fuses can be checked in situ using a good ohm-meter. The exact resistance depends on the polarity of the ohm-meter, the integrity of the fuse and of the collector-emitter junctions of the power transistors in that bank. To check the fuses measure directly across each fuse in turn. A good fuse will indicate a short-circuit and a blown fuse shows as a high resistance ($>100\ \Omega$).

The fuses used are very fast acting and designed specially for use with semi-conductors. Any replacement used must be of a similar specification and such that for a current of 4 times their rated value of 10 A (i.e. for a current of 40 A) they will blow within 40 msec and for a x 10 overload within 5 msec.

The power transistors should also be checked for damage, the most common mode of failure being a short circuit collector-emitter. The simple resistance check is made by placing one terminal of the ohm-meter on the case (collector) of one transistor of a bank, holding the other terminal on the emitter bus. If all of the transistors in that bank are undamaged the reading will be high ($>100\ \Omega$). If one of the transistors is shorted between collector and emitter the reading will be 0.4 Ω. Now measure the resistance between the collector bus (Fig.3.1(b)) and each of the seven emitters (at the resistor soldering point as indicated in Fig.3.5). Damaged transistors will give an indication of 0 Ω while an undamaged transistor gives 0.8 Ω.

If a 2 N 4348 transistor is not immediately available, it is possible to operate the amplifier at slightly reduced specifications (approx. 96% current rating). The damaged transistor must be removed and the transistor fuse replaced.

The transistors are mounted in plug-in sockets and can be removed as directed in the Service Instructions for 2708. Always ensure that the size of the base and emitter pins of the replacement transistors used is not greater than 1 mm ± 0.05 or the transistor holder will be damaged.

When replacing transistors a good thermal bond, using Heat Sink Cement, must be made with the surrounding heat sink.

After replacing any damaged components the test can be recommenced as previously detailed.

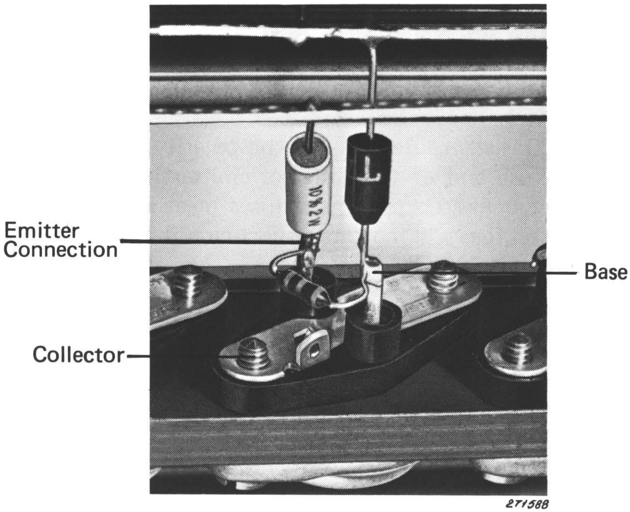

Fig.3.5. Bottom view of a Power Transistor

3.3. CURRENT LIMIT TIME CONSTANT

• The averaging time constant of the CURRENT protection circuitry can be reduced from the nominal 60 seconds to 2.5 seconds by removing the shorting link between the terminal pins on Card ZL 0033 (Fig.3.6).

3.4. MULTIPLE EXCITER VIBRATION TESTING

Certain vibration applications require more than one Exciter to drive the test specimen. This type of connection is shown in the schematic diagram of Fig.3.7. To provide complete protection, a trip in any one Amplifier-Exciter combination must remove the input signal from all Amplifier-Exciter pairs in use. This is accomplished using Terminal Board 2 (TB 2) of the 2708s, as follows:

1. Select one of the Amplifiers as the Master and the remainder as Slaves.

2. Remove the shorting link between terminals 2 and 3 on all the Slave amplifiers.

3. Using external wiring, link terminal 2 of each amplifier to terminal 2 of every other amplifier.

The FET gates at the input to each amplifier are now parallelled and the gates' "on" bias is supplied from the Master amplifier.

If any Amplifier-Exciter pair trips, the input and DC centring signals will be gated off from all amplifiers, but the only failure lamps lit will be the relevant lamp on the amplifier that initiated the trip. Thus the offending pair can be easily recognized and corrective action taken before continuing the test. Only the tripped amplifier requires to be reset before the test can continue, but one should ensure that the drive signal is re-applied gradually to the whole test set-up.

To reset the system when using multiple shakers driven from one signal source (as in Fig.3.7), first reduce the output of the oscillator, then reset the tripped amplifier and finally return to full operation by turning up the oscillator to regain the required table levels.

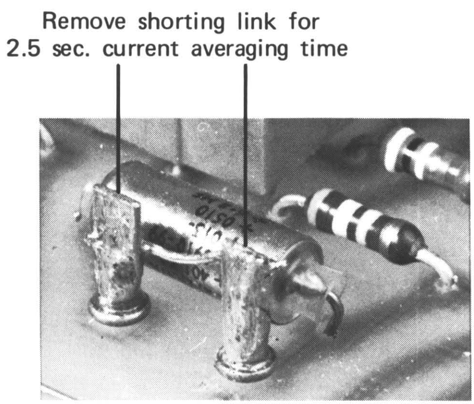

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Fig.3.6. Shorting link to increase CURRENT protection circuitry averaging time

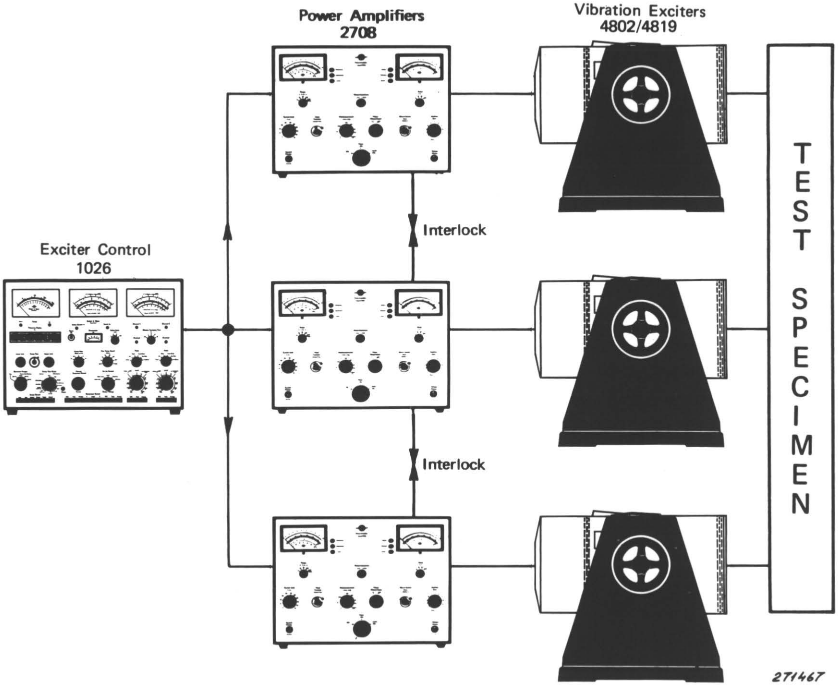

Fig.3.7. Multiple Shaker system

If multiple oscillators are used it is recommended that an n-way (where n is the number of exciter in use) potentiometer is wired in series with the inputs to each of the amplifiers. This then can be used as the "gain" control and controls the switch on process.

3.5. VERY HIGH OUTPUT IMPEDANCE

In the "High" impedance mode an even higher output impedance (for frequencies greater than 30 Hz) can be obtained by soldering a link across the two terminals on Card ZE 0090 (Fig.3.8). Typically, an output impedance increase of 10 dB may be obtained for frequencies greater than 100 Hz. The link must be removed for operation in the "Low" impedance mode or the amplifier will oscillate.

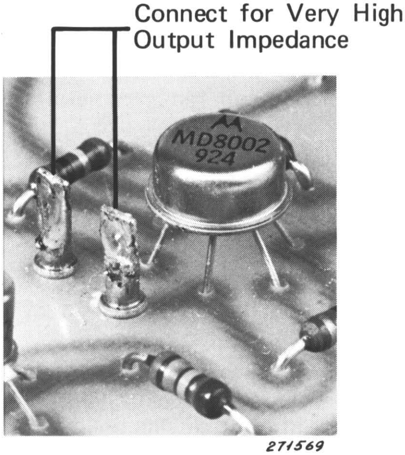

Fig.3.8. Shorting link to further increase the output impedance when in "High" mode

3.6. EXCITER TRIGGER

The shorting link between terminals 4 and 5 on Terminal Block 2 (TB 2) can be replaced by an external normally-closed pair of relay or switch contacts. When the contacts are opened the amplifier EXCITER protection circuitry will be triggered. The contacts could be controlled by a temperature overload thermostat of an environmental test chamber, a failure on the test specimen, etc.

3.7. REDUCTION OF BACKGROUND NOISE AT THE EXCITER TABLE

The field supply current is normally derived from a full-wave, three phase rectifier, and because of ripple some residual motion will still exist at the exciter table even with no input applied to the amplifier. The ripple is at six times the mains frequency (300 Hz or 360 Hz).

The residual motion of B & K systems with the Power Amplifier Type 2708, the Exciter Body Type 4802 and a matching Exciter Head is typically 70 dB below the motion corresponding to full force. This low level of background motion is insignificant for most applications.

Background noise can be reduced by reducing the strength of the exciter field. With B & K exciters, this can be done by reducing the mains supply voltage to the Field Coil Rectifiers. For non-B & K exciters the manufacturer's instructions on reduced field strength operation must be followed.

3.8. OPERATION WITH REDUCED EXCITER FIELD

If operation is desired at very low vibratory levels, two methods are available to shift the dynamic range of the system to a lower range of accelerations levels:

a) A large mass can be added to the table. The same forces then cause smaller motions without reducing the dynamic range.

b) The mains voltage to the Field Supply can be reduced. Since the same current causes smaller deflections when the magnetic field is reduced, the background level is lower but the dynamic range is substantially the same. The amplifier mains voltage must remain at the nominal value.

Operation at levels in the 0.001 g range is very difficult. Very good instrumentation and a good seismic block system, to isolate the exciter from building motions, are essential.

A flexible means of providing reduced voltage operation is to wire a three-phase variable autotransformer in the power line to the exciter, providing a voltmeter to monitor the exciter mains voltage. An alternative method is to set the exciter transformers' primary taps for a nominal voltage greater than the actual mains voltage used.

Reduction of the mains supply to an exciter field affects the HEAD CONSTANT and CURRENT LIMIT setting requirements, reduces the effectiveness of the Exciter Interlock protective circuitry, the displacement capability and the available force.

Reduced mains voltage lowers the effectiveness of the exciter cooling, so the current to the moving coil must be limited to prevent its overheating. The amplifier CURRENT LIMIT control will provide this protection if properly set, assuming the exciter cooling system is otherwise operating normally. The correct setting of the CURRENT LIMIT for the 4802 system is given in Fig.3.9.

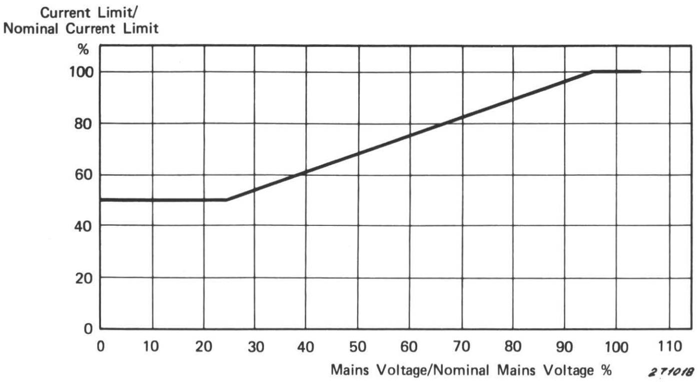

Fig.3.9. CURRENT LIMIT v. Mains Voltage

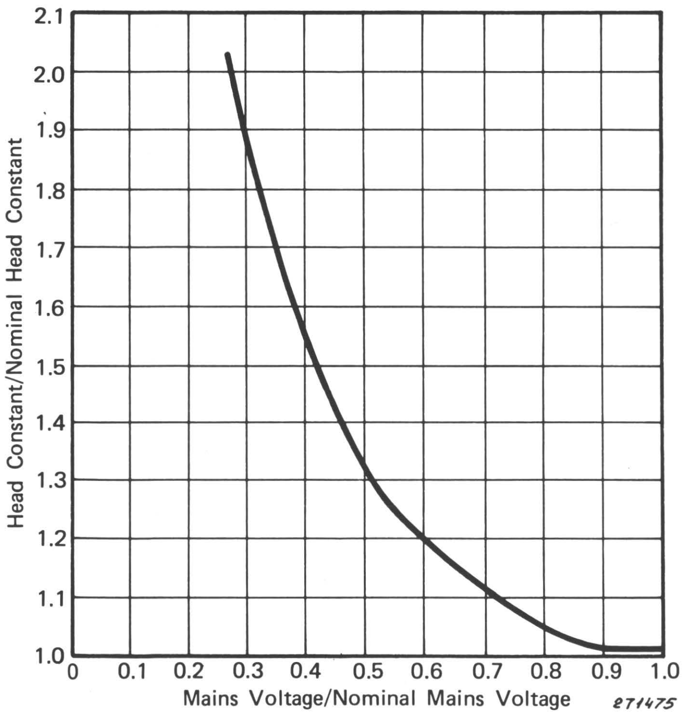

Fig.3.10. HEAD CONSTANT v. Mains voltage

Adjustment of the HEAD CONSTANT control on the amplifier front panel is necessary to maintain calibration of the DISPLACEMENT LIMIT protection (Fig.3.10 for B & K Type 4802). The circuit integrates the exciter moving coil voltage to obtain an analogue of displacement, and the proportionality between voltage and velocity depends upon mains voltage.

The Exciter Interlock protective circuitry will normally shut down the signal to the driver coil in the event of an exciter cooling system failure caused by power loss or a stalled motor. With very much reduced voltage this protective circuit must be by-passed (EXCITER INTERLOCK switch to "Bypass") so the operator must check that the cooling is operating. Note that at voltages below 25% of normal, forced cooling is not required for either the moving coil (provided the CURRENT LIMIT is properly set) or the exciter body components, so protection against cooling system failure is unnecessary. The exciter field coils and field supply components will cool adequately at reduced voltage, and are still protected against cooling system failure by the thermostat on the rectifier heat sink.

The force capability of the exciter is reduced at low mains voltages. The force generated by the driver coil is proportional to the product of the flux density and the driver coil current. The lowered voltage reduces the field current and thus the flux density, and the useable moving coil current is reduced because of reduced cooling. See Fig.3.11 for typical Type 4802 force capability.

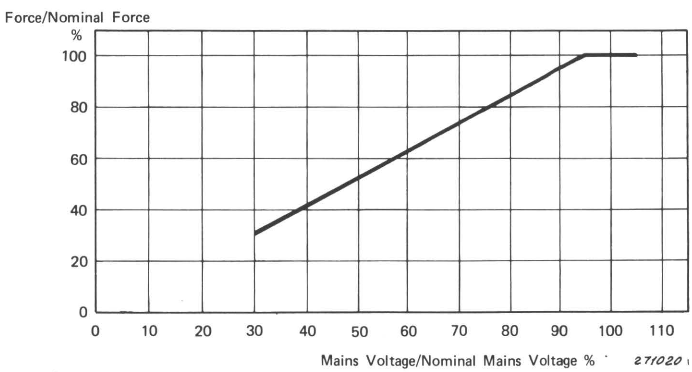

Fig.3.11. Force capability with reduced mains voltage

Displacement capability is also reduced in the low frequency region where the force required to deflect the suspension is dominant over the force required to accelerate the moving mass. As well as lowered background noise at the table, low voltage operation may be required to reduce power demand from the mains, reduce heat dissipated from the exciter, etc.

For the 4802 Exciter Body, the power input to the field supply at nominal mains voltage is about 4200 watts: this power is dissipated to the envorinment after the exciter has attained thermal equilibrium. The dissipated power can be reduced by operating at lower mains voltages, and can reasonably be approximated to:

$$\text{Power Dissipated} = 4200 \times \left(\frac{E_{mains}}{E_{nominal}}\right)^2$$

Thus operation at 70% of nominal voltage cuts the power to 2100 watts: operation at 50% of nominal voltage reduces the power to 1050 watts.

To summarize, the operating steps with reduced field supply are:

a) Wire a 3 phase variable autotransformer in the line supplying mains power to the Exciter Body.

b) Set amplifier controls:

CURRENT LIMIT	See Fig.3.9.
HEAD CONSTANT	See Fig.3.10.
EXCITER INTERLOCK	"Bypass".

c) Turn amplifier POWER switch to "On". Adjust (as necessary) the variable autotransformer for the desired mains voltage to the exciter.

d) Ensure that the cooling fan is working in the Exciter Body and then proceed as for normal operation.

4. DESCRIPTION

4.1. GENERAL

Vibration testing of large specimens or testing at high g levels requires a high power drive to the exciter. However, unless provision is made to avoid accidental mis-use of the power, considerable damage can be done to the test object, the shaker head or body, or even the amplifier itself. The block diagram (Fig.4.1) of the Power Amplifier Type 2708 shows that as well as power amplification, the instrument protects against electrical, mechanical and thermal overstressing. Facilities for waveform monitoring and continuous metering are also provided. Description of the circuit elements follows.

4.2. INPUT CIRCUITS

The rear-mounted BNC input sockets are connected via the AMPLIFIER GAIN control and a FET gate to the preamplifier. The 2708 will accept either an AC coupled input (at the AC INPUT socket) or a direct coupled input (at the DC INPUT socket). The DC static centring signal from the DIRECT CURRENT OUTPUT control is applied to the preamplifier through a similar FET gate. The two gates are normally held open, but if the protection circuitry is activated the gates are closed and disconnect the preamplifier input from the static centring and amplifier drive signals. The gate controlling the static deflection signal is purposely made slow-acting so that large static offsets in table position are not transmitted to the test object as fast transients when the equipment is switched on or when the protection circuitry triggers.

The amplifier input impedance is minimum when the AMPLIFIER GAIN control is set for maximum gain, but is never less than 10 kΩ.

In this amplifier the output phase is determined by the mode (inverting or non-inverting) of a linear amplifier immediately prior to the pre-amplifier. Mode switching is done by the PHASE switch. The polarity of the DC offset current (set up by the DIRECT CURRENT OUTPUT control) and thus the direction of the mechanical offset at the table is independent of the output/input phase.

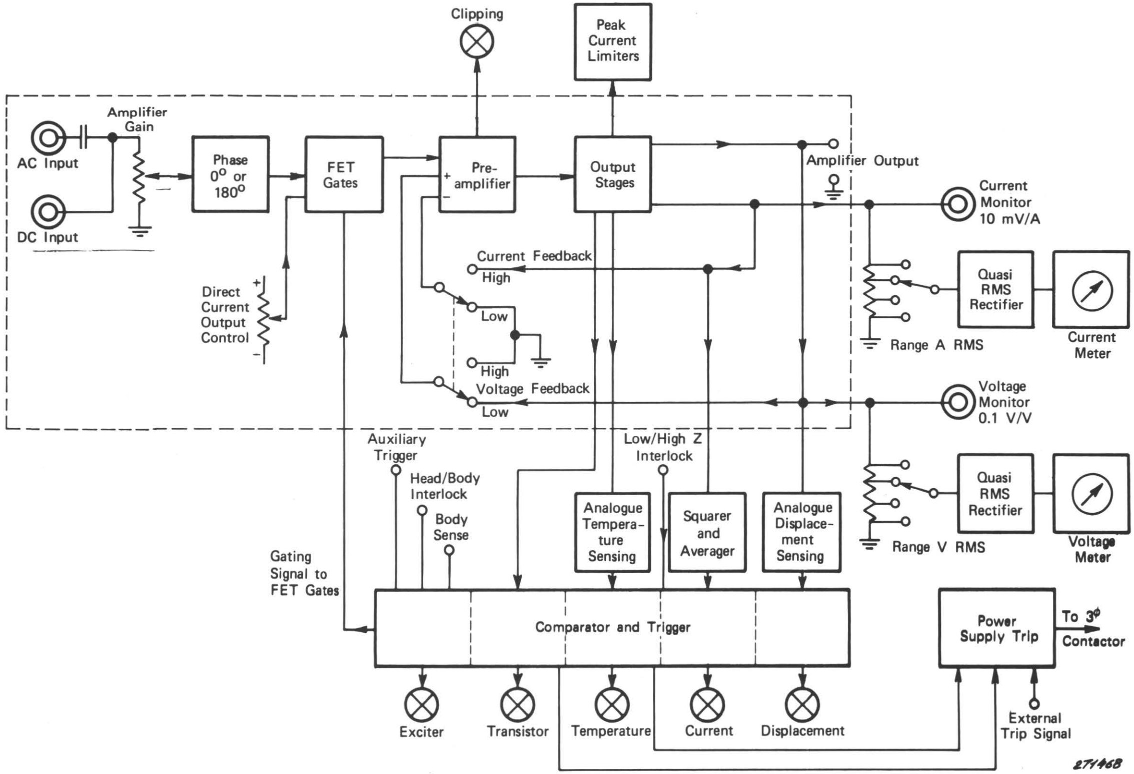

Fig.4.1. Block diagram of 2708

4.3. PREAMPLIFIER

The preamplifier consists of a balanced differential amplifier for inherent temperature stability, high common mode rejection and a simply set DC output level. This is followed by a high gain, large voltage swing stage, which is used to set the dominant pole in the amplifier's high frequency response and to drive the power output stage. Thus, generous feedback can be applied to the circuit to optimize linearity while still maintaining a comfortable stability margin. Distortion curves are shown in Fig.4.2.

The type of feedback from the power amplifier is selected by the OUTPUT IMPEDANCE switch. In the position "Low", a fraction of the 2708 output voltage is fed back to the input. This gives voltage source characteristics (constant output voltage, very low output impedance) to the overall amplifier. If the OUTPUT IMPEDANCE switch is at "High" the 2708 has feedback proportional to the current flowing in the load. This gives current source characteristics (constant output current, high output impedance). However, at very low frequencies the feedback becomes a combination of both current and voltage feedback and the output impedance is reduced. At frequencies greater than 30 Hz an even higher output impedance can be obtained by inserting a shorting link when using the amplifier in the "High" mode (see section 3.5).

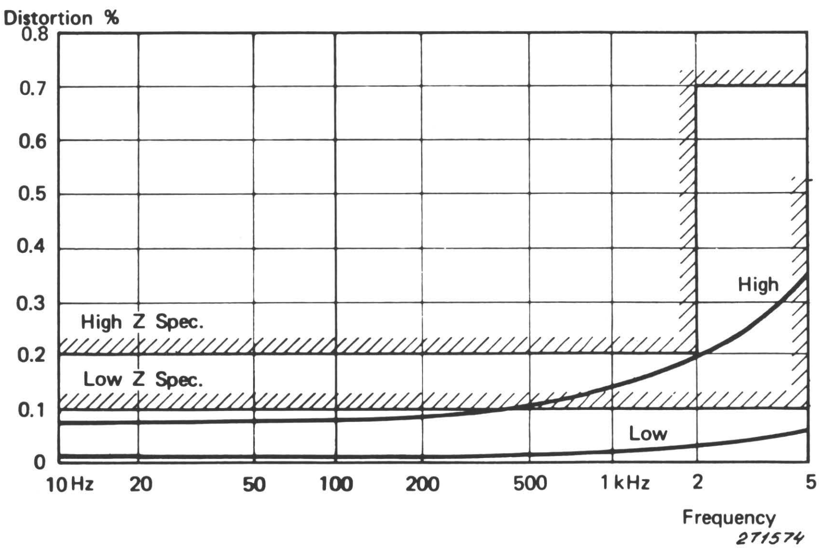

Fig. 4.2. Percentage Distortion in "Low" and "High" Impedance Modes

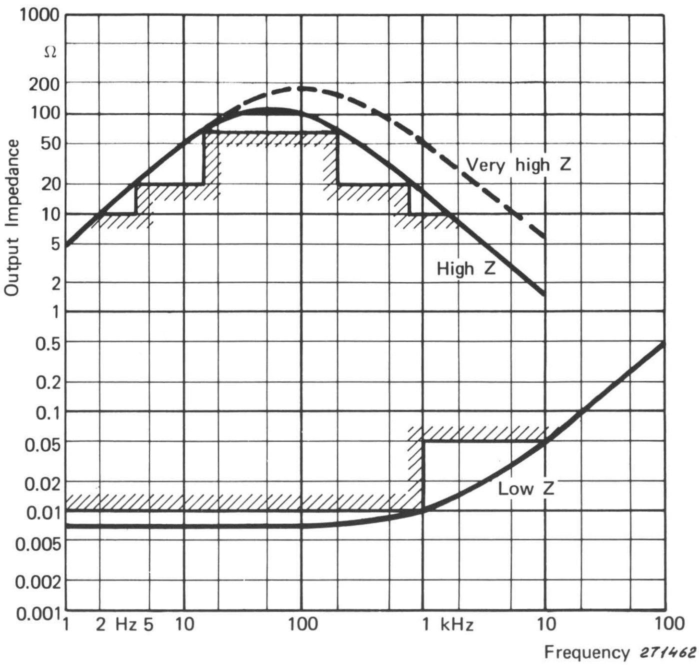

Fig.4.3. Output Impedance in "Low" and "High" Impedance Modes

Graphs of output impedance variation over the frequency range in "Low" and "High" impedance modes, are shown in Fig.4.3.

Excessive output signal levels will saturate the amplifier and cause clipping of the output waveform. This will trigger the clipping detector in the preamplifier, which lights the yellow CLIPPING lamp on the front panel.

4.4. POWER AMPLIFIER

The output stages are complementarily connected and operate in Class AB. The standing current is large enough to ensure very low cross-over distortion. Each complementary half of the output stages is made up of NPN transistors, with suitably arranged driver circuits so that the push-pull characteristic can be achieved. The use of all NPN transistors gives many advantages in availability, price, matching, etc.

The harmonic distortion of the 2708 is very low, mainly because of the separate power supplies to preamplifier and output stages, the use of direct coupling (thus eliminating a bulky and distortion-prone output transformer) and the use of a push-pull output stage (with its inherent harmonic cancellation properties).

The power output transistors (56 NPNs Type 2N4348) are protected in banks of 7 by 8 fast acting 10 A fuses. A high transient current or a transistor failure, resulting in a short circuited emitter-collector junction, will blow the fuse. This in turn is sensed by the TRANSISTOR protection circuitry which reduces the drive to the amplifier and turns off the three phase mains supply.

Peak current limiting circuitry is arranged to provide limiting of instantaneous positive and negative output current peaks. The limiting value can be adjusted independently for positive and negative peaks. It is set up to limit at 100 A. Current limiting is indicated by the CLIPPING lamp.

The rated current into a 0.6 Ω load is 45 A RMS over the frequency range 5 Hz – 10 kHz, 25 A RMS over the low frequency range (0.1 – 5 Hz) and 20 A at DC.

The small signal frequency response across the same load is shown in Fig.4.4. The high frequency response in the "High" mode is determined to a certain extent by the load resistance and is thus not given. Amplifier gain is 13.5 V/V ±2 dB in the "Low" impedance mode and 24 A/V ±2 dB in the "High" impedance mode.

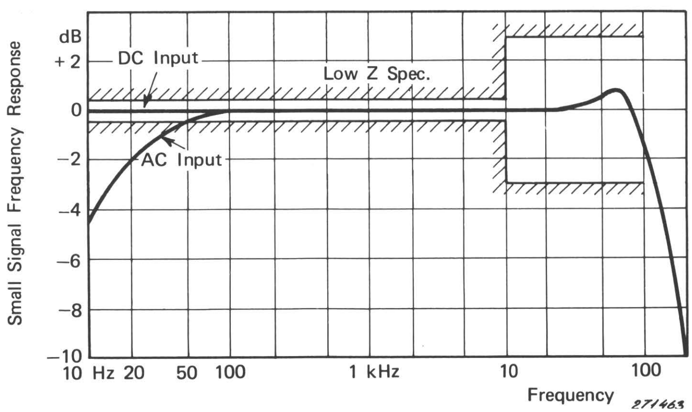

Fig.4.4. Amplifier Frequency Response

4.5. PROTECTIVE CIRCUITS

The 2708 is protected by fast-acting Silicon Controlled Rectifiers (SCR's) which, when triggered, turn-off the two FETs at the input, thus disconnecting the drive and DC centring signals. Each triggered SCR also lights a lamp which gives an indication of the reason for equipment shut-down.

Overload protection is provided against excessive coil drive current (CURRENT), shaker table displacement (DISPLACEMENT) and amplifier temperature increase (TEMPERATURE). In the event of a power transistor protection fuse blowing, the TRANSISTOR circuitry operates. Unbalanced operation (if one of the phases is lost) and triggering of any of the Exciter Body protection circuits will cause the EXCITER trip to operate.

TEMPERATURE and TRANSISTOR trips switch off the three phase supplies to the system.

After fault finding the amplifier can be reset by reducing the AMPLIFIER GAIN control to its fully anti-clockwise click-position marked "Reset". This opens the anodes of all protection SCR's. Increasing the gain once more returns the amplifier to its normal operating condition with the protection circuitry again enabled.

4.5.1. Current

A front-panel control (CURRENT LIMIT) is used to pre-set the RMS output current (including the DC component) at which the CURRENT circuitry trips. The limit can be set anywhere between 5 A and 55 A.

The squared and averaged value of the voltage across the current feed-back resistor is compared to a reference. If the reference level is exceeded the CURRENT SCR will be triggered, turning on the red front-panel lamp labelled CURRENT and disconnecting the system inputs. The time-constant of the averaging circuitry is 60 sec., matching the minimum thermal time-constant of the Exciter Heads used with the B & K Exciter Body Type 4802. This permits short-term current overload and means the shaker system can be used in a pulsed mode. The averaging time-constant can simply be reduced to 2.5 sec (see section 3.3) if a "snap-action" current trip is required or if a non-B & K exciter is to be used.

It is a fundamental requirement that when operating at the maximum current limit of the amplifier for a long period the CURRENT limit circuitry is not tripped. The time taken for the CURRENT trip (t_n) for various degrees of overload is shown in Fig.4.5. This follows the relationship.

$$t_n = 60 \log_e \left(\frac{n^2}{n^2 - 1}\right)$$

$$\text{where} \quad n = \frac{\text{Actual RMS Current}}{\text{CURRENT LIMIT setting}}$$

Interlocking ensures that any attempt to alter the OUTPUT IMPEDANCE switch or the OUTPUT PHASE switch when the amplifier is delivering power to its load will trip the CURRENT protection circuitry. The Exciter Head moving coil is not connected to the amplifier until the three-position POWER switch is at "Load On". When switching on the system, a short pause in the "Power On" position gives the field time enough to build up to its final value. This delay in switch-on will prevent large and possibly damaging surges being transmitted to the object under test.

If the amplifier is switched from "Off" to "Power On" when the AMPLIFIER GAIN is not at "Reset", the CURRENT trip circuitry will be triggered. This prevents transients being transmitted to the exciter load if the input to the amplifier is still connected.

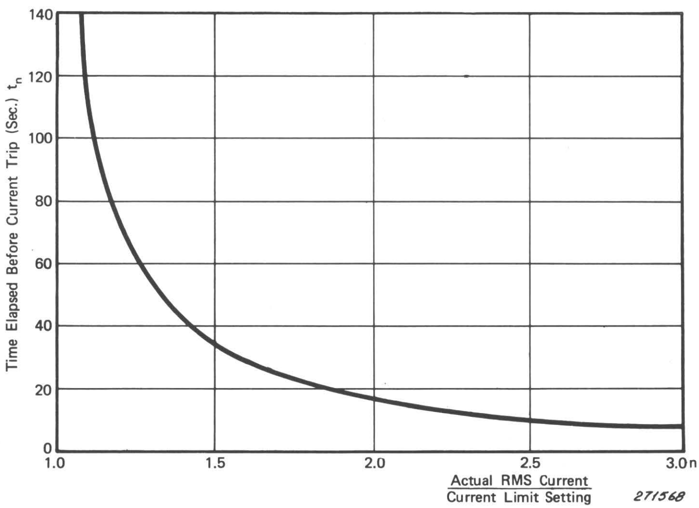

Fig.4.5. Time for trip of CURRENT limiting circuitry

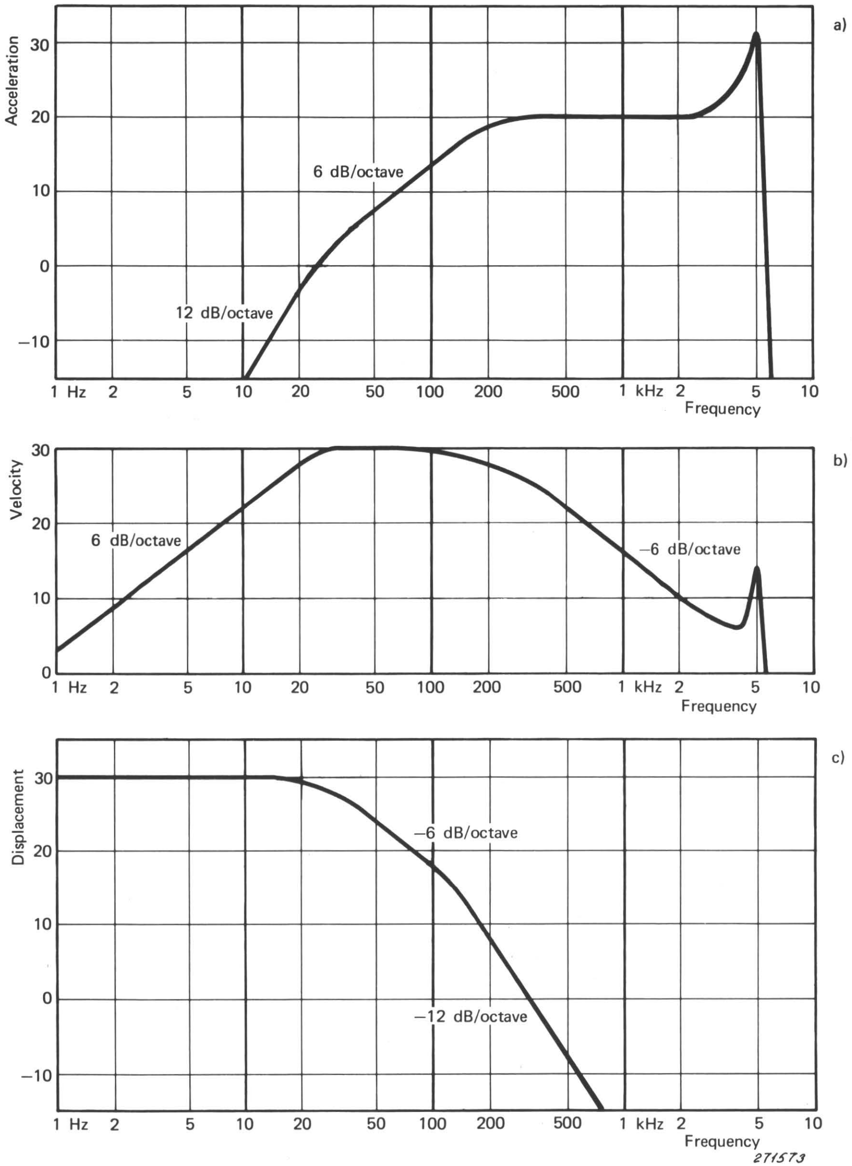

Fig.4.6. (a) Acceleration v. Frequency
(b) Velocity v. Frequency
(c) Displacement v. Frequency

4.5.2. Displacement

The front panel control DISPLACEMENT LIMIT is used to pre-set the peak-to-peak level of shaker table displacement at which the DISPLACEMENT circuitry trips. The control is continuously variable and can be set anywhere between 0.2 — 4.0 inches (5 — 100 mm).

With sine wave excitation the wide band performance of electrodynamic shakers is generally as shown in the plot of acceleration against frequency for constant excitation voltage (Fig.4.6(a)). At low frequencies (up to approx. 25 Hz), acceleration is limited by the available table displacement between end-stops. The maximum attainable velocity is determined by the maximum amplifier output voltage and dynamic loss effects in the mounts and other suspension parts. The velocity limitation usually falls within the frequency range 20 — 200 Hz. Above about 200 Hz the maximum acceleration available depends on the driving coil current and the moving mass. The regions of constant velocity and constant displacement are shown in Figs.4.6(b) and 4.6(c).

Since the amplifier output voltage is proportional to the table velocity over the frequency range where full displacement is attainable, and since velocity is the first derivative of displacement, integrating the output voltage will give a signal proportional to the table displacement. The constant of proportionality (termed the "Head Constant") depends on the dimensions of the driving coil, number of turns, and field flux density and is electrically set-up using the HEAD CONSTANT control. The numerical value of the Head Constant is stamped on each Exciter Head of the B & K shaker system.

The logarithmic plot of displacement against frequency (Fig.4.6(c)) shows that the available displacement falls off as frequency increases. The gain/frequency characteristic of the displacement sensing circuitry is arranged to match the displacement fall-off slope of a typical shaker system and includes a margin of safety. Below 1 Hz, and above 200 Hz, the gain is suppressed to give good noise rejection. The DISPLACEMENT LIMIT control adjusts the overall gain level of the displacement sensing characteristic, high gain corresponding to low displacement limits. The circuit provides protection for both positive and negative displacement peaks, and operates equally well for noise or transient signals as for a sinusoidal signal.

However, the sensing circuit is AC coupled and thus takes no account of any DC centring current flowing. For a heavy specimen the DC current is generally used to offset the static deflection of the flexures to re-centre the table, thus the full displacement capability is unaltered. When the DC centring signal is used to give a static displacement to the test specimen, the mean table position will not be at the centre of travel. This offset is not accounted for by the displacement sensing circuitry and must be kept in mind when setting the DISPLACEMENT LIMIT control.

4.5.3. Temperature

Abnormal load conditions, failure of the heat sink cooling fan, or high ambient temperatures could result in output transitor junction temperatures in excess of design limits, and subsequent failure of transistors. To prevent damage to the output transistors under these conditions, the TEMPERATURE SCR will trigger, removing the inputs, lighting the red front-panel lamp labelled TEMPERATURE, and switching off the three phase supply.

The heating effect of the drive current is a function of both current and frequency. The drive current in the useable frequency range, as limited by the TEMPERATURE circuitry, is shown in Fig.4.7. The TEMPERATURE protective circuitry is calibrated to trigger at 47 A RMS load current. at a frequency of 100 Hz, in an ambient temperature of 25°C (77°F). This gives a trip margin over the rated output current, thus allowing the shaker system to be operated at higher temperatures than 25°C. A rise of 20°C (36°F) ambient temperature reduces the tripping current by about 10% (i.e. to 42.3 A).

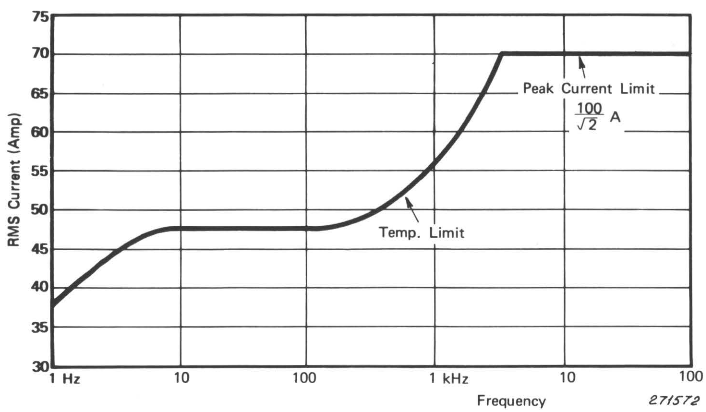

Fig.4.7. Output Current as limited by TEMPERATURE protective circuitry

At DC, output currents up to 38 A can be obtained without the temperature trip operating but the output transistor heat-sink thermostats will close at 80°C (176°F) and trigger the TEMPERATURE protective circuitry.

4.5.4. Exciter

The EXCITER protection circuitry is triggered by:

a) Failure of fuse protecting the cooling fan or field windings.

b) Attempted operation with the Exciter Head separated from the Exciter Body.

c) Loss of one of the three phases of the mains power line.

d) Opening of an external pair of contacts connected to the shaker system using the ACCESSORY connector.

4.5.5. Transistor

The TRANSISTOR protection circuit will be triggered when one or more of the eight transistor fuses protecting the 56 output transistors is blown. Rectification of the fault is discussed in section 3.2.6.

Normally, the transistor fuses will be blown before any damage to the transistors themselves is sustained. However, should a transistor be damaged, operation without tripping the protection circuitry is possible provided the damaged transistor is removed and the broken fuse replaced.

4.6. METERING AND MONITORING

The meter rectifiers used have a quasi-RMS characteristic. This gives correct reading for sinusoidal and Gaussian distributed signals.

4.6.1. Voltage Metering

The output voltage of the 2708 is applied to the meter via a four position range selector switch. The ranges available are 3, 10, 30 and 100 V RMS. From the range selector the signal is applied via a unity gain isolating amplifier to the quasi-RMS rectifier. The output of the rectifier drives the VOLTAGE METER.

4.6.2. Current Metering

The voltage across the current feedback resistor is applied via a range selector switch (3, 10, 30, 100 A RMS and ±30 A DC) to a voltage amplifier with a gain of approximately 50. The measuring amplifier's output is rectified, again using a quasi-RMS rectifier, and drives the CURRENT METER. For Exciter Head centring using the DC OUTPUT control, the drive coil current can be monitored with the CURRENT METER on the ±30 A DC range. A DC offset signal is applied to the meter to give the centre-zero display.

4.6.3. Monitoring

Two oscilloscope or external meter take-off points have been provided, one as a Current Monitor (10 mV/a) and the other as a Voltage Monitor (0.1 V/V).

5. USE WITH OTHER INSTRUMENTS

5.1. FREQUENCY SWEEP VIBRATION TESTING

Sine wave testing is a powerful laboratory tool during equipment development and can be used not only to detect resonance, but also for extended testing at the known resonances (dwell testing) and for testing by sweeping through a band of frequencies.

Sweep testing requires the exciter to be fed with a sinusoidal drive signal, at a pre-determined rate of change of frequency (sweep rate). Resonances in the test object and exciter system mean that the power supplied to the exciter is frequency dependent and must be automatically decreased or increased. This is usually done by the compressor amplifier within the signal source, the time constant (regulation speed) of which must be selected according to the expected Q-values of the system resonances.

An instrument set up to implement such a test is shown in Fig.5.1. The Exciter Control Type 1026 is the basic signal source. This produces the low distortion, variable frequency sine wave signal as a drive to the moving coil of the Exciter Head after suitable power amplification in the Power Amplifier Type 2708.

The table vibration is monitored by one of the two accelerometers and fed via a suitable Conditioning Amplifier, to one of the built-in vibration meter of the 1026. The output of the vibration meter is used to control the output level of the 1026 by varying the gain of the internal compressor amplifier. If the test specimen is large and unbalanced, considerable distortion can be present on the feedback signal. Under these conditions the built-in slave filters (6% constant percentage in the sine mode) would be used to "clean-up" the feedback loop signal. The three phase contactor and the control signals are also shown.

5.2. SWEEP RANDOM TESTING

Wide-band random frequency testing can be expensive because of the equalization filters required to shape the test frequency spectrum to comply

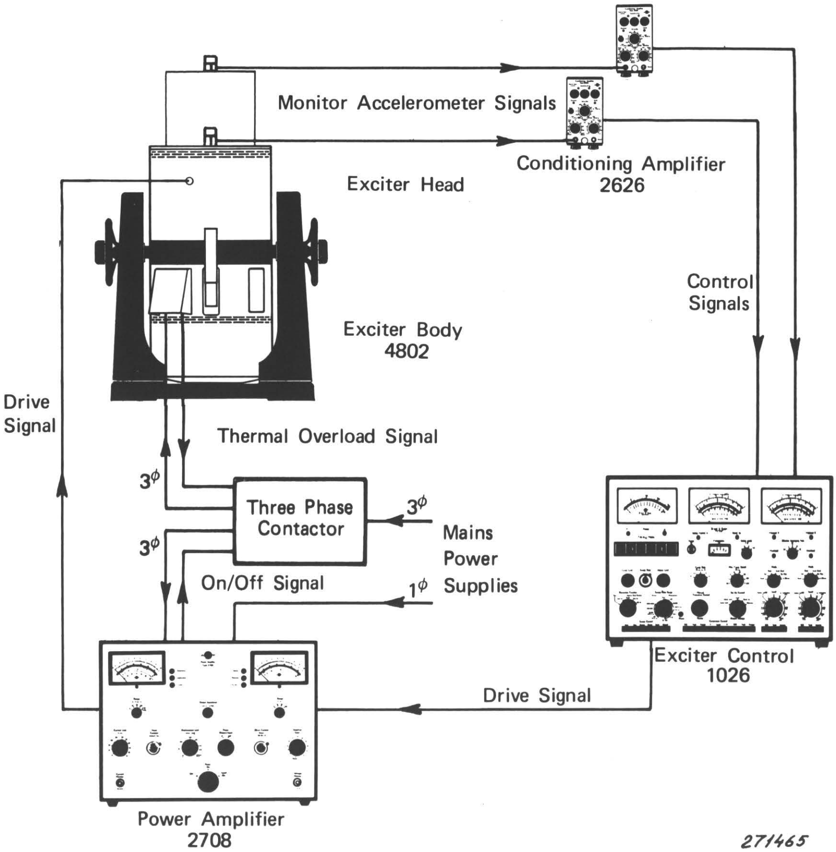

Fig.5.1. Basic equipment for a Sweep Sine vibration test

with the specifications set. An economic alternative to wide band testing is sweep random testing. It consists of one or more narrow bands of noise, sweeping (or dwelling) according to a detailed test programme and emphasizing various important frequency regions.

The test arrangement shown in Fig.5.2 is set up for two such bands. The Exciter Control Type 1026 drives the Power Amplifier Type 2708 which in turn drives the moving coil of the Exciter Head/Body combination Type 4802/4817. Isolation transformers are required to isolate the outputs of the two 1026s from each other. Each generator sweeps a narrow band random signal (maybe of different bandwidths as well as different frequency ranges and sweep rates) back and forth as required. The 1026 has built-in slave filters. These are constant bandwidth filters in the random mode, the bandwidth being equal to the selected noise bandwidth. This ensures that the feedback signal fed to each compressor is that required for correct operation, independent of the other generator signal and of spurious accelerometer and table resonances.

A single band sweeping narrow band random test could be carried out with the test setup in Fig.5.1.

The number of narrow band generators necessary to perform the proper test will depend upon the number of important frequency regions.

The arrangement can be extended to include more generators whenever required. In this way the capital investment required to perform adequate random vibration testing is reduced to a minimum and a very flexible test system is obtained.

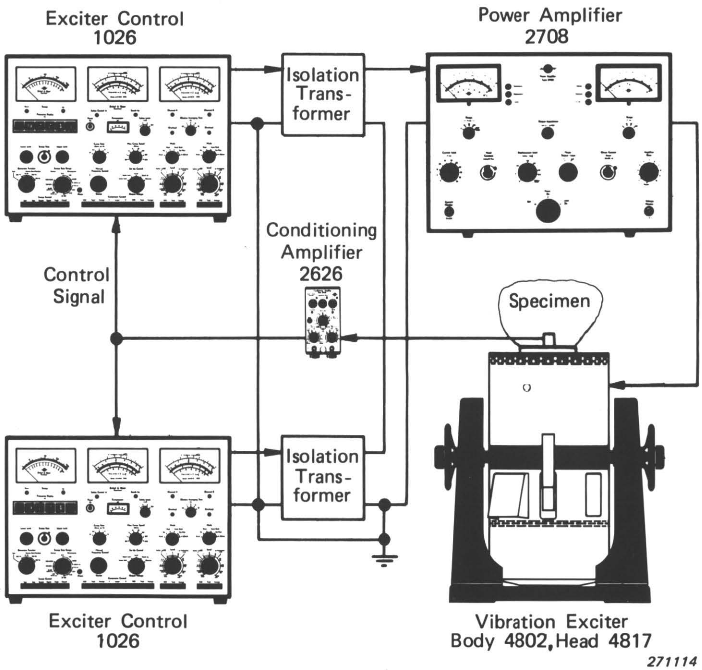

Fig.5.2. Example of test set-up for multiple sweep random testing

5.3. WIDE BAND RANDOM VIBRATION TESTING

In practical situations it is often desirable to test a component to the same levels and with the same spectra as it receives in operation. Such tests are often used when assessing the prototypes of a product to assess their suitability under the vibration environment envisaged. Commonly the working levels experienced by an automotive suspension element are determined. This can be done by taking the vehicle over a suitably designed test track and recording the vibration signals from transducers mounted on the suspension. After suitable data reduction, the test signal is recorded onto a test loop and is used to drive the vibration exciter on which the suspension component is mounted. However, the response of the exciter system will not necessarily be flat because of inherent resonances in the shaker.

The test set up of Fig.5.3 is suitable for pre-equalising the shaker system and then accepting the test signal as drive.

The Automatic Shock-Random Equaliser-Analyser Type 3380 first uses its own internal signal source, operating at low level, and by adjusting the Level Set controls for a flat spectrum the test arrangement is allowed to equalise. The system is then switched to Hold and Ext. Signal and the desired external signal is applied. The Power Amplifier Type 2708 is used to drive the Exciter Type 4802. Feedback is provided via the conditioning Amplifier Type 2626.

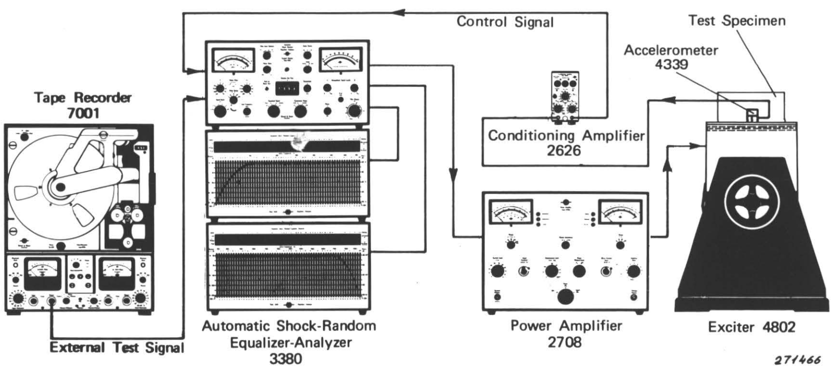

Fig.5.3. Pre-equalisation for External Test signals

6. SPECIFICATIONS

Capacity:	1200 VA into 0.6 Ω exciter or resistor load.
Voltage:	27 V RMS DC to 5 kHz 13.5 V RMS. At 10 kHz
Current:	20 A at DC 25 A RMS at 0.1 Hz 45 A RMS 5 Hz to 10 kHz.
Frequency Range:	
Full capacity:	5 Hz to 5 kHz
Reduced capacity:	DC to 100 kHz

Frequency Response: (typical, small signal, "Low" impedance mode)

DC Input	DC to 10 kHz $<\pm 0.5$ dB DC to 100 kHz $<\pm 3.0$ dB
AC Input	15 Hz to 100 kHz $<\pm 3.0$ dB.
Output Phase:	Selectable in-phase (0^{o}) or anti-phase (180^{o}) referred to input. Variable by a front-panel control.
Input Impedance:	>10 kΩ.
DC Stability:	<100 mV drift for +5% to −15% variation of mains supply from nominal, 10^{o}C to 45^{o}C variation in ambient temperature.

Direct Current Output: Not less than 20 Amps in 4802 exciter heads (corresponds to ±5 Volts) available at output (Terminal Board 3). Variable by a front panel control.

Output:

	"Low" Impedance	"High" Impedance
Gain (at 1 kHz)	13.5 V/V ±2 dB	24 A/V ±2 dB
Output Impedance	<0.01 Ω DC to 1 kHz <0.05 Ω 1 kHz to 10 kHz	>10 Ω 2.5 Hz to 1.5 kHz >20 Ω 5 Hz to 200 Hz >70 Ω 20 Hz to 200 Hz
Harmonic Distortion (Full capacity)	<0.2% DC to 5 kHz <0.4% 5 kHz to 10 kHz	<0.3% DC to 2 kHz <0.7% 2 kHz to 5 kHz
Noise and Hum (below full output)	At least 80 dB	At least 70 dB

Metering: Quasi-RMS rectifier circuits indicate Current and Voltage output. Correct for sinusoidal and Gaussian inputs.

	Voltmeter	Ammeter
Scales	3 V, 10 V, 30 V, 100 V RMS	3A, 10A, 30A, 100A RMS ±30 A DC
Response	±2% 20 Hz to 10 kHz	±2% 20 Hz to 5 kHz ±4% To 10 kHz
Accuracy (at 1 kHz)	±2% of FSD	±4% of FSD

Monitoring:

Voltage socket 0.1 V/V
Current socket 10 mV/A.

Protection: Input signal is removed and an indicator lamp is lit in the event of
Exciter Displacement exceeds preset limit.
Moving Coil Current exceeds preset limit.

Power Transistor junction temperatures.
Amplifier cooling failure.
Exciter cooling failure.
Loss of Exciter fuse.
Attempted operation of Exciter Head separate from Body.
Moving interlocked controls.
Loss of one phase of three phase mains.
External interlocking.
Front panel indication of output signal clipping is also provided.

Temperature Range: 10 to 40°C (41 to 104°F).

AC Power Requirements:

Single Phase (50 to 60 Hz)	30 VA at full output. 100, 120, 127, 200, 220, 227, 240, 247, 254 V RMS + 5% to −15%
Three Phase (50 to 60 Hz)	2400 VA at full output 200, 208, 220, 230, 240, 340, 360, 380, 400, 420, 440, 460, 480 V RMS ±5%

Almost full output voltage capability down to −15% of nominal mains supply.
Exciter Body power must be provided in addition to this.

Cabinet: Model A (Lightweight metal cabinet)
Model C (As A, but with mounting flanges for Standard 19" racks).

Dimensions:

(A model, excluding connectors). Height 31.3 cm (12.3 in)
Width 43.0 cm (16.9 in)
Depth 50.0 cm (19.7 in)
Weight 59 kg (130 lb).

Accessories Included:

1 x AT 0078	Cable
1 x JP 0035	BNC 75 connector
1 x VF 0010	1A/250 V Fuse
10 x VF 0025	10 A Transistor Protection Fuses
2 x VS 1274	Scale lamps.

BRÜEL & KJÆR instruments cover the whole field of sound and vibration measurements. The main groups are:

ACOUSTICAL MEASUREMENTS
Condenser Microphones
Piezoelectric Microphones
Microphone Preamplifiers
Sound Level Meters
Precision Sound Level Meters
Impulse Sound Level Meters
Standing Wave Apparatus
Noise Limit Indicators
Microphone Calibrators

ACOUSTICAL RESPONSE TESTING
Beat Frequency Oscillators
Random Noise Generators
Sine-Random Generators
Artificial Voices
Artificial Ears
Artificial Mastoids
Hearing Aid Test Boxes
Audiometer Calibrators
Telephone Measuring Equipment
Audio Reproduction Test Equipment
Tapping Machines
Turntables

VIBRATION MEASUREMENTS
Accelerometers
Force Transducers
Impedance Heads
Accelerometer Preamplifiers
Vibration Meters
Accelerometer Calibrators
Magnetic Transducers
Capacitive Transducers
Complex Modulus Apparatus

VIBRATION TESTING
Exciter Controls – Sine
Exciter Controls – Sine – Random
Exciter Equalizers, Random or Shock
Exciters
Power Amplifiers
Programmer Units
Stroboscopes

STRAIN MEASUREMENTS
Strain Gauge Apparatus
Multi-point Panels
Automatic Selectors

MEASUREMENT AND ANALYSIS
Voltmeters and Ohmmeters
Deviation Bridges
Measuring Amplifiers
Band-Pass Filter Sets
Frequency Analyzers
Real Time Analyzers
Heterodyne Filters and Analyzers
Psophometer Filters
Statistical Distribution Analyzers

RECORDING
Level Recorders
Frequency Response Tracers
Tape Recorders

DIGITAL EQUIPMENT
Digital Encoder
Digital Clock
Computers
Tape Punchers
Tape Readers

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