STUDER PCM SFC 16

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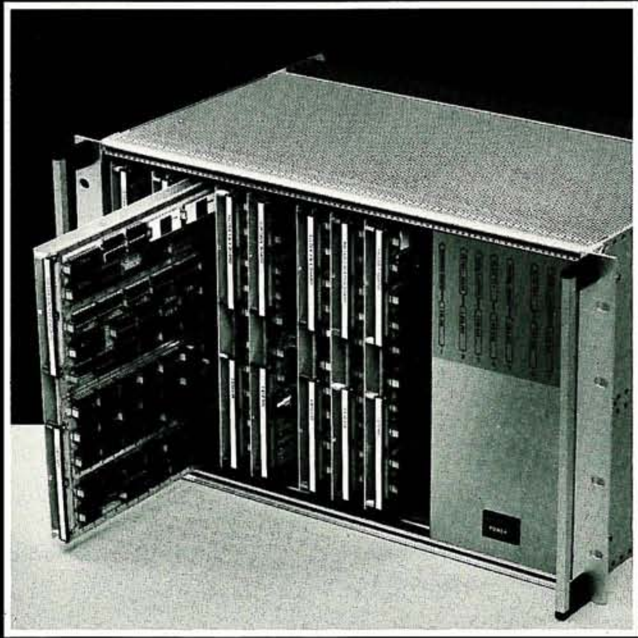

OPERATING INSTRUCTIONS

STUDER

PCM SFC 16

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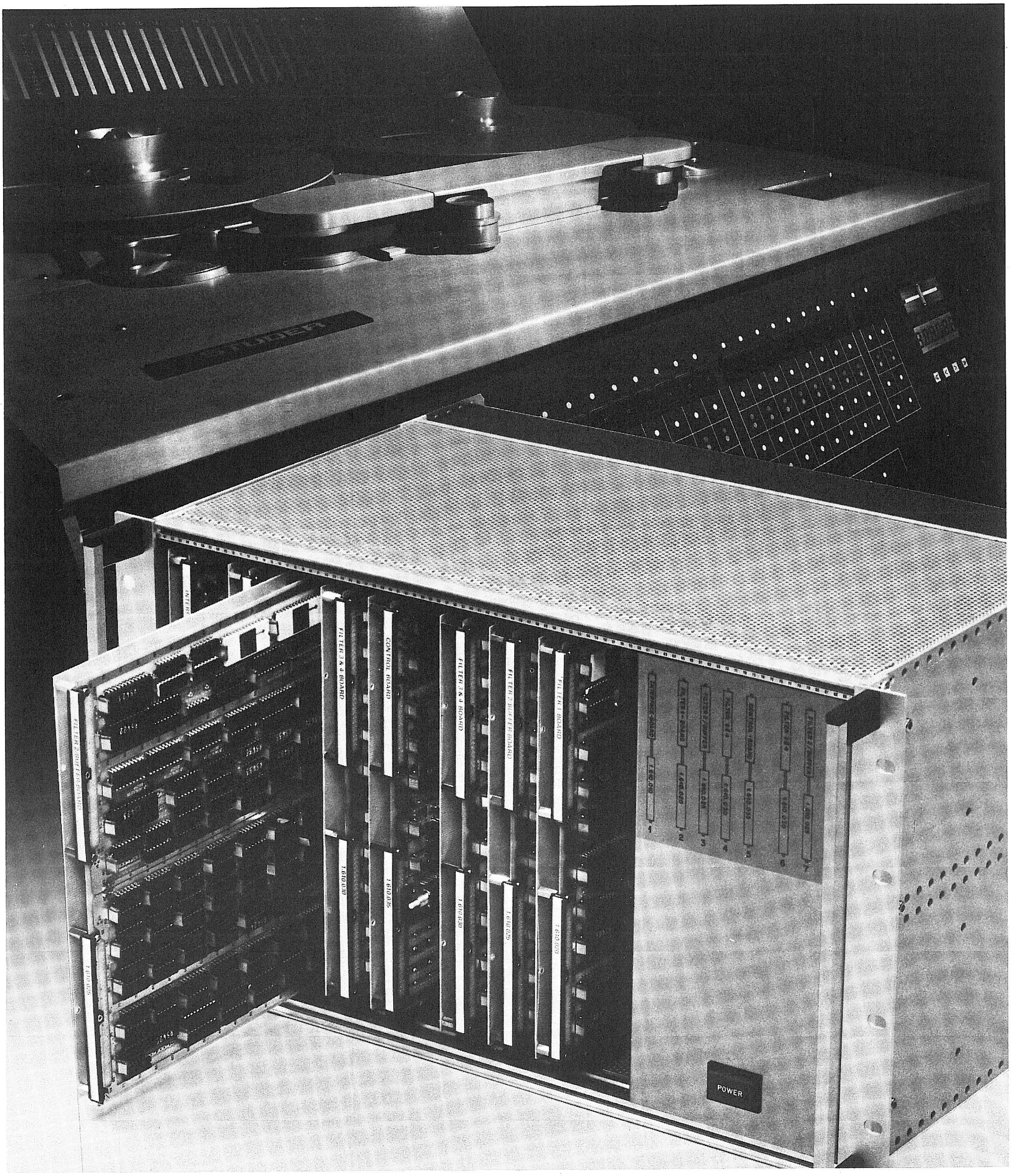

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We reserve the right to make alterations.

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SICHERHEIT UND ERSTE HILFE

SICHERHEIT
Durch Entfernen von Gehäuseteilen, Abschirmungen etc. werden stromführende Teile freigelegt. Aus diesem Grunde müssen die folgenden Sicherheitsvorschriften unbedingt beachtet werden:

1. Eingriffe in ein Gerät
dürfen nur von Fachpersonal vorgenommen werden.

2. Vor Entfernen von Gehäuseteilen:
Gerät ausschalten und vom Netz trennen.

3. Bei geöffnetem Gerät:
- Netzteil- oder Motorkondensatoren mit einem passenden Widerstand entladen.
- Bauteile grosser Leistung, wie Leistungstransistoren und -widerstände sowie Magnetspulen und Wickelmotoren erst nach dem Abkühlen berühren.

4. Servicearbeiten bei geöffnetem, unter Spannung stehendem Gerät:
- Keine blanken Schaltungsteile berühren
- Isolierte Werkzeuge verwenden
- Metallene Halbleitergehäuse nicht berühren, da sie hohe Spannungen aufweisen können.

ERSTE HILFE (bei Stromunfällen)

1. Bei einem Stromunfall die betroffene Person raschmöglichst vom Strom trennen:
- Durch Ausschalten des Gerätes
- Ausziehen oder Unterbrechen der Netzzuleitung
- Betroffene Person mit isolierendem Material (Holz, Kunstoff) von der Gefahrenquelle wegstossen
- Nach einem Stromunfall sollte immer ein Arzt aufgesucht werden.

ACHTUNG
EINE UNTER SPANNUNG STEHENDE PERSON DARF NICHT BERÜHRT WERDEN, SIE KÖNNEN DABEI SELBST ELEKTRISIERT WERDEN!

2. Bei Bewusstlosigkeit des Verunfallten:
- Puls kontrollieren,
- bei ausgesetzter Atmung künstlich beatmen,
- Seitenlagerung des Verunfallten und Arzt verständigen.

SAFETY AND FIRST AID

SAFETY
There are no user serviceable components inside the equipment, live parts are laid open when removing protective covers and shieldings. It is essential therefore to ensure that the subsequent safety rules are strictly observed when performing service work or repairs.

1. Servicing of electronic equipment
must be performed by qualified personnel only.

2. Before removing covers:
Switch off the equipment and unplug the mains cable.

3. When the equipment is open:
- Discharge power supply- and motor capacitors through a suitable resistor.
- Components, that carry heavy electrical loads, such as power transistors and resistors as well as solenoid coils and motors should not be touched before a cooling off interval, as a precaution to avoid burns.

4. Servicing unprotected and operating equipment:
- Never touch bare wires or circuitry
- Use insulated tools only
- Never touch metal semiconductor cases because they may carry high voltages.

FIRST AID (in case of electric shock)

1. Separate the person as quickly as possible from the electric power source:
- by switching off the equipment,
- unplugging or disconnecting the mains cable,
- pushing the person away from the power source by using dry insulating material (such as wood or plastic).
- After having sustained an electric shock, always consult a doctor.

WARNING:
DO NOT TOUCH THE PERSON OR HIS CLOTHING BEFORE POWER IS TURNED OFF, OTHERWISE YOU STAND THE RISK OF SUSTAINING AN ELECTRIC SHOCK AS WELL!

2. If the person is unconscious
- Check the pulse,
- reanimate the person if respiration is poor,
- lay the body down and turn it to one side, call for a doctor immediately.

SÉCURITÉ ET PREMIERS SECOURS

SÉCURITÉ
Si les couvercles de protection sont enlevés, les parties de l'appareil qui sont sous tension ne sont plus protégées. Il est donc d'une nécessitée absolue de suivre les instructions suivantes:

1. Les intervensions dans les appareils électriques
doivent être faites uniquement que par du personnel qualifié

2. Avant d'enlever les couvercles de protection:
Couper l'interrupteur principal et débrancher le câble secteur.

3. Après avoir enlevé les couvercles de protection:
- Les condensateurs de l'alimentation et des moteurs doivent être déchargés à l'aide d'une résistance appropriée.
- Il est prudent de laisser refroidir les composants de haute puissance, par ex.: transistors de puissance, résistances de puissances de même que des électroaimants et les moteurs de bobinage.

4. S'il faut que l'appareil soit sous tension pendent les réglages internes:
- Ne jamais toucher les circuits non isolés
- Travailler seulement avec des outils isolés

PREMIERS SECOURS (en cas d'électrocution)

1. Si la personne est dans l'impossibilité de se libérer:
- Couper l'interrupteur principal
- Couper le courant
- Repousser la personne de l'appareil à l'aide d'un objet en matière non conductrice (matière plastique ou boîs)
- Après une électrocution, consulter un médecin.

ATTENTION
NE JAMAIS TOUCHER UNE PERSONNE QUI EST SOUS TENSION, SOUS PEINE DE SUBIR ÉGALEMENT UNE ÉLECTROCUTION!

2. En cas de perte de connaissance de la personne électrocutée:
- Controller le pouls
- Si nécessaire, pratiquer la respiration artificielle
- Mettre l'accidenté sur le coté latérale et consulter un médecin.

1. INTRODUCTION

The SFC-16 is the first digital sampling frequency converter for digital audio to be introduced on the market. As opposed to previous designs described in the technical literature, the SFC-16 accommodates arbitrary, a priori unknown sampling frequencies as they may exist in items of digital audio equipment operating with different formats and without synchronization to a common clock signal.

The SFC-16 processes a stereo pair of digital audio channels operated synchronously, i.e. with the same word clock frequency. The outputs of the SFC-16 are also a stereo pair of digital audio channels at the desired sampling frequency, both channels being strictly in synchronicity.

The SFC-16 cannot be programmed to a specific ratio of sampling frequencies. Rather, the input and output sampling frequencies are dictated to the SFC-16 by the input and output formats.

Thus the SFC-16 does not introduce any constraints of its own on the sampling frequencies used in a digital audio system, but converts passively between sampling frequencies dictated from the outside.

Applications of the SFC-16 range from program transfer between digital recorders with conflicting formats to mastering for the Compact Disc system, which has a 44.1kHz sampling frequency rather than the 48kHz sampling frequency generally accepted as the professional standard. The SFC-16 can also interface between digital recorder formats and the 32kHz format for digital transmission over PCM telephony systems.

As it imposes no constraint of synchronicity on the sampling frequencies, the SFC-16 can be used as a link between systems with nominally identical, but plesiochronous sampling frequencies.

The conversion between different sampling frequencies can require an amount of band limiting which depends on both the sampling frequencies in use. The SFC-16 performs the right amount of band limiting automatically, based on an almost-ideal filter response of very low ripple.

The SFC-16 is a true 16-bit device. Its contribution to the signal-to-noise ratio of a 16-bit system is commensurate with the theoretical noise floor, i.e. far below the noise contribution of today's state-of-the-art a-to-d converters.

In fact, its performance can be improved if input and/or output formats in excess of 16 bit wordlength are used.

Due to its design as a cascade of linear-phase, FIR digital filters, the SFC-16 does not introduce phase distortion. It is also free of limit cycles, and its noise contribution is essentially white over the whole frequency range of digital audio.

The SFC-16, despite featuring a large number of essentially new ideas and techniques in digital signal processing, is based on conventional, moderate-speed digital hardware and conservative design. In order, however, to alleviate its maintenance and troubleshooting in the case of integrated circuit malfunction, it has received a new feature called Selftest. When activated by the operator, a selftesting routine indicates whether the SFC-16 is working correctly and helps to locate possible malfunctions, including such error modes as LSB errors which would be extremely difficult to detect otherwise.

In today's digital audio community, there exist many items of equipment with conflicting sampling frequencies and digital audio input/output formats. In addition to accommodating the whole range of sampling frequencies in use today, the SFC-16 can be fitted with custom-made interfaces. The list price of the SFC-16 includes either the serial Digital Interface proposed by Studer, or a custom-made interface for signal transfer from one specified item of digital audio equipment to another specified item. More complex types of interfacing can be accomodated on a case-by-case basis. The circuit board which holds the interface circuitry is housed within the SFC-16 itself, so that no external circuitry is required.

The next chapter (chapter 2) describes in some details the theory and principle of the SFC-16, which is based on original developments in digital signal processing by Studer. It also describes the SFC-16's main building blocks, as well as its limitations and some of the problems encountered in assessing its audio performance with conventional analog audio equipment. A study of Chapter 2 is not required for trouble-shooting.

Chapter 3 deals with the installation and operation of the SFC-16, including the digital interfaces.

Chapter 4 deals with the hardware of the SFC-16.

Chapter 5 lists the technical data of the SFC-16 and describes how its audio performance can be measured.

Chapter 6, finally, deals with the important issue of troubleshooting the SFC-16, and describes in some details one of its most important features, selftesting.

2. THEORY AND DESCRIPTION OF THE SFC-16

2.1 Sampling frequency conversion with arbitrary ratio

Today's digital audio equipment exhibits a large variety of sampling frequencies and input-output interface formats. The conversion of digital audio signals between different sampling frequencies is thus an ever-present task.

Until recently, two basic techniques existed for changing the sampling frequency of a digital audio signal without modifying its audio content:
- going back to the analog domain
- operating a digital filter at a fixed conversion frequency

The first technique is essentially limited by the required d-to-a converter, smoothing and anti-aliasing filter, and a-to-d converter. There are no state-of-the art converters and filters of sufficient quality to guarantee true 16-bit performance.

The first technique consists of converting to an analogue format with a d-to-a operating at the input sampling frequency; smoothing the d-to-a's output signal with a lowpass filter; submitting the signal to additional bandlimiting if required by the output sampling frequency; and redigitizing the signal.

A disadvantage of this method is that filters of adjustable bandwidth are required if a wide range of sampling frequencies is to be accommodated - an extremely difficult thing to achieve with high-quality analog filters. On the other hand, changing sampling frequencies via the analog domain has the advantage that small changes in the sampling frequencies can be tolerated.

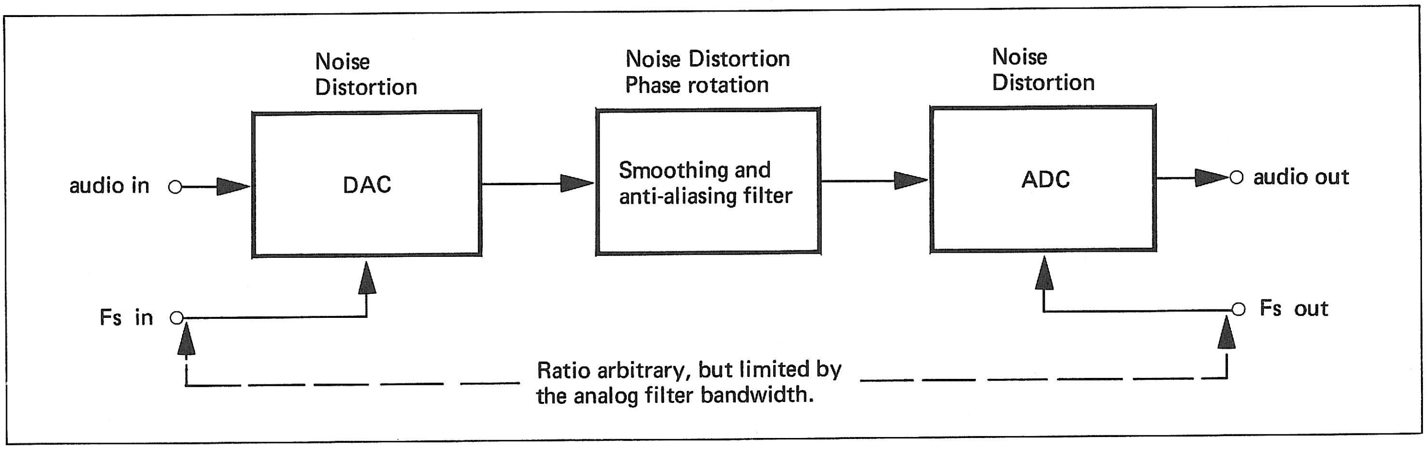


Fig. 2.1
"Conventional" conversion via analog: the sampling frequencies are arbitrary but limited by the analog filter bandwidth; signal degradation occurs through noise, distortion, and phase shift in the converters and the filter.

The second method consists of increasing the sampling frequency to a "conversion sampling frequency" generally chosen as the least common multiple of the two (input and output) sampling frequencies.

This is achieved with a digital filter of FIR (Finite Impulse Response) type, designed as a lowpass filter which passes only the first spectral image, with additional bandlimiting if the output sampling frequency is lower than the input sampling frequency. A digital audio signal at the desired output sampling frequency is obtained by subsampling the signal, and proper filter design keeps the aliasing effects due to subsampling below the specified tolerances.

Though inherently free of the limitations of the first method, this second approach is by its very nature limited to simple ratios of sampling frequencies (otherwise the filter design becomes extremely difficult) and also to fixed ratios (as each individual ratio corresponds to a unique filter design). As today's digital audio features such complex sampling frequency ratios as 147:160 (in the case of 44.1 and 48kHz), as well as the necessity of tolerating fluctuations in the sampling frequencies, the simple approach via one single digital filter is not acceptable.

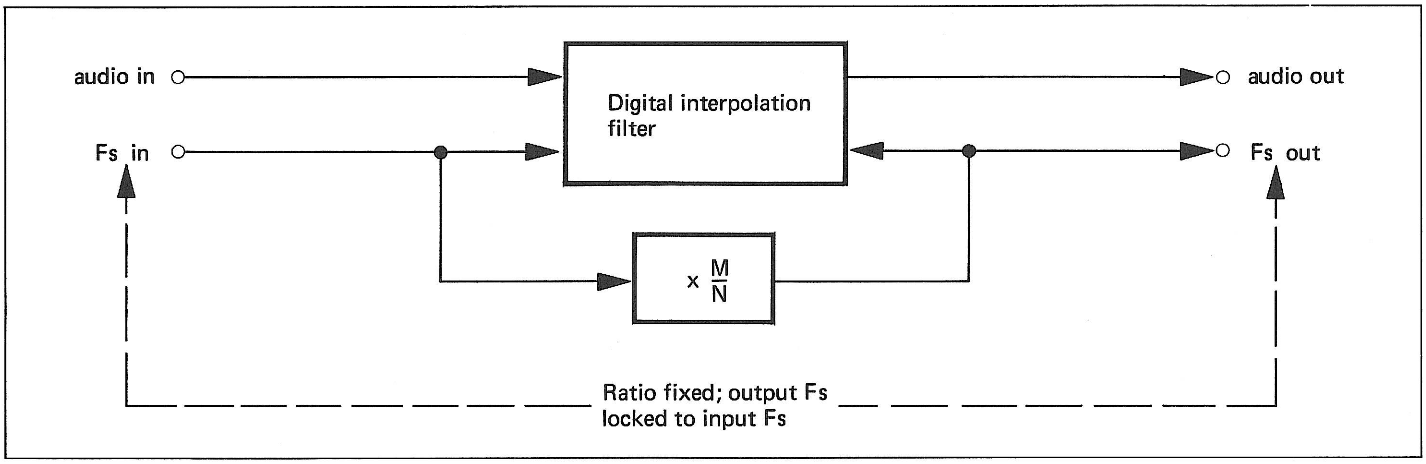


Fig. 2.2
"Conventional" conversion via digital: the sampling frequencies are in a fixed, unique ratio; small and large changes in the sampling frequencies cannot be accomodated. No distortion or phase-shift.

The basic premise of the SFC-16 Sampling Frequency Converter is that conversion between arbitrary ratio can be achieved with a single, extremely high conversion frequency, provided that a finite accuracy is required, a condition which is of course met in the case of 16-bit digital audio. When a fixed, very high conversion sampling frequency is used and the nearest samples at the conversion frequency are used as output samples, a small sampling time uncertainty results, which depends on the digital audio frequency and amplitude. The result can be made arbitrarily small by selecting a correspondingly high conversion frequency. Theoretical models indicate that a conversion frequency of approximately 2^{15} times the digital audio sampling frequency is required for errors compatible with 16-bit accuracy.

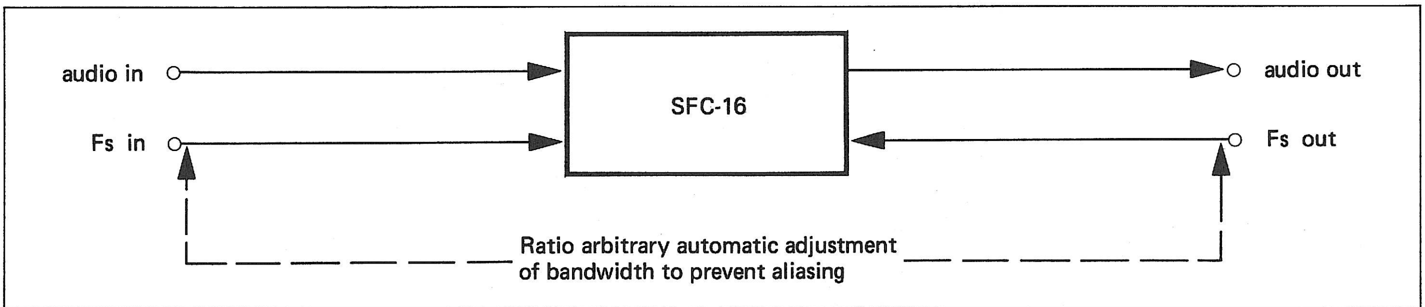


Fig. 2.3
The new approach of the Sampling Frequency Converter SFC-16: arbitrary (even fluctuating) sampling frequencies can be accommodated, and anti-aliasing is built into the converter. No distortion or phase-shift.

Conversion at 2^{15} times 48kHz (i.e. almost 1.6GHz) is of course difficult to achieve. A careful study of the filtering algorithms indicates, however, that the majority of the operations at this very high conversion frequency can be discarded. The number of arithmetic operations actually required is quite low, and can be dealt with by conventional computing circuitry.

Thus, the SFC-16 converts between arbitrary sampling frequencies with 16-bit accuracy by first increasing the sampling frequency by a factor of 2^{15} then subsampling down to the required output sampling frequency.

In the case of arbitrary sampling frequency ratios, the position of output sampling times with respect to input sampling times can be anywhere (this is in contrast to the case of fixed ratios of sampling frequencies, in which both input and output samples are on a common time grid defined by the conversion frequency and only a discrete and deterministic number of relative positions is possible).

In order to perform sampling frequency conversion with the required accuracy, this relative position must be determined with an accuracy of better than one part in 2^{15} every time, and without any buildup of systematic errors. A direct measurement would imply clock frequencies in the Gigahertz range, and is thus unrealistic. In the SFC-16, digital processing of the sampling clocks themselves is used instead, and the relative position is computed rather than measured directly. A direct advantage of this approach is to smooth the clock signals and suppress any short-term jitter component due, for example, to clock signal transmission, Thus, the SFC-16 is quite tolerant with respect to the quality of the clock signals (which may display jitter) and the digital audio signals (which only have to be readable by their own clocks). In the case of the SFC-16, 16-bit quality processing does not imply costly 16-bit compatible clock quality - an essential feature when digital signals have to be transmitted.

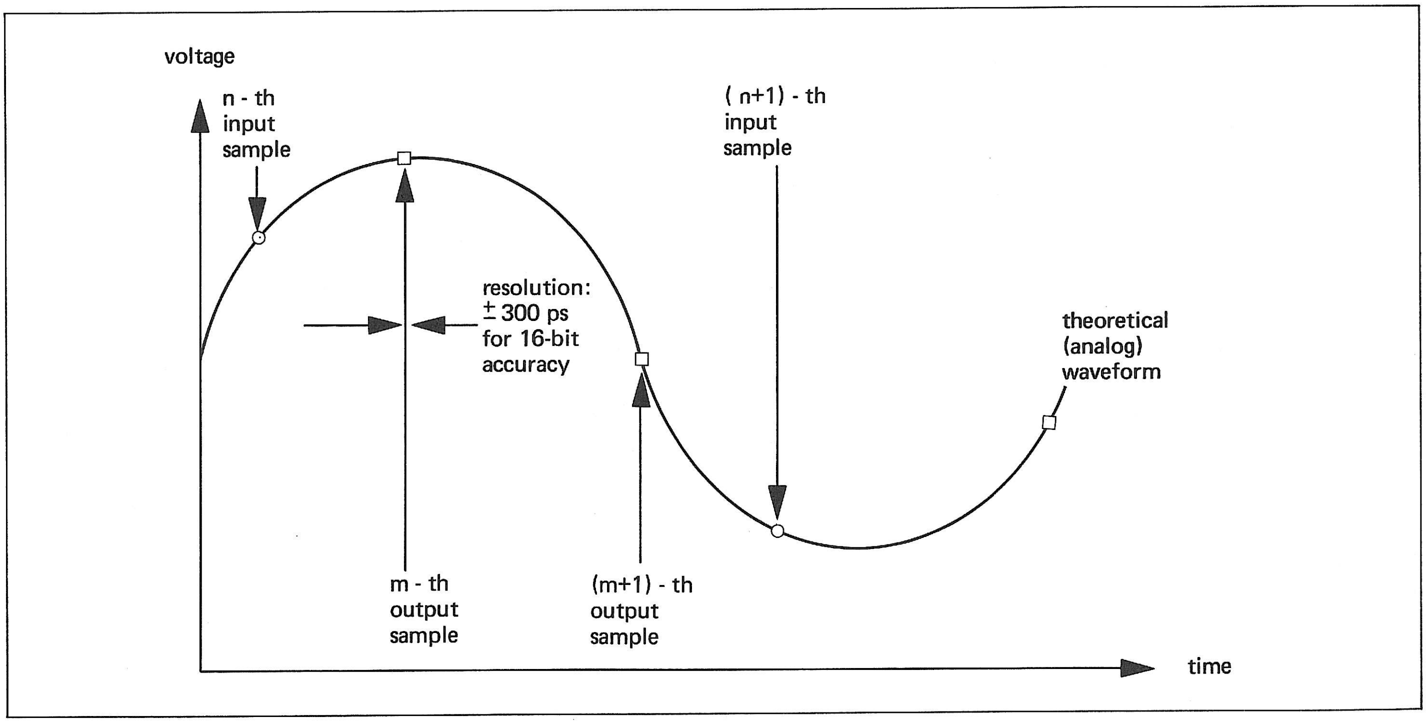


Fig. 2.4
Time-domain accuracy of the SFC-16:
In order for 16-bit performance to be achieved, a time-domain resolution of at least ±300ps (i.e. ±0.0003us) is required. The SFC-16 achieves this resolution by digital processing, and eliminates shorttime jitter on the clock signals in the process.

2.2 Multistage design

Sampling frequency conversion can be described mathematically as the interpolation of a discrete-time digital audio signal. Obviously, going from an input sampling frequency f_{sin} to an output sampling frequency f_{sout} via a very high conversion frequency f_c will not require that all intermediary samples at the conversion frequency f_c are computed (actually, only one per output sample is required).

Although single-stage designs can be envisaged, a multistage approach was selected for the SFC-16, for reasons of hardware simplicity and filter design. In a multistage approach, the sampling frequency is gradually increased by powers of two, while of course discarding all unnecessary arithmetical operations. In the following, the basic features of the SFC-16's operation will be illustrated, as they can be observed in its individual filtering stages. For reasons of clarity, the explanations will restrict themselves to the so-called Up-mode, in which the sampling frequency has to be increased and in which, accordingly, no reduction of the input signal's bandwidth is required.

In digital audio systems with approximately 20kHz of bandwidth and 48kHz of sampling frequency, there is little guard space between the maximum possible audio frequency and its mirror image just above one-half the sampling frequency. A sampling frequency increase followed by subsampling will require that all spectral images above the base band are suppressed. In our case with an internal increase in sampling frequency of 2^{15} = 32'768, this means that the 32'767 spectral images between baseband and one-half the conversion frequency will have to be removed by filtering.

The combination of a narrow transition bandwidth and an extremely wide stopband leads to formidable specifications for a single-stage filter. A multistage filter design, however (corresponding of course to a multistage interpolation), can easliy accommodate the specifications.

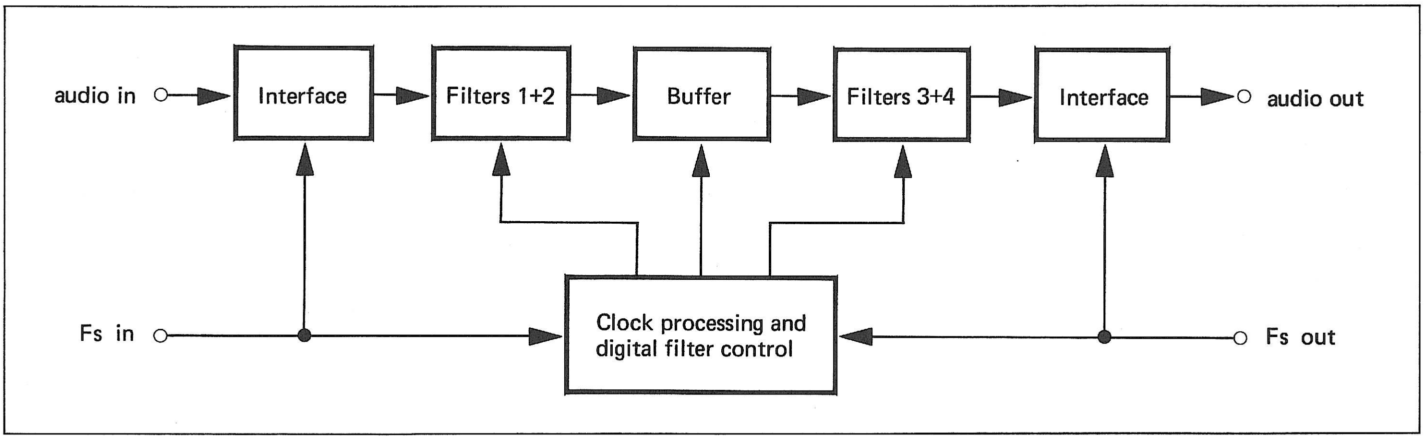


Fig. 2.5
Block diagram of the SFC-16: the real-time control signals for the operation of the sampling frequency converter are obtained by digital processing of the clock signals, and thus the converter does not need to be programmed for any particular ratio of sampling frequency.

The lowest possible integer increase in sampling frequency is by a factor of two. In this case, the filter will have only an easy task to perform. For 20kHz bandwidth and 48kHz sampling frequency, for example, the relative transition width will be only 8/96 = 0.0833.., leading to a simple filter. (In order to accomodate other, lower sampling frequencies, rather steeper filters are of course used in the SFC-16).

The effect of the first filter stage is that it computes new samples of the digital audio signal exactly midway between the original input samples. In the spectral domain, the task is to preserve the baseband (or 0-th image), to suppress the first and second images, to preserve the third and fourth images, and so on, in accordance with the periodic frequency response of the digital filter.

Once the first and second spectral images have been suppressed, the specifications for subsequent filter stages become far less severe, as the transition region has now been widened considerably (in other words: once the sequence of digital audio samples is relatively dense, i.e. when only frequencies much lower than one-half the sampling frequency have to be represented, interpolation becomes much simpler).

A second filter will again increase the sampling frequency by a fixed factor of two, and thus compute new input samples exactly mid-way between the already existing ones.

Mathematical analysis indicate that after a total increase in sampling frequency of four has been effected, very simple algorithms suffice to increase the sampling frequency arbitrarily with a very good accuracy. In the case of the SFC-16, a length-255 FIR filter processing only four input samples increases the sampling frequency by 64, and generates two samples immediately before and after the desired output sample. The last stage is a linear interpolator of length 255 which computes the desired output sample by increasing the sampling frequency by a factor of 128 to its final value of 2^{15} times the input sampling frequency.

As the two input filters operate in lock with the input sampling frequency, whereas the output stages must operate synchronously with the output sampling frequency, an asynchronous buffer is required between filter stages 2 and 3. Its error-free operation with arbitrary and particularly with time-varying sampling frequencies is one of the essential design features of the SFC-16.

2.3 Up-mode and Down-mode

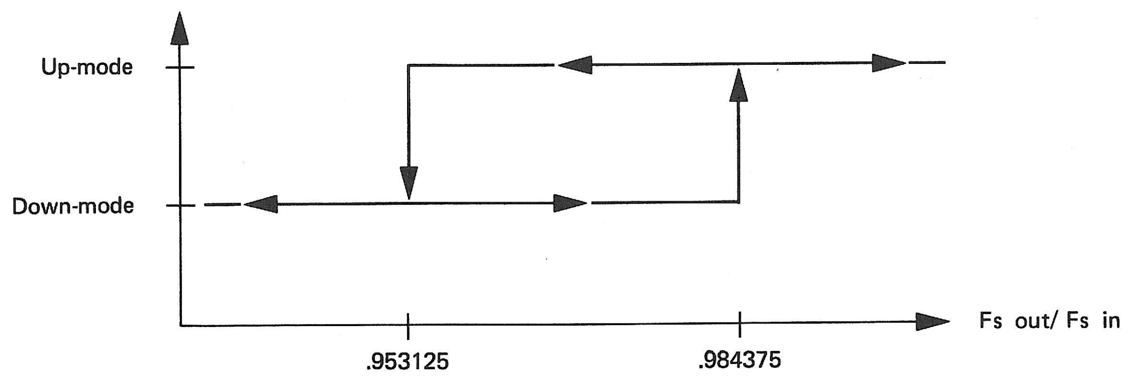
The above explanations were valid for an increase in the sampling frequency, in which the very steep overall filter does not have to provide additional band limiting of the digital audio signal. When the sampling frequency has to be decreased significantly, however, band-limiting related to the ratio of sampling frequencies has to be provided.

In the Up-mode multistage design described above, the first stage performs band-limiting implicitely while suppressing the second and third spectral images. This band-limiting operation takes place on the side with the lower sampling frequency, and is thus inherently correct. In order for band-limiting to be also provided in the Down-mode, where the sampling frequency has to be decreased, it would thus be advantageous to operate the same filter at the output instead of the input.

Sampling frequency conversion in the Up-mode was achieved by increasing f_s by steps, then subsampling in one single step. Another approach is to first increase the sampling frequency in one step, then bring it down in several filtering stages. A mathematical analysis of this second approach indicates that the same filter stages can be used in reverse order and as sampling frequency decreasing devices; that this second approach simplifies overall system control, though in the Down-mode only; and that the amount of band-limiting introduced by the cascade of filters in the Down-mode is automatically correct, at the last filter, performing a sampling frequency decrease by a factor of two, is now locked to the output sampling frequency.

Whether a sampling frequency converter must operate in the Up-or Down-mode can be determined by observing the clock signal frequencies themselves. In most cases, the SFC-16 will operate in the Up-mode if the input sampling frequency is lower than the output sampling frequency.

Switching from the Up- to the Down-mode or vice-versa cannot be achieved without a short (approximately 2 millisecond minimum) discontinuity in the digital audio signal. In most practical cases, the mode of operation is perfectly defined and switching between the two modes will not occur in operation. In order to guarantee smooth operation even at ratios which are nominally unity (as when connecting two asynchronous systems with the same nominal sampling frequency), a decision on the mode is made on the basis of a hysteresis rather than a simple threshold; the converter will thus stay in the Up-mode also for ratios of output to input frequency slightly smaller than unity, the limit being set at a ratio of.953125 for the transition from Up to Down and at a ratio of.984375 for the transition from Down to Up. These limits are sufficiently far away from practical ratios to ensure safe operation under all circumstances except widerange varispeed.



The Up- / Down-mode hysteresis

Fig. 2.6
The up- / down-mode hysteresis.

2.4 Clock Processing

As mentioned in 2.1, real-time measurement of the relative position of output vs. input samples would involve Gigahertz sampling clocks and extremely costly circuitry. Instead, the relative positions are determined digitally.

In the case of digital audio, which is based on periodic sampling, the relative position of output vs. input samples can have an arbitrary value, but there exists a strong correlation between two successive positions, as they are exactly one output sampling period apart. Thus, if one relative position has once been determined, the next one can be computed by simply adding the output sampling period and performing a modulo operation, if necessary, in order to restrict the relative position to its range of one input sampling period.

Thus, a computing circuit can generate the relative position on the basis of a measurement of the sampling periods. A requirement to the computing circuit is that no long-term error occurs. Therefore, it is necessary to monitor the sampling frequencies continously and thus adapt to fluctuations. The high-accuracy determination of the sampling periods can occur via averaging techniques, which have the added advantage of suppressing short-term clock jitter. On the other hand, very large averaging time constants tend to mask slow or fast changes in the ratio of the sampling frequencies, and could thus lead to errors such as buffer overflows.

In the SFC-16, medium-complexity filtering ensures a very-high accuracy measurement of the sampling frequencies . Only a minor amount of sudden change in the sampling frequency ratio is tolerated (1 in 256), but this amount is well in excess of what can be tolerated in a digital audio system if good audio quality is to be ensured. Although the principle of the SFC can easily be extended to the general case of varispeed and arbitrarily fast fluctuations in the sampling frequencies, the SFC-16 is not designed for varispeed applications.

The internal scaling of the sampling clock measurement circuitry imposes a slight restriction on the range of sampling frequencies which can be accommodated by the SFC-16. The lowest sampling frequency has been selected as 30kHz, as no professional digital audio application exists with a sampling frequency significantly below 32kHz. As no application is known either with a sampling frequency significantly higher than 50kHz, the maximum sampling frequency is set at 52kHz.

Once the ratio of the sampling frequencies has been determined with the necessary accuracy, it is necessary to compute the relative position of the output versus the input samples. As mentioned above, the current relative position can be computed from the previous position by a simple modulo addition.

As it consists of a series of FIR linear-phase digital filters, the SFC-16 can be considered as an almost ideal delay system (in the Up-mode, for example, the delay is of approximately 0.5 milliseconds when operating at 48kHz). Computing the relative positions on a worst-case basis will increase this delay by one sampling interval, i.e. approximately 20 microseconds - a negligible effect in today's applications. Thus, the SFC-16 assumes an arbitrary alignment of the sampling times immediately after power-up, although more sophisticated methods with an overall delay uncertainty well below the microsecond can be envisaged in the future.

An advantageous feature of the digital filter cascade implemented in the SFC-16 is that the digital word representing the relative position of the samples can be split into subwords, which control the digital filters and the buffer circuit.

2.5 The SFC-16 building blocks

Let us begin with a list of the functional building blocks of the SFC-16:

- power supply system
- clock input circuitry
- clock monitoring and mode setting
- clock processor
- filter control
- input interface
- filter F1
- filter F2
- buffer
- filter F3
- filter F4
- output interface
- self-test circuitry (control)
- self-test circuitry (digital audio)
- power-up circuitry

The power supply system, the interfaces and the self-test circuitry are described in a later chapter.

The clock input circuitry consists of differential line receivers and phase-locked loops of relatively wide bandwidth covering the frequency range of 30 to 52kHzm and generating locked higher-frequency clocks for counting and control purposes.

The clock monitoring and mode setting circuit compares the two input clock frequencies and defines the operating mode of the SFC-16 with separate threshold for switching from Up to Down and from Down to Up.

The clock processor measures the higher of the sampling frequencies with a fast clock derived from the lower sampling frequency, with an accuracy of 9 bits. The measured value is averaged in a two-stage FIR filter of total length 128 and its resolution is thus brought up to the required 16-bit value.

The 16-bit accurate value of the sampling frequency ratio is accumulated in a modulo adder to yield the current relative position of the sampling times at output and input, which in its turn controls the digital filters and the buffer circuit.

Filter control is made on the basis of a fixed timing locked on the input or output sampling frequency (depending on the mode) in the case of filter stages 1 and 2. The buffer circuit is controlled by both a sampling frequency and one subword of the relative samples position, and the same holds also for filter stages F3 and F4.

Filter stage F1 increases or decreases the sampling frequency by a factor of 2 (depending on whether Up- or Down-mode is present). It is a transversal (FIR) filter of length 63, designed for a relative bandwidth with respect to the input or output sampling frequency of 0.4375 for a bandwidth of 21kHz at 48kHz sampling frequency and 19.3kHz at 44.1kHz. The passband ripple is ±0.15 dB worst case, and the stopband attenuation is in excess of 110dB. (The attenuation at 20kHz with 44.1kHz sampling frequency is approximately 2dB).

Filter stage F2 again increases or decreases the sampling frequency by a factor of 2. Its design does not in any way influence the audio bandwidth of the converter. Filter F2 is a FIR filter of length 15, with a stopband attenuation in excess of 118dB. The ripples of F2 and F3 compensate each other, for a total resulting value of ±0.05dB.

The buffer circuit allows the error-free connection of the two asynchronous halves of the SFC-16, and its design will not be detailed here.

Filter F3 increases or decreases the sampling frequency by 64. It is a length-255 FIR filter with a stopband attenuation in excess of 120dB for distant images.

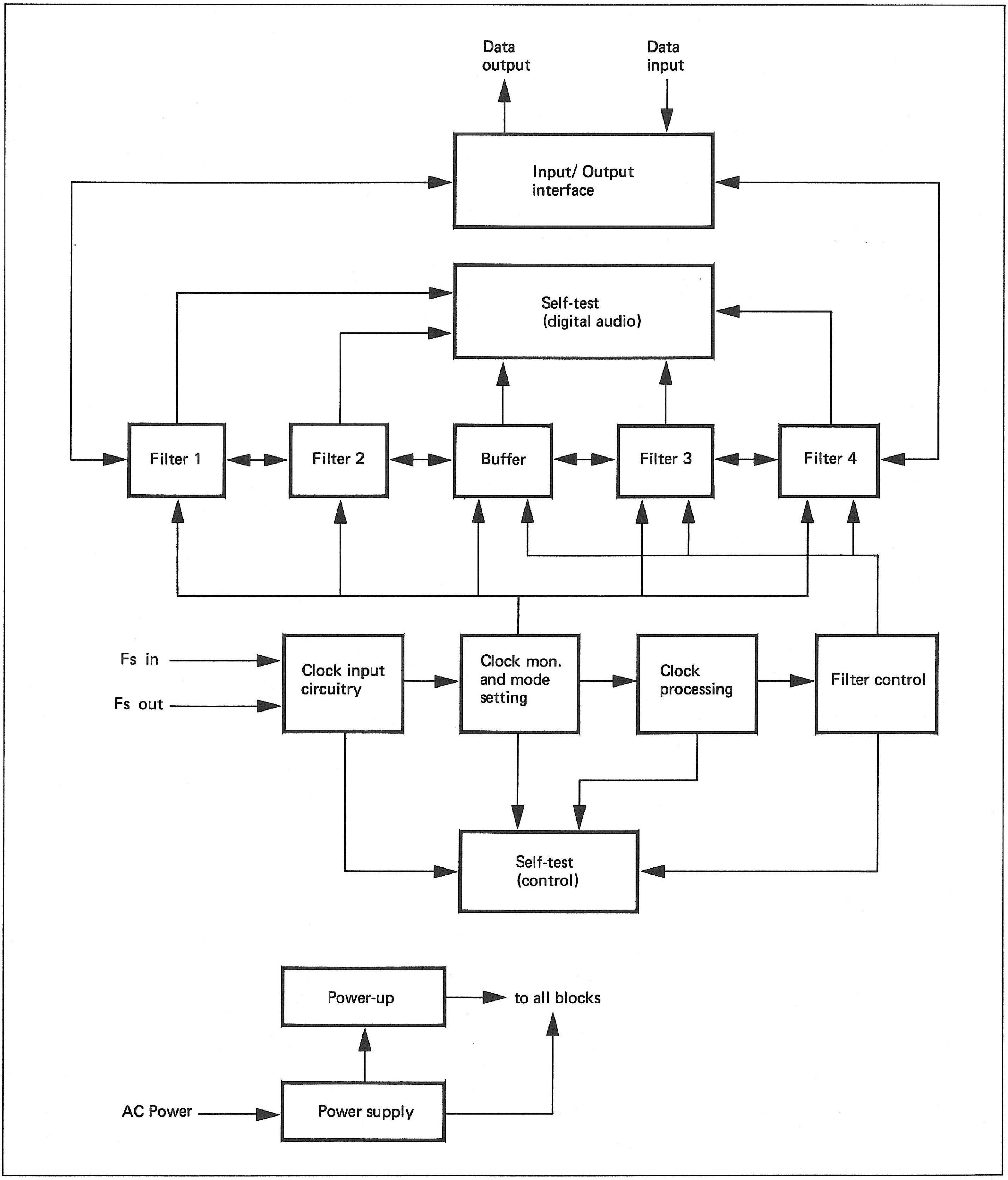


Fig. 2.7
The SFC-16 Building Blocks interconnections.

Filter F4 increases or decreases the sampling frequency by a factor 128. Its length is 255, and it is a linear interpolator. Its minimal stopband attenuation is 112dB for near images.

As good 16-bit performance requires coefficient word lengths in excess of 16-bits in most cases, parallel multipliers are not used in the filter and clock processor circuits. Rather, serial-parallel arithmetics and look-up tables are used in the filters.

In order to guarantee high performance, internal transfer word lengths of 20 bits are used for the digital audio signals.

An essential building block is the power-up circuit, which has to impose valid initial conditions for the computing circuitry of the SFC-16, both in the processing of the clocks and the digital audio signals.

2.6 Performance, limitations and measurements

As a signal processing element, the SFC-16 can be characterized in terms of its frequency-domain and amplitude-domain behavior, including effects due to clock processing.

The SFC-16's frequency response derives from the individual filters' responses. It is defined on the basis of the lower of the two sampling frequencies. The overall frequency response is that of a very wideband lowpass filter, with an almost flat response up to 43.75% of its sampling frequency (corresponding to 21kHz at 48kHz sampling frequency) which then decreases to -17dB at one-half the sampling frequency.

The phase response of the SFC-16 is linear with frequency, as the system consists of a cascade of linear-phase FIR filters and pure delay elements. The overall delay of the SFC-16 is approximately 24 samples at the lower of the two sampling frequencies, with some uncertainty introduced by initial conditions at power-up (this uncertainty corresponds to ±1/2 sample, with a uniform distribution). Thus, at 48kHz sampling frequency, total delay is approximately 0.5 milliseconds from digital input to digital output.

In conventional filter design, the passband gain is caused to ripple around its average value of unity, or 0dB. In a digital filter design, such an amplitude response would cause extremely severe distortions whenever the input signal level is very near maximum at a frequency where the filter displays larger-than-unity gain. In the context of digital audio, severe distortion would also occur whenever recordings have been made at a high level, in which case there is a very real possibility that long sequences of samples are at their saturation level. Such sequences with a length exceeding the delay of the SFC-16 would generate a larger-than-unity output signal which would be heavily distorted by output quantizing. Although deliberate signal clipping might be used, the SFC-16 has rather been designed with a slight level loss built into the digital processing. Thus, at the cost of an average signal level loss of 0.3dB, the SFC-16 processes all possible input signals without additional clipping or distortion.

The SFC-16 accepts input signals in a 16-bit format, and delivers 16-bit format output signals. Its internal dynamic ranges and scaling factors ensure operation in the linear domain exclusively. Due to finite stopband attenuations and limited internal signal word lengths, some amount of noise is folded back or otherwise added to the digital audio signal. Finally, output quantizing to the desired 16-bit format introduces quantization noise.

(Actually, larger wordlengths than 16 bits can be accommodated at the input and output with a slight but real improvement in audio performances).

The design of the SFC-16 (as confirmed by careful measurements) indicates that the input signal, which already displays a theoretical noise component with a level of -97.8dB (theoretical, and for a sinewave signal; state-of-the-art a-to-d conversion imposes much higher noise components), will be degrades by another noise component due to output quantizing at -97.8dB, plus a foldback-plus-quantizing component at -96dB maximum. The SNR will also be decreased by 0.3dB due to the shift in signal level between input and output.

Thus, the SFC-16 can, from the point of view of noise as spurious signals, be modelled as an ideal 16-bit quantizer plus a noise source with level -96dB, the whole system having an overall gain of -0.3dB. This means, incidentally, performances very much in excess of what might be achieved by cascading a d-to-a, an analog filter and an a-to-d.

Clock jitter has some effect on the SFC-16's behavior. Its own PLL circuitry is relatively wideband, and does not have the task of smoothing the clock signals, but only of tracking them. Short-term jitter suppression is made by digital filtering and averaging. An analysis of the noise component due to the finite conversion frequency of 2^{15} times the lower of the sampling frequencies indicates that jitter-induced noise will be particularly severe at high audio frequencies. The internal design of the SFC-16 is such that constant noise behavior is observed up to audio frequencies of 20kHz (at a sampling frequency of 48kHz) at maximum level.

The dynamic behavior of the clock signals imposes some limitations on the SFC-16. Clock signal jitter in excess of the PLL locking capability will cause the system to lose lock. The amount of jitter required for loss of lock, however, is far beyond what is required in a 16-bit digital audio system.

Very large clock jitter components must be considered as characteristic of a faulty or ill-designed system, and may cause errors. As a guideline, jitter values of 20 nanoseconds are tolerable.

Slow drift components in the sampling frequencies are accommodated and the SFC-16 adjusts to them automatically.

Fast variations in the sampling frequencies (which, incidentally, will always be accompanied by large distortion components due to intermodulation between the digital audio and the sampling signals) may cause the SFC-16 to lose lock and re-synchronize, due to buffer overflow. The maximum step size in sampling frequency (which depends to some extent on initial conditions) which can be accomodated with no possibility of lock loss is one quarter of a percent. The inability to operate with fast-varying sampling frequencies is no basic limitation of the digital approach to sampling frequency conversion, but a safety feature aiming at avoiding faulty operation with uncontrolled sampling frequencies. Sampling frequency converters designed for coping with the full specifications of, say, a digital recorder with varispeed control are perfectly possible.

Measuring the performance of the SFC-16 is not a trivial task. For one, no measuring equipment in existence today can quantify its performance directly; rather, complex indirect methods are required. Further, measuring the signal parameters in the digital domain, although quite possible, is certainly not within the reach of the normal user of an SFC-16. Finally, greatest care must be given while measuring to the elimination of non-idealities belonging to the measurement system (including clocks, d-to-a converters, analog filters and the measuring equipment itself).

The way the noise performance of the SFC-16 can be assessed is as follows. A digital sinewave generator with a 16-bit format - if properly designed - will yield a reference signal with 97.8dB signal-to-noise ratio. Operating first at the desired output sampling frequency, it will serve to calibrate the d-to-a converter system used in making the measurements. Measurements with a spectrum analyzer will indicate whether the d-to-a conversion system introduces nonlinearities. This calibration measurement yields a simple noise model for the d-to-a conversion system.

The preferred type of measurement equipment is the analog audio distortion measurement set as used in highest-accuracy analog audio measurements.

In the next step, the SFC-16 is inserted,with the digital sinewave generator now operating at the desired input sampling frequency and the output sampling frequency dictated to the SFC-16. The measured ratio of signal to spurious components (THD + noise) can be used for computing the amount of noise introduced by the SFC-16, and this amount of noise in its turn can be split into internal noise (due to foldback, finite word lengths and clock jitter) and the unavoidable output quantization noise. Due to the difficulty of making perfectly reproducible measurements at SNR's of approximately 90dB, there is a fundamental uncertainty in the results, but purely digital and direct measurements confirm the observed results quite well.

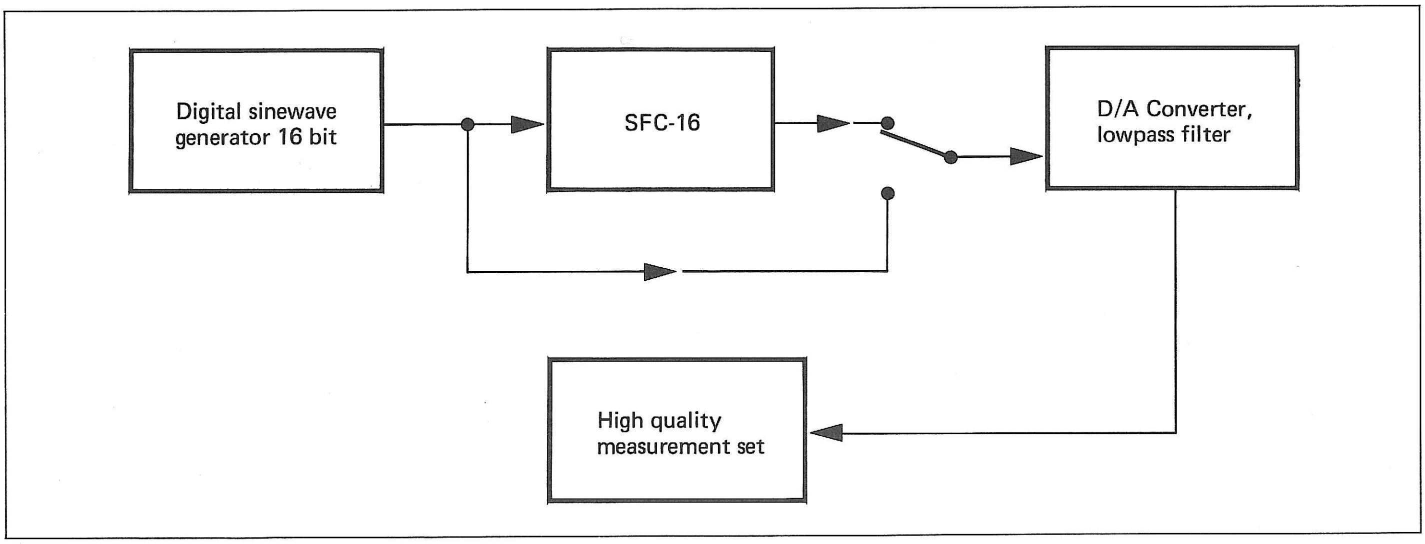


Fig. 2.8
Measuring setup

3. INSTALLATION, INTERFACING AND OPERATION

3.1 Installation

3.1.1 Introduction

This section provides the information needed to install the Sampling Frequency Converter (SFC). Included you find information pertinent to initial inspection, power requirements, line voltage selection, environment conditions, mounting, storage and shipment

3.1.2 Initial inspection

Inspect the shipping container for damage. If the container is damaged, it should be kept until the contents of the shipment have been checked for completeness and the SFC has been inspected mechanically and electrically.

If the contents are incomplete, if there is mechanical defect or damage, or if the equipment does not pass the electrical performance test, please contact the nearest STUDER office.

3.1.3 Power requirements

Voltage: 100, 120, 140, 200, 220, 240V +5% to -10%

Line frequency: 48 to 62Hz,single phase

Power consumption: 220VA max.

The SFC is a safety class I product (i.e. provided with a protective earth terminal). A safety earth ground must be provided from the main power source to the SFC input wiring terminals.

3.1.4 Line voltage and fuse selection

Before connecting the SFC to the supply voltage, make sure that the correct voltage and the according fuse have been selected:

Line voltage	Primary fuse
100, 120, 140V	3.15A
200, 220, 240V	1.6 A

3.1.5 Environment

The operating environment should not exceed the following ratings:

Temperature: +10°C to +35°C

Humidity : 95% relative

3.1.6 Mounting

The SFC has been designed for rack mounting.

> Make sure that a natural air flow can circulate through the perforated top and bottom covers of the SFC.
> Do not mount excessively heating equipment underneath the SFC!

3.1.7 Storage and shipment

If the SFC is being returned to STUDER for service:

- please attach a repair tag, describing the fault of the SFC as exactly as possible,
- wrap the SFC into heavy paper or plastic and use a strong shipping container,
- use enough shock-absorbing material around the whole equipment to provide firm cushion and prevent movement in the container,
- seal the shipping container securely,
- mark the shipping container "FRAGILE" to assure careful handling.

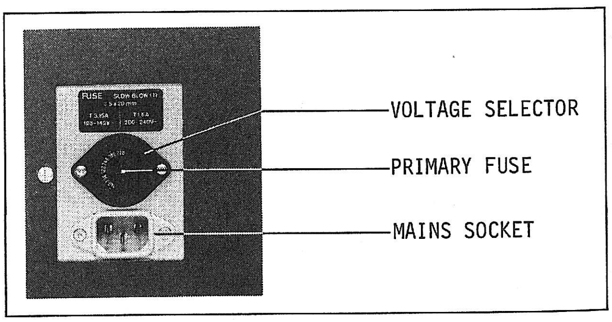


Fig. 3.1

3.2 Interfacing

3.2.1 Standard interface/custom interface

Because of the variety of interfaces, the user may order a custom made interface, or he may design an interface circuitry by himself and build it onto the interface board in the SFC.
If you have ordered a custom made interface, please refer to its description,enclosed to the equipment, for interfacing.

If you are going to build your own interface circuitry onto the interface board, the input/output description given in section 3.2.2 may be useful to you.
There should be space enough for your interfacing hardware on the interface board. About 40 IC sockets have been prepared for mini-wire-wrapping the hardware.

3.2.2 SFC input/output description

The information given in this section may be useful to customers who want to build their own interface circuitry onto the interface board located in the SFC.

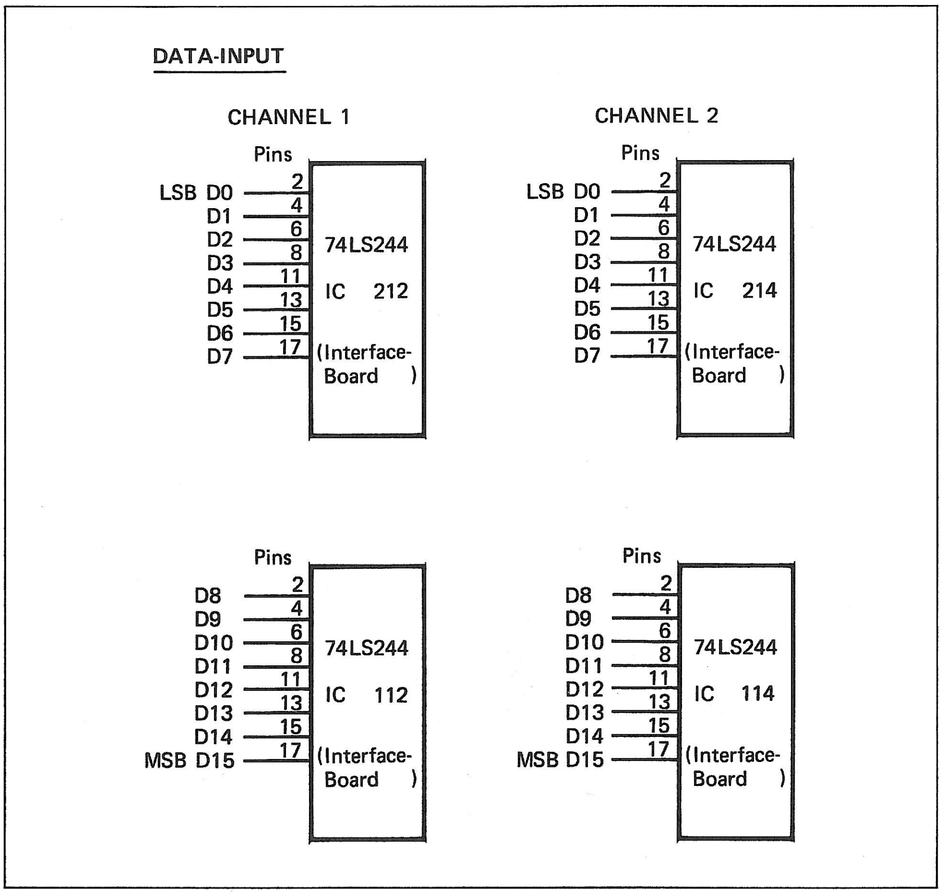


Fig. 3.2

Special care must be taken if parallel input interfacing will be implemented!
In this case remove the ICs 112, 114, 212, 214 on the interface board (see fig.3.5) and connect the input wires directly onto the backpanel connector of the interface board as follows:

LOWER CONNECTOR !

CHANNEL 1	Pin	CHANNEL 2	Pin
LSB D0	A2	LSB D0	C2
D1	A3	D1	C3
D2	A4	D2	C4
D3	A5	D3	C5
D4	A6	D4	C6
D5	A7	D5	C7
D6	A8	D6	C8
D7	A9	D7	C9
D8	A10	D8	C10
D9	A11	D9	C11
D10	A12	D10	C12
D11	A13	D11	C13
D12	A14	D12	C14
D13	A15	D13	C15
D14	A16	D14	C16
MSB D15	A17	MSB D15	C17

Fig. 3.3

Two clocks ($256xFs_{in}$ and $256xFs_{out}$) are available for interfacing purposes from IC 115 on the interface board. The lower of the two frequencies appears at pin 3, the higher at pin 5.
Another useful signal is the down/$\overline{up}$ signal that indicates the current working mode of the SFC. This signal appears at the lower connector pin A29. It may be used to switch over the two clocks ($256xFs_{in}$ and $256xFs_{out}$) mentioned above, so that in both up and down-mode the $256xFs_{in}$ and the $256xFs_{out}$ clock respectively always appear at the same pins:

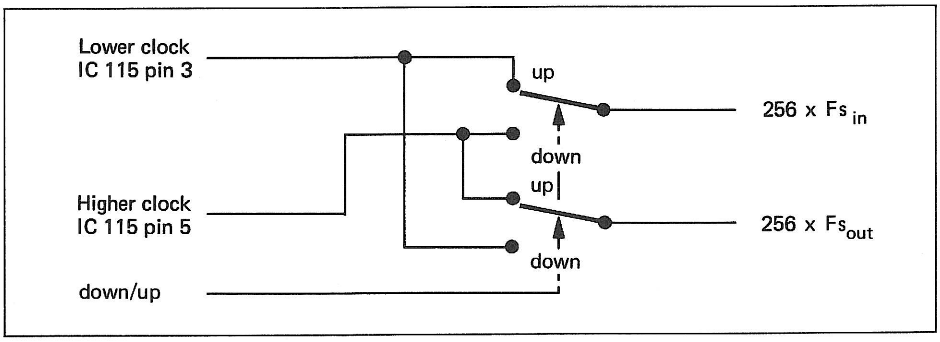


Fig. 3.4

INTERFACE-BOARD 1.610.010.00

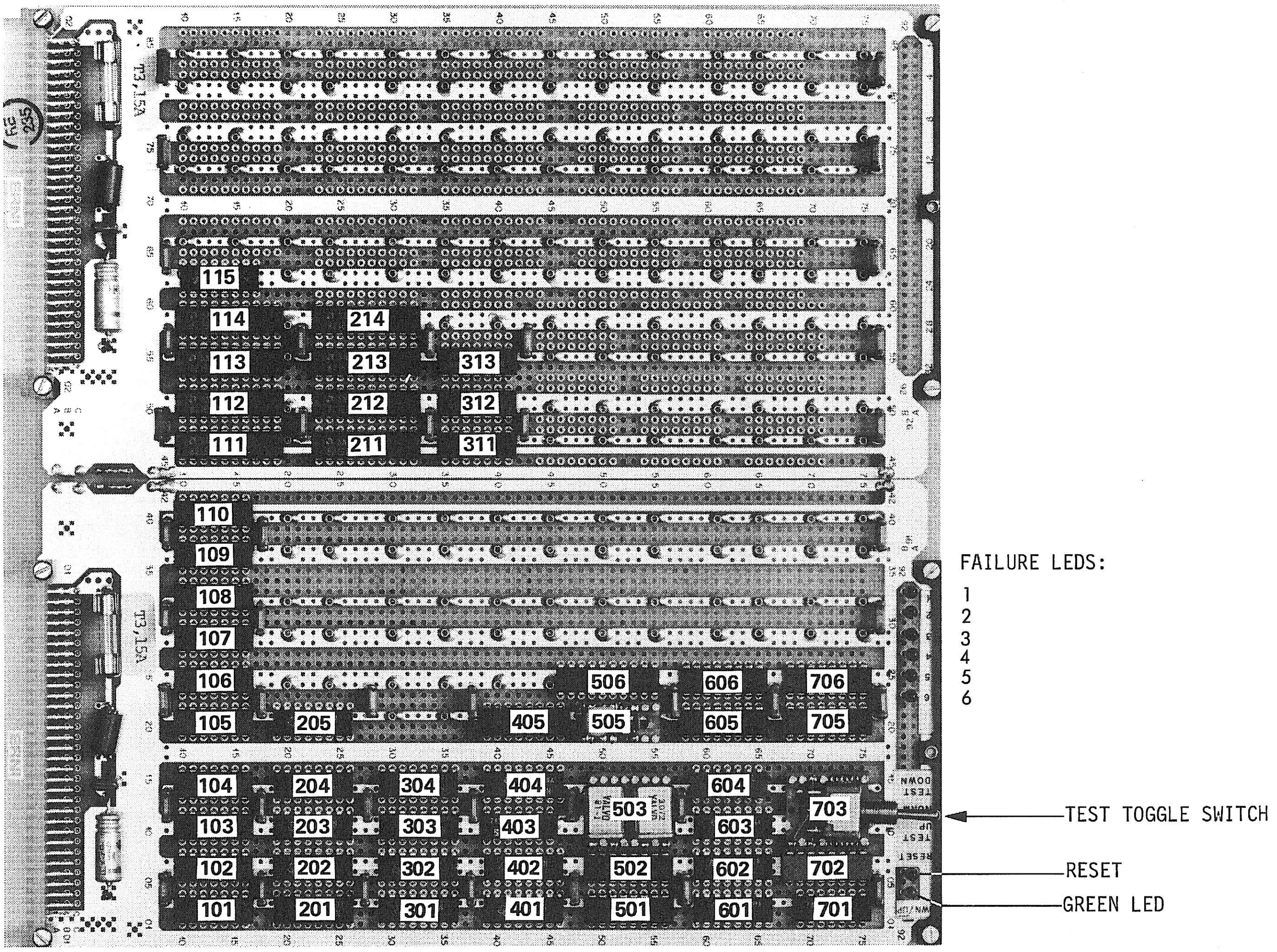
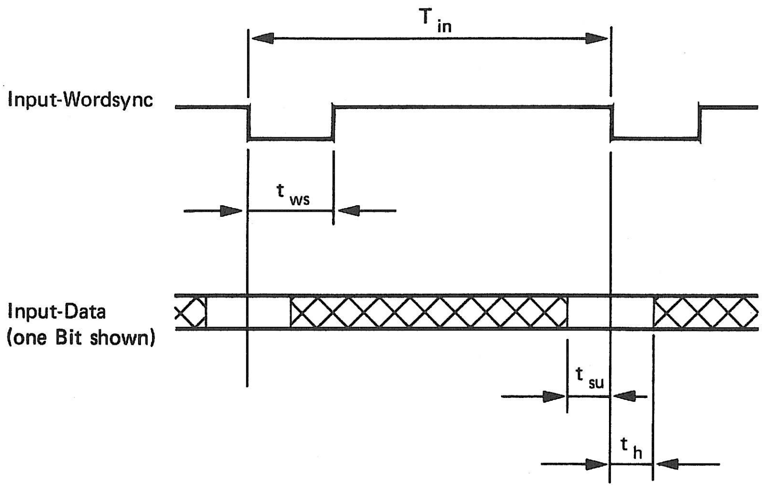


Fig. 3.5

IND.	POS.NO.	PART NO.	VALUE	SPECIFICATIONS / EQUIVALENT		MANUF.
	AS.0405	1.099.204.00		GLITCHSUPPRESSION ASSEMBLY		
	AS.0503	1.099.202.00		OSZILLATOR ASSEMBLY		
	AS.0703	1.099.203.00		UPDOWN ASSEMBLY		
	C..1001	59.25.3470	47u	-50%, 10V, ELECTROLYTIC	QUANTITY: 2	
	C..1002	59.99.0205	68n	-20%, 63v, CERAMIC	QUANTITY: 2	
	C..1003	59.99.0267	68n	-50%, 20V, CERAMIC	QUANTITY: 42	
	DL.0001	50.04.2129		LED, RED	QUANTITY: 7	
	DL.0002	50.04.2131		LED, GREEN		
	F..1001	51.01.0122		FUSE, T3.15/250V, 5*20mm	QUANTITY: 2	
	P..1001	54.01.0354		CARD CONNECTOR, 3*32 WRAP	QUANTITY: 2	
	RZ.03C5	57.85.3102	15*1 K	10%, DIL16		
	RZ.C405	57.88.3151	8*150	10%, DIL16		
	XF.1001	53.03.0142		CLAMP, 5*20	QUANTITY: 4	

IND.	POS.NO.	PART NO.	VALUE	SPECIFICATIONS / EQUIVALENT		MANUF.
IC.0101		50.06.0086		SN 74 LS 86 N	TTL	
IC.0102		50.06.0086		SN 74 LS 86 N	TTL	
IC.0103		50.06.0086		SN 74 LS 86 N	TTL	
IC.0104		50.06.0086		SN 74 LS 86 N	TTL	
IC.0105		50.06.0086		SN 74 LS 86 N	TTL	
IC.0106		50.06.0086		SN 74 LS 86 N	TTL	
IC.0107		50.06.0086		SN 74 LS 86 N	TTL	
IC.0108		50.06.0086		SN 74 LS 86 N	TTL	
IC.0109		50.06.0086		SN 74 LS 86 N	TTL	
IC.0110		50.06.0086		SN 74 LS 86 N	TTL	
IC.0111		50.06.0244		SN 74 LS 244 N	TTL-3	
IC.0112		50.06.0244		SN 74 LS 244 N	TTL-3	
IC.0113		50.06.0244		SN 74 LS 244 N	TTL-3	
IC.0114		50.06.0244		SN 74 LS 244 N	TTL-3	
IC.0115		50.15.0109		AM26 LS33 PC,DS26 LS33 CN		
IC.0201		50.06.0151		SN 74 LS 151 N	TTL	
IC.0202		50.06.0151		SN 74 LS 151 N	TTL	
IC.0203		50.06.0151		SN 74 LS 151 N	TTL	
IC.0204		50.06.0151		SN 74 LS 151 N	TTL	
IC.0205		50.06.0151		SN 74 LS 151 N	TTL	
IC.0206		50.06.0240		SN 74 LS 240 N	TTL-3	
IC.0211		50.06.0244		SN 74 LS 244 N	TTL-3	
IC.0212		50.06.0244		SN 74 LS 244 N	TTL-3	
IC.0213		50.06.0244		SN 74 LS 244 N	TTL-3	
IC.0214		50.06.0244		SN 74 LS 244 N	TTL-3	
IC.0301		50.06.0151		SN 74 LS 151 N	TTL	
IC.0302		50.06.0151		SN 74 LS 151 N	TTL	
IC.0303		50.06.0151		SN 74 LS 151 N	TTL	
IC.0304		50.06.0151		SN 74 LS 151 N	TTL	
IC.0306		50.06.0669		SN 74 LS 669 N		
IC.0311		50.06.0086		SN 74 LS 86 N	TTL	
IC.0312		50.06.0164		SN 74 LS 164 N	TTL	
IC.0313		50.06.0164		SN 74 LS 164 N	TTL	
IC.0401		50.06.0151		SN 74 LS 151 N	TTL	
IC.0402		50.06.0151		SN 74 LS 151 N	TTL	
IC.0403		50.05.0179		SN74S 00-N,	TTL	
IC.0404		50.06.0153		SN 74 LS 153 N	TTL	
IC.0406		50.06.0669		SN 74 LS 669 N		
IC.0501		50.06.0669		SN 74 LS 669 N		
IC.0502		50.06.0669		SN 74 LS 669 N		
IC.0504		50.05.0219		MC 4024 P ,	TTL	
IC.0505		50.06.0669		SN 74 LS 669 N		
IC.0601		50.06.0174		SN 74 LS 174 N	TTL	
IC.0602		50.06.0174		SN 74 LS 174 N	TTL	
IC.0603		50.06.0123		SN 74 LS 123 N	TTL	
IC.0605		50.06.0669		SN 74 LS 669 N		
IC.0701		50.06.0004		SN 74 LS 04 N	TTL	
L..1001		62.01.0115		INDUCTOR, RF-SUPPRESSION	QUANTITY: 2	
MP.1001		1.010.100.49		INSULATOR, 233*219mm, HGW		
MP.1002		1.010.101.49		SHEET METAL PLATE, 233*216mm		
MP.1003		1.010.030.49		EUROCARD, DOUBLE SIZE, 2*CU .3/.6" WRAP		
MP.1004		1.010.096.49		TRANSPARENT COVER	QUANTITY: 2	
MP.1005		1.010.128.49		POSITIONING PLATE	QUANTITY: 2	
MP.1006		1.010.006.33		MARKING HANDLE	QUANTITY: 4	
MP.1007		21.01.0280		SCREW, CYL. HEAD, M2.5*8	QUANTITY: 4	
MP.1008		21.01.0282		SCREW, CYL. HEAD, M2.5*12	QUANTITY: 4	
MP.1009		21.01.2278		SCREW, FLAT HEAD, M2.5*5	QUANTITY: 8	
MP.1010		28.21.1380		TUBULAR RIVET, D2.25*6.5mm	QUANTITY: 2	
MP.1011		1.010.008.54		CONTACT PIN, WRAP-L= 8,00	QUANTITY: 1650	
MP.1012		1.010.009.54		DUMMY PIN, WRAP-L= 8,00	QUANTITY: 280	
MP.1013		1.010.074.27		STAND-OFF, M2.5*11.0	QUANTITY: 4	
MP.1014		1.010.205.27		STAND-OFF, M2.5*13.0	QUANTITY: 4	
MP.1015		23.01.1025		WASHER D 2.5/5 *0.5	QUANTITY: 4	
MP.1016		24.16.1025		LOCK WASHER D 2.7/5 *0.5	QUANTITY: 8	
MP.1017		64.01.0345		WIRE, GN, D .255	LENGHT: 60000 mm	
MP.1018		1.610.010.01		NAME - PLATE		
MP.1019		1.610.010.02		NUMBER - PLATE		

INPUT TIMING



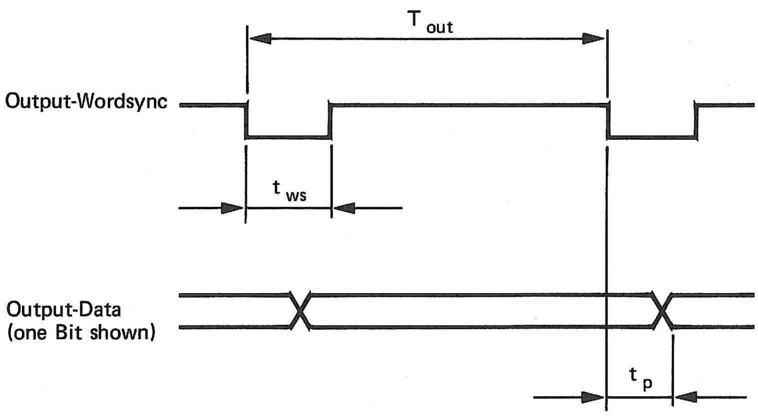
$t_{ws} = 0{,}025 \cdot T_{in} \ldots\ldots 0{,}975 \cdot T_{in}$ $\qquad$ $T_{in} = 1/fs_{in}$

$t_{su} \geq 0\ s$ $\qquad$ $30\ kHz \leq fs_{in} \leq 52\ kHz$

$t_h \geq 60\ ns$

Fig. 3.6

OUTPUT TIMING



$t_{ws} = 0{,}025 \cdot T_{out} \ldots\ldots 0{,}975 \cdot T_{out}$ $\qquad$ $T_{out} = 1/fs_{out}$

$t_p \leq 50\ ns$ $\qquad$ $30\ kHz \leq fs_{out} \leq 52\ kHz$

Fig. 3.7

DATA-OUTPUT

CHANNEL 1 Lower connector of interface board, pin:		CHANNEL 2 Lower connector of interface board, pin:	
A20	D0 LSB	C20	D0 LSB
A21	D1	C21	D1
A22	D2	C22	D2
A23	D3	C23	D3
A24	D4	C24	D4
A25	D5	C25	D5
A26	D6	C26	D6
A27	D7	C27	D7
A28	D8	C28	D8
B20	D9	B10	D9
B21	D10	B11	D10
B22	D11	B12	D11
B23	D12	B13	D12
B24	D13	B14	D13
B25	D14	B15	D14
B26	D15 MSB	B16	D15 MSB

Driven by 74LS244 Drivers

Fig. 3.8

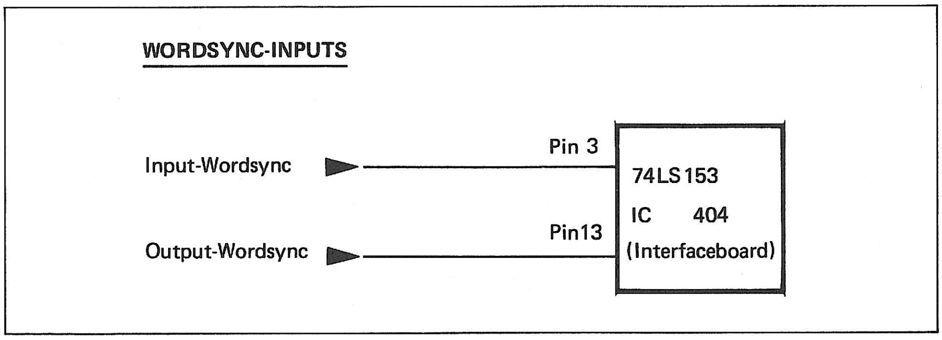


Fig. 3.9

3.3 Operation

3.3.1 Power-on procedure

Before you switch on the SFC, read sections 3.1.3 through 3.1.6 attentively.

Depress the power switch after having connected the mains cable and the input/output connectors.

Note

The input and output wordsyncs have to be apparent at the moment when you switch on the SFC.
After a power-up time of about 5 seconds, the SFC will be ready for operation.

3.3.2 Self-test

The SFC is equipped with a standard self test facility. The self test circuits are located on the interface and control board.
Two kinds of self tests are implemented, they are described below.

To initialize the self tests:

- Unplug the input/output connectors,
- Toggle the micro switch on the interface board out of its middle position in upward direction to test the up-mode,
- Toggle the micro switch through its middle position to the lower setting to test the down-mode.

In both tests all the red LEDs located on the interface board have to go out after about 5 seconds.

If one or more of the red LEDs stay lighted, please refer to section 6 (trouble shooting). This part of the self test checks all the filter 1, filter 2/buffer and filter 3/4 boards.

The control board will be checked by the second test:

- Toggle the micro switch on the interface board in its two test positions for up and down mode as described for the first test above.
- In addition toggle the push button switch on the control board through its 16 positions, indicated by four binary coded green LEDs on the control board.
- In none of the 16 states the red LED, adjacent to the four green ones, may light up. Otherwise please refer to section 6 (trouble shooting).
- Repeat this test with the toggle switch on the interface board in its lower position to check the down mode.

Do not forget to toggle the switch on the interface board to its middle position after the tests, otherwise the SFC will not work correctly!

4. HARDWARE DESCRIPTION

4.1
Front view

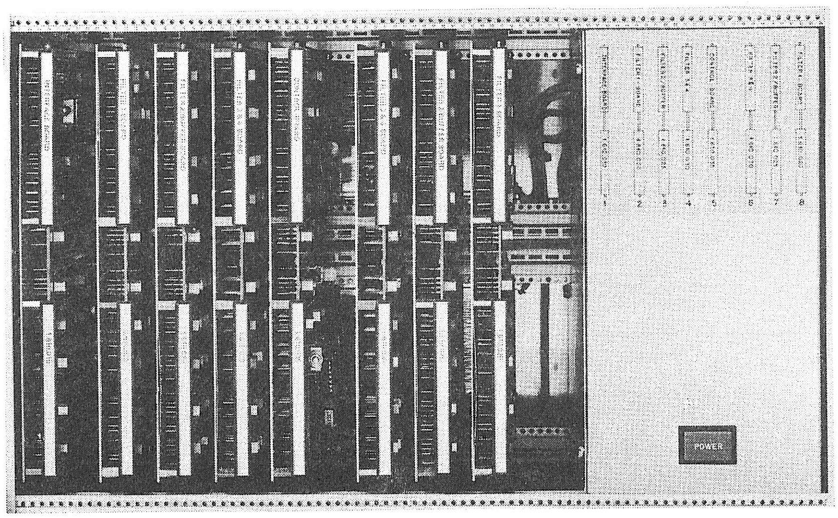


Fig. 4.1 shows the whole hardware of the SFC.

From left to right:

- Interface board 1.610.010 (common to channels 1+2)
- Filter 1 board of channel 2 1.610.020
- Filter 2/Buffer board of channel 2 1.610.025
- Filter 3/4 board of channel 2 1.610. 030
- Control board 1.610.035 (common to channels 1+2)
- Filter 3/4 board of channel 1 1.610.030
- Filter 2/Buffer board of channel 1 1.610.025
- Filter 1 board of channel 1 1.610.020
- Power supply with power switch (refer to section 4.3).

The filter boards are identical for both channels.

The interface board holds a self test facility beside the input/output interface for both channels.

4.2 Rear view

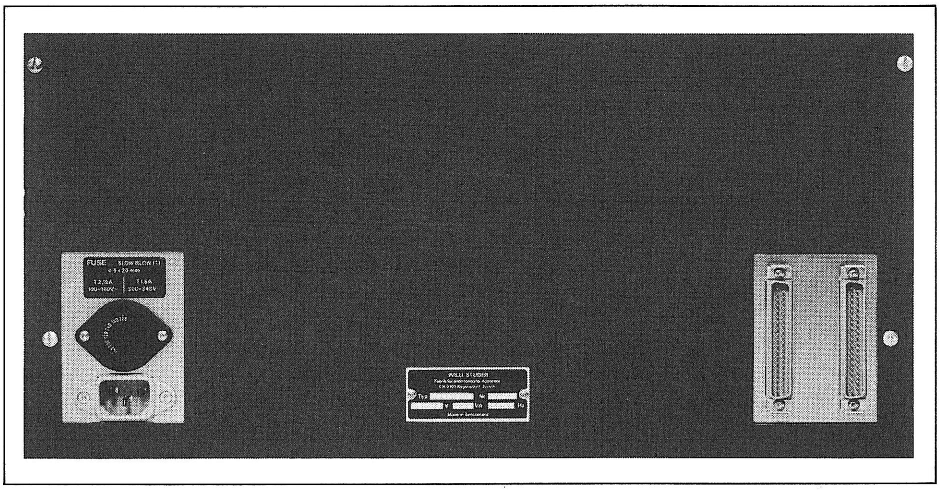


Figure 4.2 shows from left to right:

- Power socket and mains voltage selector including the primary fuse,
- Type label
- Input connector D-type 37 poles male (left)
- Output connector D-type 37 poles male (right) (refer to section 4.4).

4.3 Power supply

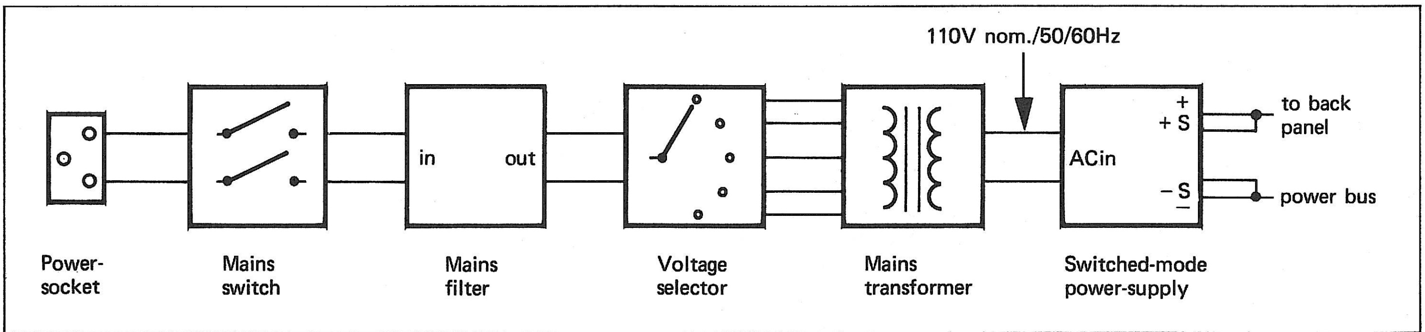


Figure 4.3 shows a block diagram of the power supply:

The switched mode power supply should have a voltage of 5.00V at its sensing connections.
The boards consume a current of about 25amps DC.

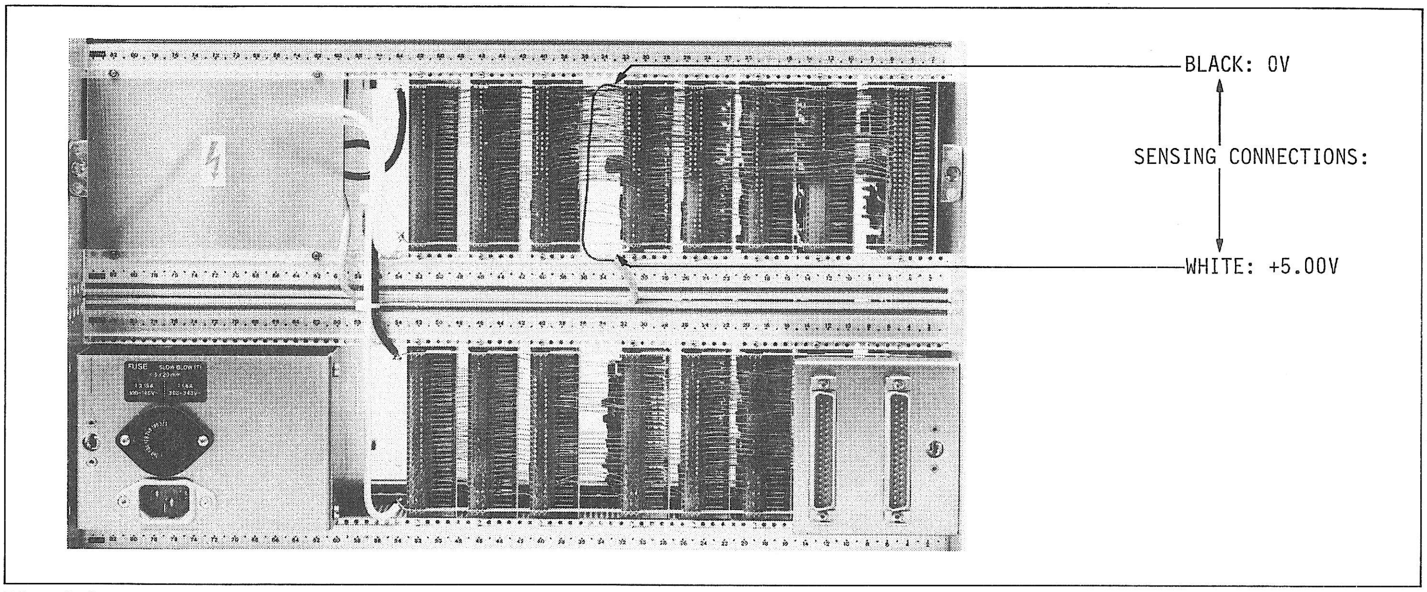


Fig. 4.4

4.4 Input/output connectors

The pinout of these connectors depends on whether the SFC includes a custom made interface or not.
If you have received a SFC including a custom made interface please refer to its enclosed description.
For further information on this subject please refer to section 3.2.2

5. TECHNICAL SPECIFICATIONS

5.1 Data input/output

Input wordlength : 16Bit

Output wordlength: 16Bit

Input sampling frequency range : 30kHz to 52kHz

Output sampling frequency range: 30kHz to 52kHz

5.2 AC power

Mains voltage: 100/120/140/200/220/240V

Line frequency: 48 to 62Hz

AC power consumption: 220VA max.

Primary fuse: 3.15A slow blow for 100-140V operation
1.6 A slow blow for 200-240V operation

5.3 Frequency response

Input sampling frequency : 44.1kHz Output sampling frequency: 48.0kHz	±0.2dB from 0 to 20kHz
Input sampling frequency : 48.0kHz Output sampling frequency: 44.1kHz	±0.2dB from 0 to 20kHz

Remark
Due to the filter ripple of about 0.2dB it was necessary to reduce the overall gain of the SFC by about 0.3dB.
With this provision the SFC is capable to handle signals wich approach the clipping level even during several consecutive samples without distortion.

5.4 Signal to noise ratio (SNR)

SNR for input sampling frequency smaller or equal to output sampling frequency: up mode

Input amplitude 0dB, 1kHz SNR: greater than 96dB

Input amplitude 0dB, 10kHz SNR: greater than 96dB

SNR for input sampling frequency greater than output sampling frequency: down mode

Input amplitude 0dB, 1kHz SNR: greater than 96dB

Input amplitude 0dB, 10kHz SNR: greater than 96dB

Measurement set-up

The imperfections of the measurement set-up, especially the noise and distortion of the D/A-converter have been taken into consideration in the measurement results above.

An example:

Input amplitude to the SFC: -12dB , so that the D/A's distortions are eliminated. Because of this, 12dB have to be added to the measurement results.

Then:

1. Measure the D/A performance without the SFC.
   Result: +A dB
2. Measure the whole system including the SFC.
   Result: +B dB
3. Calculate the S/N ratio of the SFC by eliminating the D/A's noise:

Formulas:

$$X = (10^{-B/20})^2 - (10^{-A/20})^2$$

$$S/N = 20 \cdot \log(\sqrt{X}) \quad [dB]$$

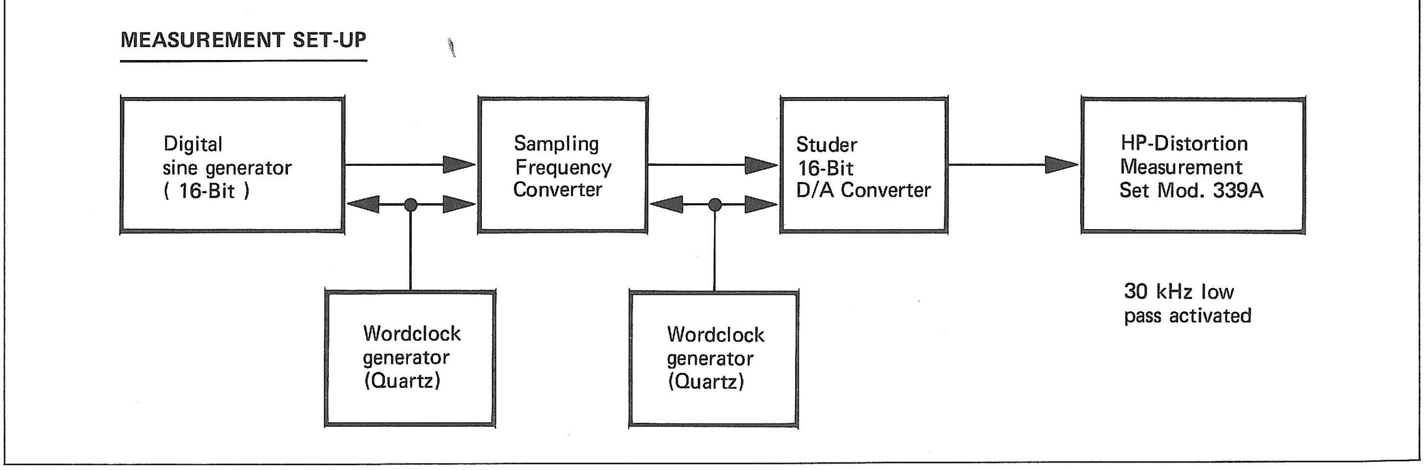
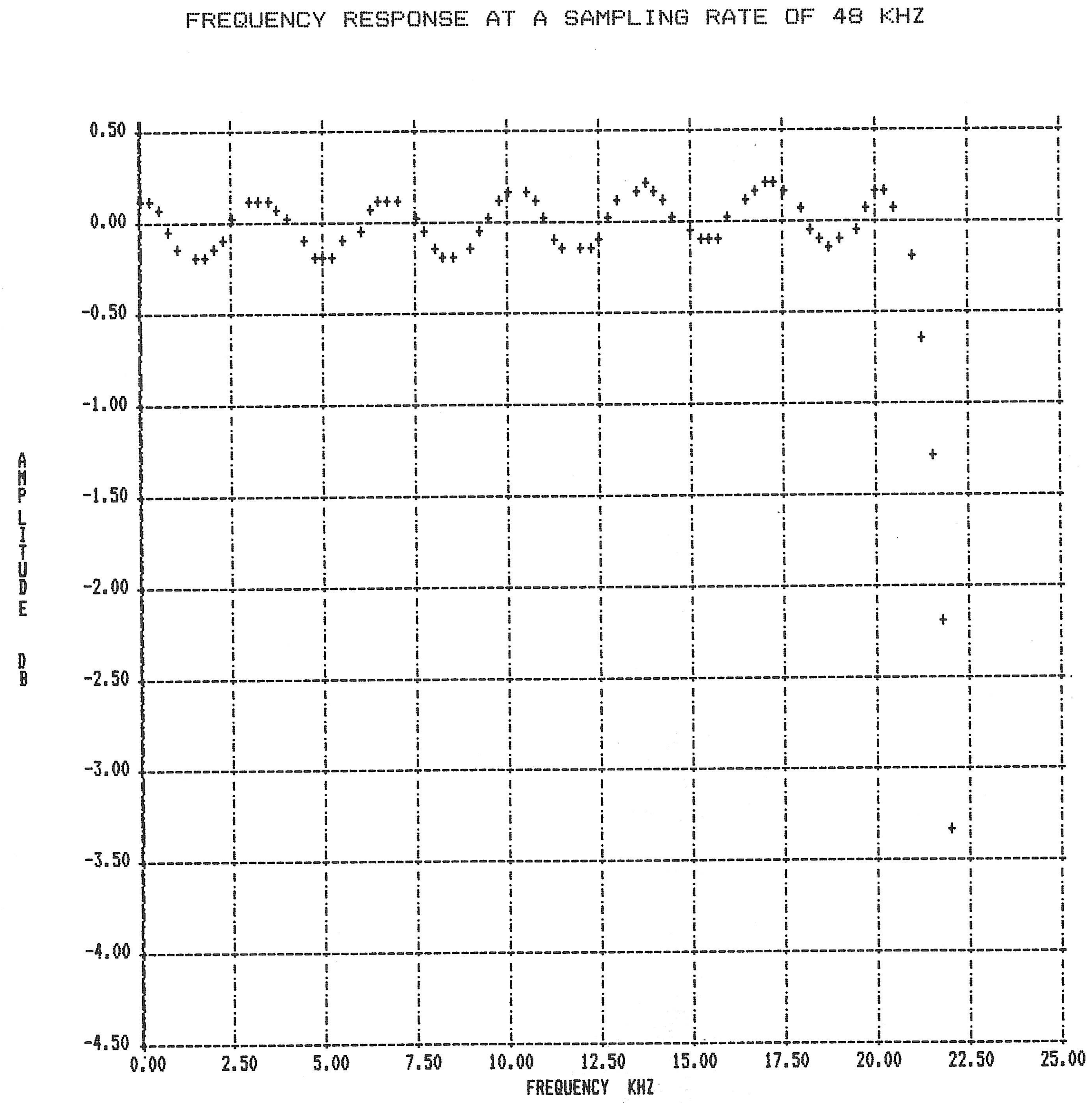


Fig. 5.1

FREQUENCY RESPONSE OF A SFC–16 F_s=48kHz



6. TROUBLE SHOOTING

Equipment problems usually fall into three general categories:

- operator errors
- operation out of specification
- catastrophic failures

The trouble shooting strategy is different for each category.

6.1 Operator errors, operation out of specification

Apparent failures sometimes can result from using the SFC out of its range. Make sure that input and output sampling frequencies are within the limits of 30kHz to 52kHz. Also check the voltage swing at the data and sampling frequency inputs for the proper values.
(For TTL interfacing:- about 0Volts for a logic 0
- about 4Volts for a logic 1)

Refer to section 3.3 for operation checks.

6.2 Catastrophic failures

Begin the troubleshooting of catastrophic failures by performing the troubleshooting checks in section 6.3. The checks will lead you through all troubleshooting possibilities associated with the self test features of the SFC.

Remark
The SFC is working in either up mode or down mode. Up mode means that the output sampling frequency is greater than the input sampling frequency, down mode vice versa.

6.3 Trouble shooting

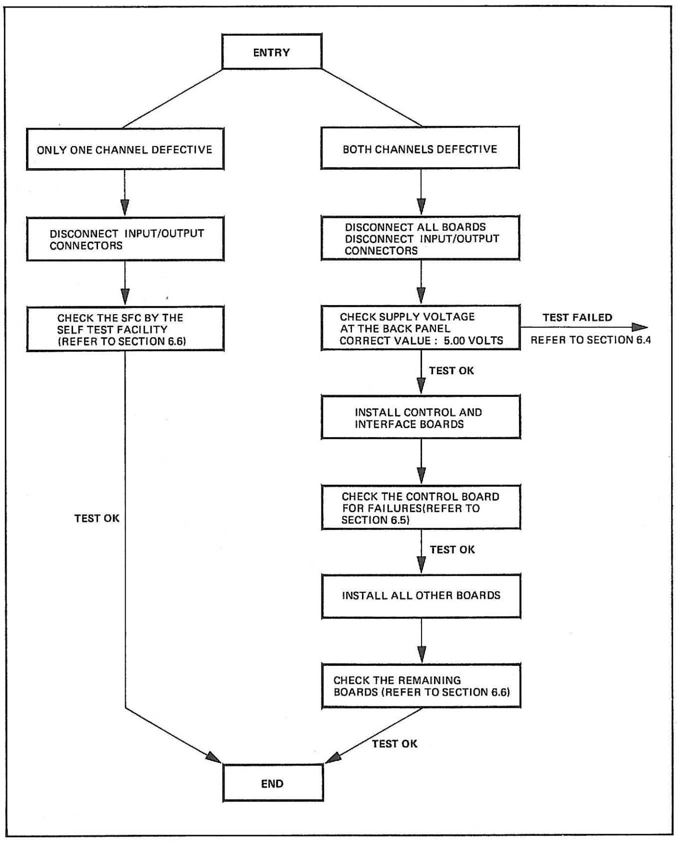


Fig. 6.1

6.4
Power supply debugging

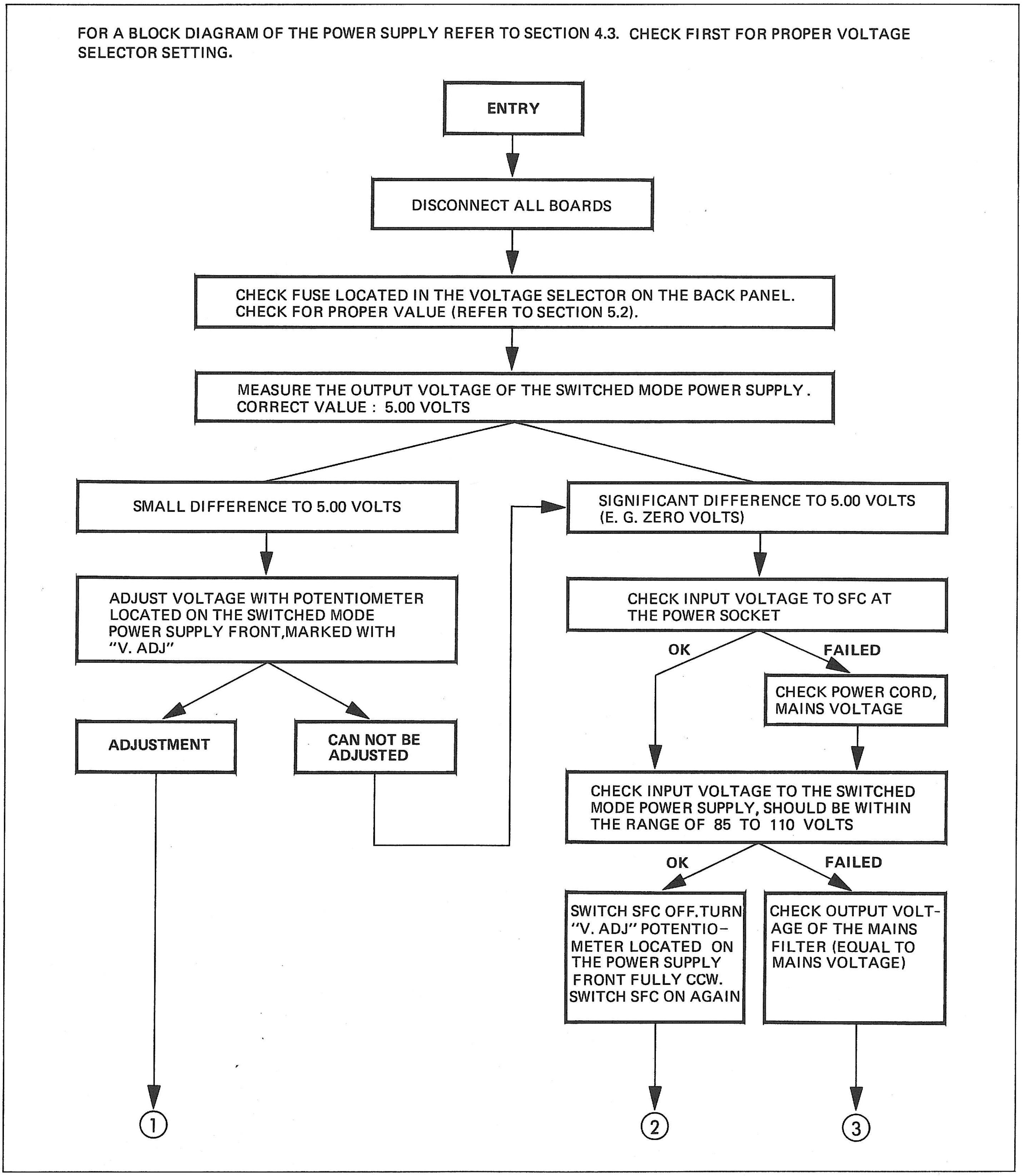


Fig. 6.2a

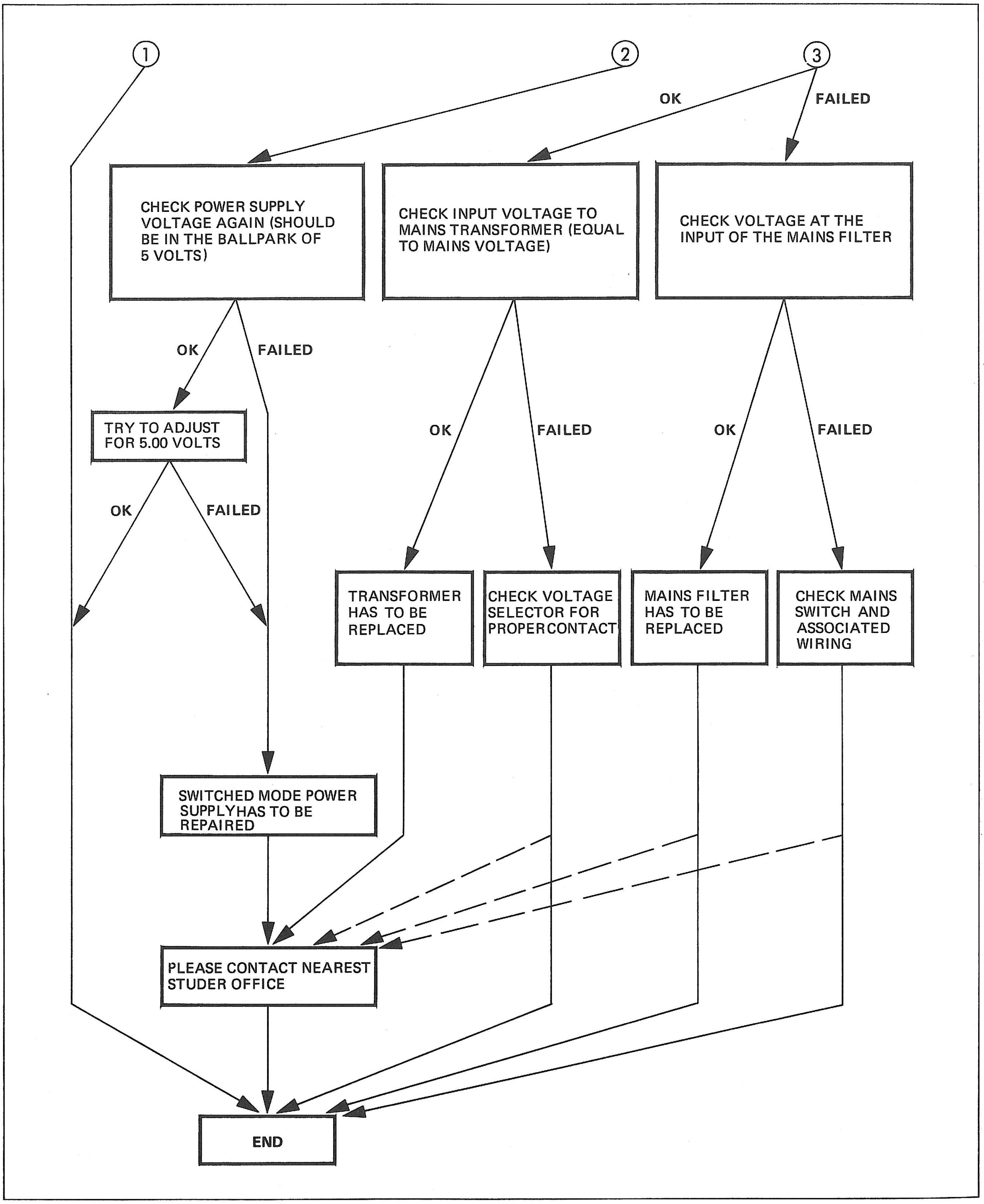

1
2
3
OK
FAILED
CHECK POWER SUPPLY VOLTAGE AGAIN (SHOULD BE IN THE BALLPARK OF 5 VOLTS)
CHECK INPUT VOLTAGE TO MAINS TRANSFORMER (EQUAL TO MAINS VOLTAGE)
CHECK VOLTAGE AT THE INPUT OF THE MAINS FILTER
OK
FAILED
TRY TO ADJUST FOR 5.00 VOLTS
OK
FAILED
OK
FAILED
OK
FAILED
TRANSFORMER HAS TO BE REPLACED
CHECK VOLTAGE SELECTOR FOR PROPERCONTACT
MAINS FILTER HAS TO BE REPLACED
CHECK MAINS SWITCH AND ASSOCIATED WIRING
SWITCHED MODE POWER SUPPLYHAS TO BE REPAIRED
PLEASE CONTACT NEAREST STUDER OFFICE
END

Fig. 6.2b

6.5
Control board testing

6.5.1
Preparing for control board test

- Turn power off.
- Disconnect all boards except the control and the interface board.
- Disconnect the input and output connectors.
- Toggle the switch on the interface board in its upper position (establishes up mode, green LED dark).
- Turn power on.

The SFC passes now the power up sequence. This sequence will not be checked by the self test, it is best monitored at some pins of the control board connectors:

upper connector pin C26 lower connector pin C26	the levels of these two pins have to changeover to logic 1 after ca. 0.3 seconds after power up.
lower connector pin C29:	level must changeover to logic 1 after more than 0.5 seconds after power on.

During the power up period (0.5seconds), the top-most red LED on the interface board stays lighted. If serious errors occur, it is possible that this LED keeps blinking (see later).

Before you execute the self test, check whether the PLLs on the control board are in lock or not:

First PLL

Oscilloscope trigger input: lower connector pin C13
Oscilloscope Y-input : lower connector pin B28

The signal on the screen has to be stable (not moving)

Second PLL

Oscilloscope trigger input: lower connector pin C23
Oscilloscope Y-input : upper connector pin B28

The signal on the screen has to be stable (not moving)

If any of the two PLLs is not in lock, check the following ICs on the control board (see fig. 6.1):

both PLL boards,
112,
311, 312, 313,
412, 413,
605, 607.

For the following tests it is necessary, that both PLLs operate properly.

If the above mentioned red LED keeps blinking, check the following ICs on the control board:

101, 102, 103, 104, 105, 106, 107, 110,
201, 202, 203, 205, 206, 207, 208,
302, 303, 304, 305, 306, 309, 310,
401, 402, 403, 404, 405, 406, 407, 408, 409, 410,
502, 504.

6.5.2
Self test of the control board 1.610.035

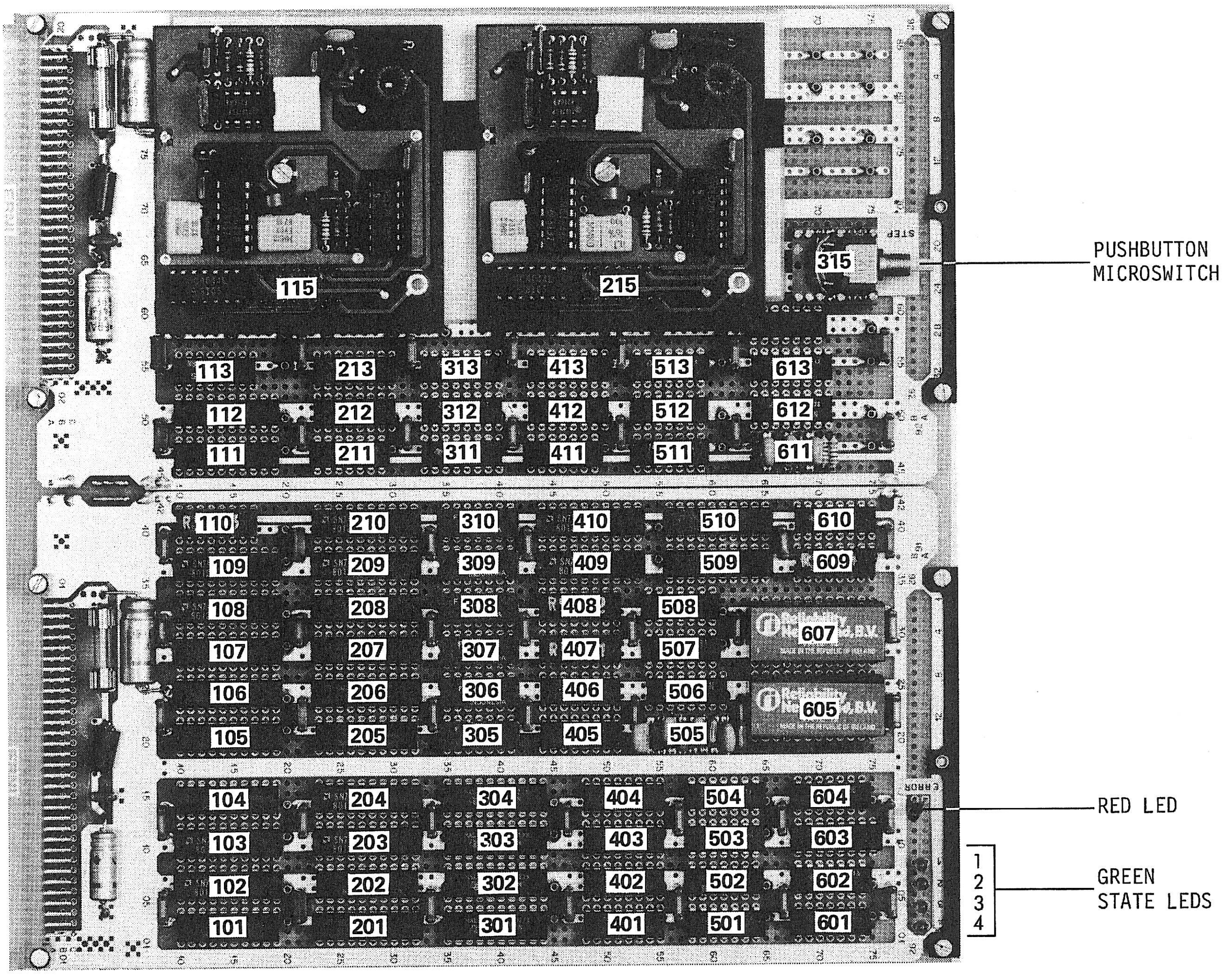


Fig. 6.3

Before executing the self test, it is necessary that all tests in section 6.5.1 have been successfully terminated:

- The topmost LED on the interface board stays dark (No more resets)

- The green LED on the control board indicates up mode (LED dark)

You are able to step the four binary coded green LEDs on the control board through their 16 states by means of the pushbutton switch underneath of these LEDs.

The 16 states correspond to different testings of the control board. If in a particular state a failure occurs, the red LED on the control board will light up.

For all failures there are several states in which the red LED lights. These states are listed below including possible defective ICs.

IND.	POS.NO.	PART NO.	VALUE	SPECIFICATIONS / EQUIVALENT	MANUF.
	AS.0115	1.610.038.00		PLL-BOARD	
	AS.0215	1.610.038.00		PLL-BOARD	
	AS.0315	1.099.205.00		TESTING ASSEMBLY	
	AS.0505	1.099.200.00		POWER-FILTER ASSEMBLY	
	AS.0611	1.099.201.00		POWERUP ASSEMBLY	
	C..0004	59.25.1471	470U	-10%, 6V ELECTROLYTIC QUANTITY: 2	
	C..1001	59.25.3470	47u	-50%, 10V, ELECTROLYTIC QUANTITY: 2	
	C..1002	59.99.0205	68n	-20%, 63v, CERAMIC QUANTITY: 2	
	C..1003	59.99.0267	68n	-50%, 20V, CERAMIC QUANTITY: 49	
	DL.0001	50.04.2129		LED, RED	
	DL.0002	50.04.2131		LED, GREEN QUANTITY: 4	
	F..1001	51.01.0122		FUSE, T3.15/250V, 5*20mm QUANTITY: 2	
	IC.0101	50.06.0244		SN 74 LS 244 N TTL-3	
	IC.0102	50.06.0273		SN 74 LS 273 N TTL	
	IC.0103	50.06.0273		SN 74 LS 273 N TTL	
	IC.0104	50.06.0244		SN 74 LS 244 N TTL-3	
	IC.0105	50.06.0374		SN 74 LS 374 N TTL	
	IC.0106	50.06.0374		SN 74 LS 374 N TTL	
	IC.0107	50.06.0374		SN 74 LS 374 N TTL	
	IC.0108	50.06.0273		SN 74 LS 273 N TTL	
	IC.0109	50.06.0273		SN 74 LS 273 N TTL	
	IC.0110	50.05.0211		N82S131F ,TTL-3	
	IC.0111	50.06.0240		SN 74 LS 240 N TTL-3	
	IC.0112	50.06.0240		SN 74 LS 240 N TTL-3	
	IC.0113	50.05.0236		N 8T97B . ,TTL-3	
	IC.0114	50.06.0000		SN 74 LS 00 N TTL	
	IC.0201	50.06.0374		SN 74 LS 374 N TTL	
	IC.0202	50.06.0244		SN 74 LS 244 N TTL-3	
	IC.0203	50.06.0273		SN 74 LS 273 N TTL	
	IC.0204	50.06.0273		SN 74 LS 273 N TTL	
	IC.0205	50.06.0244		SN 74 LS 244 N TTL-3	
	IC.0206	50.06.0374		SN 74 LS 374 N TTL	
	IC.0207	50.06.0374		SN 74 LS 374 N TTL	
	IC.0208	50.06.0374		SN 74 LS 374 N TTL	
	IC.0209	50.06.0273		SN 74 LS 273 N TTL	
	IC.0210	50.06.0273		SN 74 LS 273 N TTL	
	IC.0211	50.06.0074		SN 74 LS 74 N TTL	
	IC.0212	50.15.0108		AM26 LS 31 PC,AM26 LS31 CN	
	IC.0213	50.15.0108		AM26 LS 31 PC,AM26 LS31 CN	
	IC.0301	50.06.0382		SN 74 LS 382 N,	
	IC.0302	50.06.0382		SN 74 LS 382 N,	
	IC.0303	50.06.0382		SN 74 LS 382 N,	
	IC.0304	50.06.0382		SN 74 LS 382 N,	
	IC.0305	50.07.0021		F 4731 BDC, ,A	
	IC.0306	50.07.0021		F 4731 BDC, ,A	
	IC.0307	50.07.0021		F 4731 BDC, ,A	
	IC.0308	50.07.0021		F 4731 BDC, ,A	
	IC.0309	50.07.0021		F 4731 BDC, ,A	
	IC.0310	50.07.0021		F 4731 BDC, ,A	
	IC.0311	50.06.0153		SN 74 LS 153 N TTL	
	IC.0312	50.12.0003		SN 74S 169 N, N74 S 169N,	
	IC.0313	50.12.0003		SN 74S 169 N, N74 S 169N,	
	IC.0401	50.06.0161		SN 74 LS 161 N TTL	
	IC.0402	50.06.0161		SN 74 LS 161 N TTL	
	IC.0403	50.06.0161		SN 74 LS 161 N TTL	
	IC.0404	50.06.0161		SN 74 LS 161 N TTL	
	IC.0405	50.06.0161		SN 74 LS 161 N TTL	
	IC.0406	50.06.0161		SN 74 LS 161 N TTL	
	IC.0407	50.05.0206		82 S 123	
	IC.0408	50.05.0206		82 S 123	
	IC.0409	50.06.0273		SN 74 LS 273 N TTL	
	IC.0410	50.06.0273		SN 74 LS 273 N TTL	
	IC.0411	50.06.0086		SN 74 LS 86 N TTL	
	IC.0412	50.12.0003		SN 74S 169 N, N74 S 169N,	
	IC.0413	50.12.0003		SN 74S 169 N, N74 S 169N,	
	IC.0501	50.06.0074		SN 74 LS 74 N TTL	
	IC.0502	50.06.0008		SN 74 LS 08 N TTL	
	IC.0503	50.06.0074		SN 74 LS 74 N TTL	
	IC.0504	50.05.0197		SN74S04N 74S04 PC , TTL	
	IC.0506	50.06.0151		SN 74 LS 151 N TTL	

IND.	POS.NO.	PART NO.	VALUE	SPECIFICATIONS / EQUIVALENT		MANUF.
	IC.0507	50.06.0004		SN 74 LS 04 N	TTL	
	IC.0508	50.06.0008		SN 74 LS 08 N	TTL	
	IC.0509	50.06.0374		SN 74 LS 374 N	TTL	
	IC.0510	50.06.0374		SN 74 LS 374 N	TTL	
	IC.0511	50.06.0032		SN 74 LS 32 N	TTL	
	IC.0512	50.06.0008		SN 74 LS 08 N	TTL	
	IC.0513	50.06.0074		SN 74 LS 74 N	TTL	
	IC.0601	50.06.0002		SN 74 LS 02 N	TTL	
	IC.0602	50.06.0074		SN 74 LS 74 N	TTL	
	IC.0603	50.06.0669		SN 74 LS 669 N		
	IC.0604	50.05.0179		SN74S 00-N,	TTL	
	IC.0605	50.99.0137		VA 12-12 PM 651 ,DV-CONV		
	IC.0607	50.99.0137		VA 12-12 PM 651 ,DV-CONV		
	IC.0609	50.05.0211		N82S131F ,TTL-3		
	IC.0610	50.06.0153		SN 74 LS 153 N	TTL	
	IC.0612	50.06.0123		SN 74 LS 123 N	TTL	
	IC.0613	50.06.0123		SN 74 LS 123 N	TTL	
	L..1001	62.01.0115		INDUCTOR, RF-SUPPRESSION	QUANTITY: 2	
	MP.0021	21.01.0354		SCREW, CYL. HEAD, M 3*6	QUANTITY: 2	
	MP.0022	24.16.1030		LOCK WASHER D 3.2/5.5 *.45	QUANTITY: 2	
	MP.0023	1.010.004.54		CONNECTOR - PIN D 1*10	QUANTITY: 4	
	MP.1001	1.010.100.49		INSULATOR, 233*219mm, HGW		
	MP.1002	1.010.101.49		SHEET METAL PLATE, 233*216mm		
	MP.1003	1.010.030.49		EUROCARD, DOUBLE SIZE, 2*CU .3/.6" WRAP		
	MP.1004	1.010.096.49		TRANSPARENT COVER	QUANTITY: 2	
	MP.1005	1.010.128.49		POSITIONING PLATE	QUANTITY: 2	
	MP.1006	1.010.006.33		MARKING HANDLE	QUANTITY: 4	
	MP.1007	21.01.0280		SCREW, CYL. HEAD, M2.5*8	QUANTITY: 4	
	MP.1008	21.01.0282		SCREW, CYL. HEAD, M2.5*12	QUANTITY: 4	
	MP.1009	21.01.2278		SCREW, FLAT HEAD, M2.5*5	QUANTITY: 8	
	MP.1010	28.21.1380		TUBULAR RIVET, D2.25*6.5mm	QUANTITY: 2	
	MP.1011	1.010.008.54		CONTACT PIN, WRAP-L= 8,00	QUANTITY: 2000	
	MP.1012	1.010.009.54		DUMMY PIN, WRAP-L= 8,00	QUANTITY: 280	
	MP.1013	1.010.074.27		STAND-OFF, M2.5*11.0	QUANTITY: 4	
	MP.1014	1.010.205.27		STAND-OFF, M2.5*13.0	QUANTITY: 4	
	MP.1015	23.01.1025		WASHER D 2.5/5 *0.5	QUANTITY: 4	
	MP.1016	24.16.1025		LOCK WASHER D 2.7/5 *0.5	QUANTITY: 8	
	MP.1017	64.01.0345		WIRE, GN, D .255	LENGHT: 83000 mm	
	MP.1018	1.610.035.01		NAME - PLATE		
	MP.1019	1.610.035.02		NUMBER - PLATE		
	MP.1020	1.610.035.03		STAND - OFF M3	QUANTITY: 2	
	P..1001	54.01.0354		CARD CONNECTOR, 3*32 WRAP	QUANTITY: 2	
	XF.1001	53.03.0142		CLAMP, 5*20	QUANTITY: 4	

Green LEDs	1 ≙ LED lighted 0 ≙ LED dark X ≙ red LED lighted																possible defective ICs
4th (top)	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	
3rd	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1	
2nd	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	
1st (bottom)	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	
	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	201, 202, 205, 206, 207, 208 405, 406, 407, 408, 409, 410
	X	X	X	X	X	X	X	X			X	X	X	X	X	X	103, 203, 204, 303, 304, 307, 308, 309, 310 405, 406, 407, 408, 409, 410
	X	X	X	X	X	X	X	X					X	X	X	X	201, 202, 205, 206, 207, 208 402, 405, 406, 407, 408, 409, 410 504 602
	X	X	X	X	X	X							X	X	X	X	201, 202, 205, 206, 207, 208 405, 406, 407, 408, 409, 410
	X	X									X	X	X	X	X	X	201, 202, 205, 206, 207, 208 405, 406, 407, 408, 409, 410
	X	X			X	X	X	X					X	X	X	X	405, 406, 407, 408, 409, 410 503, 504
	X		X	X	X	X	X	X					X	X	X	X	401, 405, 406, 407, 408, 409, 410 501 601, 604
	X		X	X	X	X							X	X	X	X	401, 402, 405, 406, 407, 408, 409, 410
		X	X	X	X	X	X	X					X	X	X	X	403, 405, 406, 407, 408, 409, 410 502, 503 601, 604
		X	X	X	X	X							X	X	X	X	403, 404, 405, 406, 407, 408, 409, 410
			X	X	X	X	X	X					X	X	X	X	204 303 405, 406, 407, 408, 409, 410 504
			X	X	X	X							X	X	X	X	203, 204 303 405, 406, 407, 408, 409, 410
			X	X			X	X					X	X	X	X	203, 204 303 405, 406, 407, 408, 409, 410
			X	X	X	X											201, 202, 205, 206, 207, 208 405, 406, 407, 408, 409, 410

4th (top)	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	
3rd	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1	
2nd	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	
1st (bottom)	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	
					X	X	X	X					X	X	X	X	204 401, 405, 406, 407, 408, 409, 410
					X	X	X	X									201, 202, 203, 204, 205, 206, 207, 208 304 405, 406, 407, 408, 409, 410 501, 504
					X	X											204 405, 406, 407, 408, 409, 410
							X	X									204 405, 406, 407, 408, 409, 410
									X	X	X	X					101, 104, 105, 106, 107 405, 406, 407, 408, 409, 410
											X	X	X	X	X	X	102 302 405, 406, 407, 408, 409, 410
											X	X	X	X			301 405, 406, 407, 408, 409, 410
											X		X	X			102, 103 405, 406, 407, 408, 409, 410
													X	X	X	X	101, 102, 104, 105, 106, 107 301, 302 405, 406, 407, 408, 409, 410 502

After having tested and debugged the control board in up mode, you may test it in down mode:

Please toggle the switch on the interface board fully downward.

The green LED above the switch should now light up to indicate the down mode.
Now, go back to the debugging table of this section and proceed as described therein.

Do not forget to toggle the switch on the interface board back to its middle position after having tested the SFC.

6.6 SFC self test (except control board)

6.6.1 Preparing for the SFC self test

For this test it is necessary that one channel operates correctly because the self test facility checks the boards following the principle of comparison and therefore looks for differencies between the two channels.

- Switch power off.
- Install all boards.
- Disconnect the input and output connectors.
- Toggle the switch to upper or lower position according to the mode you want to check (up or down mode).
- It is good practice to test the SFC in both modes in case of failure, so you are able to replace only those ICs which are really suspected of beeing defective:

defective in	Replace ICs which...
up mode only	appear in the up mode list only
down mode only	appear in the down mode list only
both modes	appear in both lists only

- Turn power on.

  During the power up period (0.5seconds), the topmost red LED on the interface board stays lit. If serious errors occur it is possible that this LED keeps blinking.

In this case, please check the following ICs:

Up mode:

Filter 2: 113, 115, 116, 117, 118, 119
213, 215, 216, 217, 219
311, 312, 315, 316
403, 404, 408
503, 504
607

Filter 3: 301, 305, 307, 308, 309
407, 409
509

Down mode:

Filter 2: 112, 113, 115, 116, 117, 118, 119
213, 215, 216, 217, 218, 219
311, 312, 315, 316
403, 404, 408
504
607

Filter 3: 307, 308, 309
401, 403, 407, 409
509

For further checks it is necessary that the red LED on the interface board stays dark (no resets).

Filter 1 Board 1.610.020

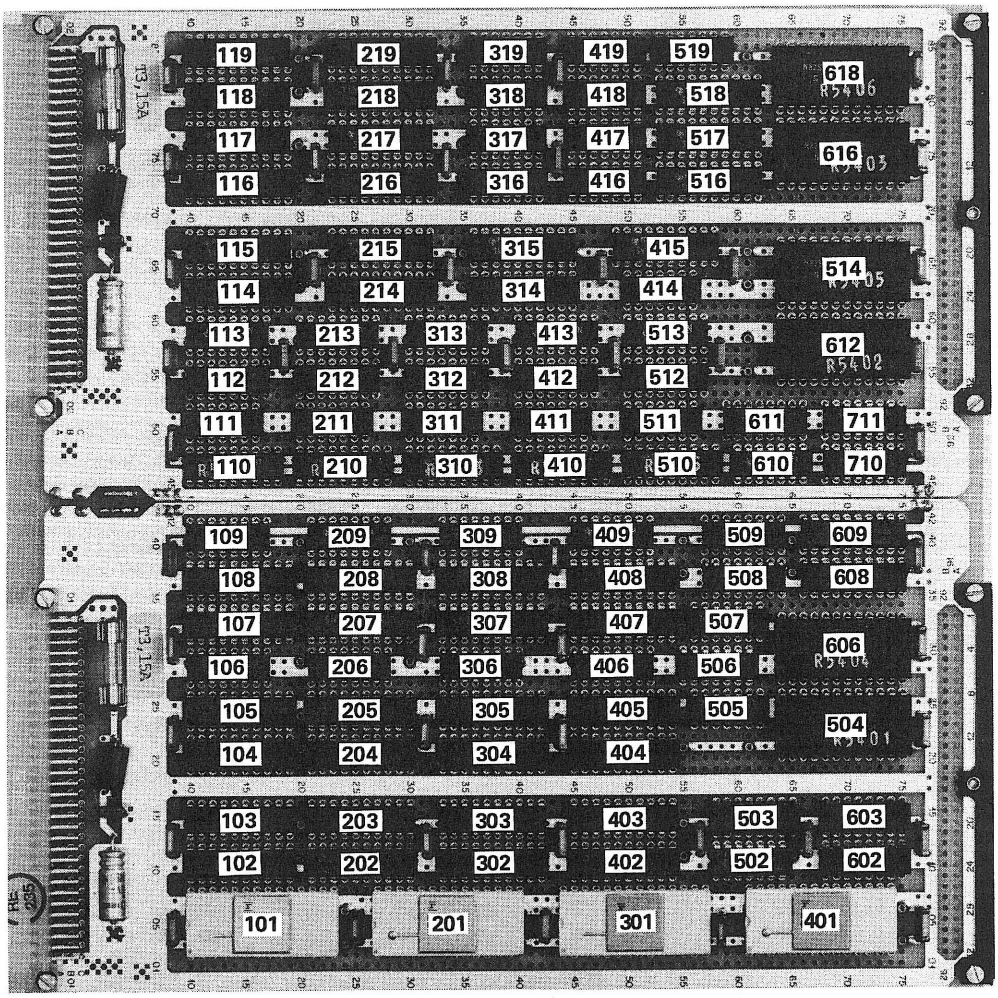


Fig. 6.4

IND.	POS.NO.	PART NO.	VALUE	SPECIFICATIONS / EQUIVALENT	MANUF.
	C..1001	59.25.3470	47u	-50%, 10V, ELECTROLYTIC QUANTITY: 2	
	C..1002	59.99.0205	68n	-20%, 63v, CERAMIC QUANTITY: 2	
	C..1003	59.99.0267	68n	-50%, 20V, CERAMIC QUANTITY:	
	F..1001	51.01.0122		FUSE, T3.15/250V, 5*20mm QUANTITY: 2	
	IC.0101	50.14.0109		N 82S 09I -N, 93419 CP,	
	IC.0102	50.06.0273		SN 74 LS 273 N TTL	
	IC.0103	50.06.0240		SN 74 LS 240 N TTL-3	
	IC.0104	50.06.0273		SN 74 LS 273 N TTL	
	IC.0105	50.06.0273		SN 74 LS 273 N TTL	
	IC.0106	50.06.0157		SN 74 LS 157 N TTL	
	IC.0107	50.06.0385		SN 74 LS 385 N,	
	IC.0108	50.06.0385		SN 74 LS 385 N,	
	IC.0109	50.06.0153		SN 74 LS 153 N TTL	
	IC.0110	50.14.0111		N82 S185 N,	
	IC.0111	50.06.0086		SN 74 LS 86 N TTL	
	IC.0112	50.12.0004		SN 74S 283 N,DM 74S 283 N,	
	IC.0113	50.12.0005		SN 74 S157 N, 74 S157 PC,	
	IC.0114	50.06.0273		SN 74 LS 273 N TTL	
	IC.0115	50.06.0322		SN 74 LS 322 AN, -P	

IND.	POS.NO.	PART NO.	VALUE	SPECIFICATIONS / EQUIVALENT	MANUF.
	IC.0116	50.06.0374		SN 74 LS 374 N TTL	
	IC.0117	50.06.0322		SN 74 LS 322 AN, -P	
	IC.0118	50.06.0244		SN 74 LS 244 N TTL-3	
	IC.0119	50.06.0244		SN 74 LS 244 N TTL-3	
	IC.0201	50.14.0109		N 82S 09I -N, 93419 CP,	
	IC.0202	50.06.0273		SN 74 LS 273 N TTL	
	IC.0203	50.06.0240		SN 74 LS 240 N TTL-3	
	IC.0204	50.06.0273		SN 74 LS 273 N TTL	
	IC.0205	50.06.0273		SN 74 LS 273 N TTL	
	IC.0206	50.06.0157		SN 74 LS 157 N TTL	
	IC.0207	50.06.0385		SN 74 LS 385 N,	
	IC.0208	50.06.0385		SN 74 LS 385 N,	
	IC.0209	50.06.0153		SN 74 LS 153 N TTL	
	IC.0210	50.14.0111		N82 S185 N,	
	IC.0211	50.06.0086		SN 74 LS 86 N TTL	
	IC.0212	50.12.0004		SN 74S 283 N,DM 74S 283 N,	
	IC.0213	50.12.0005		SN 74 S157 N, 74 S157 PC,	
	IC.0214	50.06.0273		SN 74 LS 273 N TTL	
	IC.0215	50.06.0322		SN 74 LS 322 AN, -P	
	IC.0216	50.06.0374		SN 74 LS 374 N TTL	
	IC.0217	50.06.0322		SN 74 LS 322 AN, -P	
	IC.0218	50.06.0273		SN 74 LS 273 N TTL	
	IC.0219	50.06.0273		SN 74 LS 273 N TTL	
	IC.0301	50.14.0109		N 82S 09I -N, 93419 CP,	
	IC.0302	50.06.0273		SN 74 LS 273 N TTL	
	IC.0303	50.06.0240		SN 74 LS 240 N TTL-3	
	IC.0304	50.06.0273		SN 74 LS 273 N TTL	
	IC.0305	50.06.0273		SN 74 LS 273 N TTL	
	IC.0306	50.06.0157		SN 74 LS 157 N TTL	
	IC.0307	50.06.0385		SN 74 LS 385 N,	
	IC.0308	50.06.0385		SN 74 LS 385 N,	
	IC.0309	50.06.0153		SN 74 LS 153 N TTL	
	IC.0310	50.14.0111		N82 S185 N,	
	IC.0311	50.06.0086		SN 74 LS 86 N TTL	
	IC.0312	50.12.0004		SN 74S 283 N,DM 74S 283 N,	
	IC.0313	50.12.0005		SN 74 S157 N, 74 S157 PC,	
	IC.0314	50.06.0273		SN 74 LS 273 N TTL	
	IC.0315	50.06.0322		SN 74 LS 322 AN, -P	
	IC.0316	50.06.0164		SN 74 LS 164 N TTL	
	IC.0317	50.06.0004		SN 74 LS 04 N TTL	
	IC.0318	50.06.0164		SN 74 LS 164 N TTL	
	IC.0319	50.06.0164		SN 74 LS 164 N TTL	
	IC.0401	50.14.0109		N 82S 09I -N, 93419 CP,	
	IC.0402	50.06.0273		SN 74 LS 273 N TTL	
	IC.0403	50.06.0240		SN 74 LS 240 N TTL-3	
	IC.0404	50.06.0273		SN 74 LS 273 N TTL	
	IC.0405	50.06.0273		SN 74 LS 273 N TTL	
	IC.0406	50.06.0157		SN 74 LS 157 N TTL	
	IC.0407	50.06.0385		SN 74 LS 385 N,	
	IC.0408	50.06.0385		SN 74 LS 385 N,	
	IC.0409	50.06.0153		SN 74 LS 153 N TTL	
	IC.0410	50.14.0111		N82 S185 N,	
	IC.0411	50.06.0086		SN 74 LS 86 N TTL	

IND.	POS.NO.	PART NO.	VALUE	SPECIFICATIONS / EQUIVALENT	MANUF.
	IC.0412	50.12.0004		SN 74S 283 N,DM 74S 283 N,	
	IC.0413	50.12.0005		SN 74 S157 N, 74 S157 PC,	
	IC.0414	50.06.0032		SN 74 LS 32 N TTL	
	IC.0415	50.06.0322		SN 74 LS 322 AN, -P	
	IC.0416	50.06.0164		SN 74 LS 164 N TTL	
	IC.0417	50.06.0164		SN 74 LS 164 N TTL	
	IC.0418	50.06.0164		SN 74 LS 164 N TTL	
	IC.0419	50.06.0164		SN 74 LS 164 N TTL	
	IC.0502	50.12.0001		SN 74S 32 N, 74 S 32 CP,	
	IC.0504	50.14.0110		N82 S114 N,	
	IC.0505	50.06.0004		SN 74 LS 04 N TTL	
	IC.0506	50.06.0074		SN 74 LS 74 N TTL	
	IC.0507	50.06.0004		SN 74 LS 04 N TTL	
	IC.0508	50.06.0157		SN 74 LS 157 N TTL	
	IC.0509	50.06.0157		SN 74 LS 157 N TTL	
	IC.0510	50.14.0111		N82 S185 N,	
	IC.0511	50.06.0086		SN 74 LS 86 N TTL	
	IC.0512	50.12.0004		SN 74S 283 N,DM 74S 283 N,	
	IC.0513	50.12.0005		SN 74 S157 N, 74 S157 PC,	
	IC.0514	50.14.0110		N82 S114 N,	
	IC.0516	50.06.0322		SN 74 LS 322 AN, -P	
	IC.0517	50.06.0322		SN 74 LS 322 AN, -P	
	IC.0518	50.06.0322		SN 74 LS 322 AN, -P	
	IC.0519	50.06.0164		SN 74 LS 164 N TTL	
	IC.0606	50.14.0110		N82 S114 N,	
	IC.0608	50.06.0244		SN 74 LS 244 N TTL-3	
	IC.0609	50.06.0244		SN 74 LS 244 N TTL-3	
	IC.0610	50.05.0197		SN74S04N, 74S04 PC , TTL	
	IC.0611	50.15.0109		AM26 LS33 PC,DS26 LS33 CN	
	IC.0612	50.14.0110		N82 S114 N,	
	IC.0616	50.14.0110		N82 S114 N,	
	IC.0618	50.14.0110		N82 S114 N,	
	IC.0710	50.12.0003		SN 74S 169 N, N74 S 169N,	
	IC.0711	50.12.0003		SN 74S 169 N, N74 S 169N,	
	L..1001	62.01.0115		INDUCTOR, RF-SUPPRESSION QUANTITY: 2	
	MP.0018	1.610.020.01		NAME-PLATE	
	MP.0019	1.610.020.02		NUMBER-PLATE	
	MP.1001	1.010.100.49		INSULATOR, 233*219mm, HGW	
	MP.1002	1.010.101.49		SHEET METAL PLATE, 233*216mm	
	MP.1003	1.010.030.49		EUROCARD, DOUBLE SIZE, 2*CU .3/.6" WRAP	
	MP.1004	1.010.096.49		TRANSPARENT COVER QUANTITY: 2	
	MP.1005	1.010.128.49		POSITIONING PLATE QUANTITY: 2	
	MP.1006	1.010.006.33		MARKING HANDLE QUANTITY: 4	
	MP.1007	21.01.0280		SCREW, CYL. HEAD, M2.5*8 QUANTITY: 4	
	MP.1008	21.01.0282		SCREW, CYL. HEAD, M2.5*12 QUANTITY: 4	
	MP.1009	21.01.2278		SCREW, FLAT HEAD, M2.5*5 QUANTITY: 8	
	MP.1010	28.21.1380		TUBULAR RIVET, D2.25*6.5mm QUANTITY: 2	
	MP.1011	1.010.008.54		CONTACT PIN, WRAP-L= 8,00 QUANTITY:	
	MP.1012	1.010.009.54		DUMMY PIN, WRAP-L= 8,00 QUANTITY: 280	
	MP.1013	1.010.074.27		STAND-OFF, M2.5*11.0 QUANTITY: 4	
	MP.1014	1.010.205.27		STAND-OFF, M2.5*13.0 QUANTITY: 4	
	MP.1015	23.01.1025		WASHER D 2.5/5 *0.5 QUANTITY: 4	
	MP.1016	24.16.1025		LOCK WASHER D 2.7/5 *0.5 QUANTITY: 8	
	MP.1017	64.01.0345		WIRE, GN, D .255 LENGHT:	
	P..1001	54.01.0354		CARD CONNECTOR, 3*32 WRAP QUANTITY: 2	
	RZ.0503	57.85.3102	15*1 k	10%, DIL16	
	RZ.0602	57.85.3102	15*1 k	10%, DIL16	
	RZ.0603	57.85.3102	15*1 k	10%, DIL16	
	XF.1001	53.03.0142		CLAMP, 5*20 QUANTITY: 4	

Filter 2/Buffer Board 1.610.025

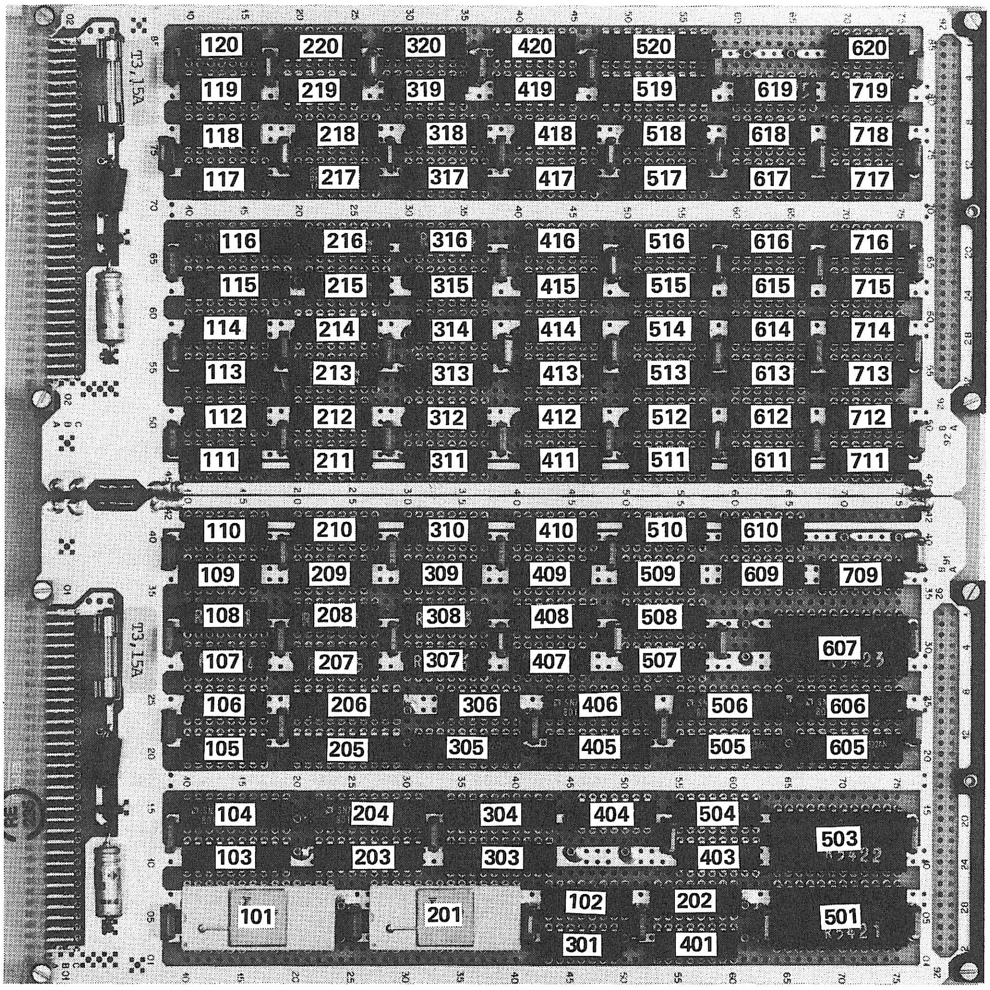


Fig. 6.5

IND.	POS.NO.	PART NO.	VALUE	SPECIFICATIONS / EQUIVALENT	MANUF.
	C..0004	59.34.2101	100 p	10%,N150 , KER	
	C..1001	59.25.3470	47u	-50%, 10V, ELECTROLYTIC QUANTITY: 2	
	C..1002	59.99.0205	68n	-20%, 63v, CERAMIC QUANTITY: 2	
	C..1003	59.99.0267	68n	-50%, 20V, CERAMIC QUANTITY: 65	
	F..1001	51.01.0122		FUSE, T3.15/250V, 5*20mm QUANTITY: 2	
	IC.0101	50.14.0109		N 82S 09I -N, 93419 CP,	
	IC.0103	50.06.0240		SN 74 LS 240 N TTL-3	
	IC.0104	50.06.0273		SN 74 LS 273 N TTL	
	IC.0105	50.06.0153		SN 74 LS 153 N TTL	
	IC.0106	50.06.0153		SN 74 LS 153 N TTL	
	IC.0107	50.05.0206		82 S 123	
	IC.0108	50.05.0206		82 S 123	
	IC.0109	50.06.0086		SN 74 LS 86 N TTL	
	IC.0110	50.12.0004		SN 74S 283 N,DM 74S 283 N,	
	IC.0111	50.06.0004		SN 74 LS 04 N TTL	
	IC.0112	50.06.0283		SN 74 LS 283 N TTL	
	IC.0113	50.06.0669		SN 74 LS 669 N	
	IC.0114	50.06.0283		SN 74 LS 283 N TTL	
	IC.0115	50.06.0244		SN 74 LS 244 N TTL-3	

IND.	PCS.NO.	PART NO.	VALUE	SPECIFICATIONS / EQUIVALENT		MANUF.
	IC.0116	50.06.0273		SN 74 LS 273 N	TTL	
	IC.0117	50.06.0157		SN 74 LS 157 N	TTL	
	IC.0118	50.06.0032		SN 74 LS 32 N	TTL	
	IC.0119	50.06.0032		SN 74 LS 32 N	TTL	
	IC.0120	50.06.0030		SN 74 LS 30 N	TTL	
	IC.0201	50.14.0109		N 82S 09I -N, 93419 CP,		
	IC.0203	50.06.0240		SN 74 LS 240 N	TTL-3	
	IC.0204	50.06.0273		SN 74 LS 273 N	TTL	
	IC.0205	50.06.0385		SN 74 LS 385 N,		
	IC.0206	50.06.0385		SN 74 LS 385 N,		
	IC.0207	50.05.0206		82 S 123		
	IC.0208	50.05.0206		82 S 123		
	IC.0209	50.06.0086		SN 74 LS 86 N	TTL	
	IC.0210	50.12.0004		SN 74S 283 N,DM 74S 283 N,		
	IC.0211	50.06.0004		SN 74 LS 04 N	TTL	
	IC.0212	50.06.0004		SN 74 LS 04 N	TTL	
	IC.0213	50.06.0138		SN 74 LS 138 N	TTL	
	IC.0214	50.06.0151		SN 74 LS 151 N	TTL	
	IC.0215	50.06.0138		SN 74 LS 138 N	TTL	
	IC.0216	50.06.0138		SN 74 LS 138 N	TTL	
	IC.0217	50.06.0138		SN 74 LS 138 N	TTL	
	IC.0218	50.05.0236		N 8T97B .	,TTL-3	
	IC.0219	50.06.0074		SN 74 LS 74 N	TTL	
	IC.0220	50.06.0004		SN 74 LS 04 N	TTL	
	IC.0303	50.05.0179		SN74S 00-N,	TTL	
	IC.0304	50.06.0273		SN 74 LS 273 N	TTL	
	IC.0305	50.06.0322		SN 74 LS 322 AN, -P		
	IC.0306	50.06.0157		SN 74 LS 157 N	TTL	
	IC.0307	50.05.0206		82 S 123		
	IC.0308	50.05.0206		82 S 123		
	IC.0309	50.06.0086		SN 74 LS 86 N	TTL	
	IC.0310	50.12.0004		SN 74S 283 N,DM 74S 283 N,		
	IC.0311	50.06.0157		SN 74 LS 157 N	TTL	
	IC.0312	50.06.0157		SN 74 LS 157 N	TTL	
	IC.0313	50.06.0010		SN 74 LS 10 N	TTL	
	IC.0314	50.06.0010		SN 74 LS 10 N	TTL	
	IC.0315	50.06.0010		SN 74 LS 10 N	TTL	
	IC.0316	50.05.0206		82 S 123		
	IC.0317	50.06.0283		SN 74 LS 283 N	TTL	
	IC.0318	50.06.0283		SN 74 LS 283 N	TTL	
	IC.0319	50.06.0283		SN 74 LS 283 N	TTL	
	IC.0320	50.06.0283		SN 74 LS 283 N	TTL	
	IC.0401	50.06.0157		SN 74 LS 157 N	TTL	
	IC.0403	50.12.0003		SN 74S 169 N, N74 S 169N,		
	IC.0404	50.05.0197		SN74S04N 74S04 PC , TTL		
	IC.0405	50.06.0322		SN 74 LS 322 AN, -P		
	IC.0406	50.06.0273		SN 74 LS 273 N	TTL	
	IC.0407	50.06.0032		SN 74 LS 32 N	TTL	
	IC.0408	50.15.0109		AM26 LS33 PC,DS26 LS33 CN		
	IC.0409	50.06.0086		SN 74 LS 86 N	TTL	
	IC.0410	50.12.0004		SN 74S 283 N,DM 74S 283 N,		
	IC.0411	50.06.0164		SN 74 LS 164 N	TTL	
	IC.0412	50.06.0164		SN 74 LS 164 N	TTL	
	IC.0413	50.06.0164		SN 74 LS 164 N	TTL	
	IC.0414	50.06.0164		SN 74 LS 164 N	TTL	
	IC.0415	50.06.0164		SN 74 LS 164 N	TTL	
	IC.0416	50.06.0164		SN 74 LS 164 N	TTL	
	IC.0417	50.06.0151		SN 74 LS 151 N	TTL	
	IC.0418	50.06.0151		SN 74 LS 151 N	TTL	
	IC.0419	50.06.0151		SN 74 LS 151 N	TTL	
	IC.0420	50.06.0151		SN 74 LS 151 N	TTL	
	IC.0501	50.14.0110		N82 S114 N,		
	IC.0503	50.14.0110		N82 S114 N,		
	IC.0504	50.12.0003		SN 74S 169 N, N74 S 169N,		
	IC.0505	50.06.0322		SN 74 LS 322 AN, -P		
	IC.0506	50.06.0273		SN 74 LS 273 N	TTL	
	IC.0507	50.06.0157		SN 74 LS 157 N	TTL	
	IC.0508	50.06.0157		SN 74 LS 157 N	TTL	
	IC.0509	50.06.0086		SN 74 LS 86 N	TTL	
	IC.0510	50.12.0004		SN 74S 283 N,DM 74S 283 N,		
	IC.0511	50.06.0164		SN 74 LS 164 N	TTL	
	IC.0512	50.06.0164		SN 74 LS 164 N	TTL	
	IC.0513	50.06.0164		SN 74 LS 164 N	TTL	
	IC.0514	50.06.0164		SN 74 LS 164 N	TTL	

IND.	POS.NO.	PART NO.	VALUE	SPECIFICATIONS / EQUIVALENT		MANUF.
	IC.0515	50.06.0164		SN 74 LS 164 N	TTL	
	IC.0516	50.06.0164		SN 74 LS 164 N	TTL	
	IC.0517	50.06.0157		SN 74 LS 157 N	TTL	
	IC.0518	50.06.0157		SN 74 LS 157 N	TTL	
	IC.0519	50.06.0385		SN 74 LS 385 N,		
	IC.0520	50.06.0385		SN 74 LS 385 N,		
	IC.0605	50.06.0322		SN 74 LS 322 AN, -P		
	IC.0606	50.06.0273		SN 74 LS 273 N	TTL	
	IC.0607	50.14.0110		N82 S114 N,		
	IC.0609	50.06.0157		SN 74 LS 157 N	TTL	
	IC.0610	50.06.0157		SN 74 LS 157 N	TTL	
	IC.0611	50.06.0164		SN 74 LS 164 N	TTL	
	IC.0612	50.06.0164		SN 74 LS 164 N	TTL	
	IC.0613	50.06.0164		SN 74 LS 164 N	TTL	
	IC.0614	50.06.0164		SN 74 LS 164 N	TTL	
	IC.0615	50.06.0164		SN 74 LS 164 N	TTL	
	IC.0616	50.06.0164		SN 74 LS 164 N	TTL	
	IC.0617	50.06.0004		SN 74 LS 04 N	TTL	
	IC.0618	50.06.0000		SN 74 LS 00 N	TTL	
	IC.0619	50.05.0206		82 S 123		
	IC.0620	50.06.0032		SN 74 LS 32 N	TTL	
	IC.0709	50.06.0157		SN 74 LS 157 N	TTL	
	IC.0711	50.06.0164		SN 74 LS 164 N	TTL	
	IC.0712	50.06.0164		SN 74 LS 164 N	TTL	
	IC.0713	50.06.0164		SN 74 LS 164 N	TTL	
	IC.0714	50.06.0164		SN 74 LS 164 N	TTL	
	IC.0715	50.06.0164		SN 74 LS 164 N	TTL	
	IC.0716	50.06.0164		SN 74 LS 164 N	TTL	
	IC.0717	50.06.0032		SN 74 LS 32 N	TTL	
	IC.0718	50.06.0032		SN 74 LS 32 N	TTL	
	IC.0719	50.06.0032		SN 74 LS 32 N	TTL	
	L..1001	62.01.0115		INDUCTOR, RF-SUPPRESSION	QUANTITY: 2	
	MP.0018	1.610.025.01		NAME - PLATE		
	MP.0019	1.610.025.02		NUMBER - PLATE		
	MP.1001	1.010.100.49		INSULATOR, 233*219mm, HGW		
	MP.1002	1.010.101.49		SHEET METAL PLATE, 233*216mm		
	MP.1003	1.010.030.49		EUROCARD, DOUBLE SIZE, 2*CU .3/.6" WRAP		
	MP.1004	1.010.096.49		TRANSPARENT COVER	QUANTITY: 2	
	MP.1005	1.010.128.49		POSITIONING PLATE	QUANTITY: 2	
	MP.1006	1.010.006.33		MARKING HANDLE	QUANTITY: 4	
	MP.1007	21.01.0280		SCREW, CYL. HEAD, M2.5*8	QUANTITY: 4	
	MP.1008	21.01.0282		SCREW, CYL. HEAD, M2.5*12	QUANTITY: 4	
	MP.1009	21.01.2278		SCREW, FLAT HEAD, M2.5*5	QUANTITY: 8	
	MP.1010	28.21.1380		TUBULAR RIVET, D2.25*6.5mm	QUANTITY: 2	
	MP.1011	1.010.008.54		CONTACT PIN, WRAP-L= 8,00	QUANTITY: 1982	
	MP.1012	1.010.009.54		DUMMY PIN, WRAP-L= 8,00	QUANTITY: 280	
	MP.1013	1.010.074.27		STAND-OFF, M2.5*11.0	QUANTITY: 4	
	MP.1014	1.010.205.27		STAND-OFF, M2.5*13.0	QUANTITY: 4	
	MP.1015	23.01.1025		WASHER D 2.5/5 *0.5	QUANTITY: 4	
	MP.1016	24.16.1025		LOCK WASHER D 2.7/5 *0.5	QUANTITY: 8	
	MP.1017	64.01.0345		WIRE, GN, D .255	LENGHT: 122500 mm	
	P..1001	54.01.0354		CARD CONNECTOR, 3*32 WRAP	QUANTITY: 2	
	RZ.0102	57.85.3102	15*1 k	10%, DIL16		
	RZ.0202	57.85.3102	15*1 k	10%, DIL16		
	XF.1001	53.03.0142		CLAMP, 5*20	QUANTITY: 4	

Filter 3&4 Board 1.610.030

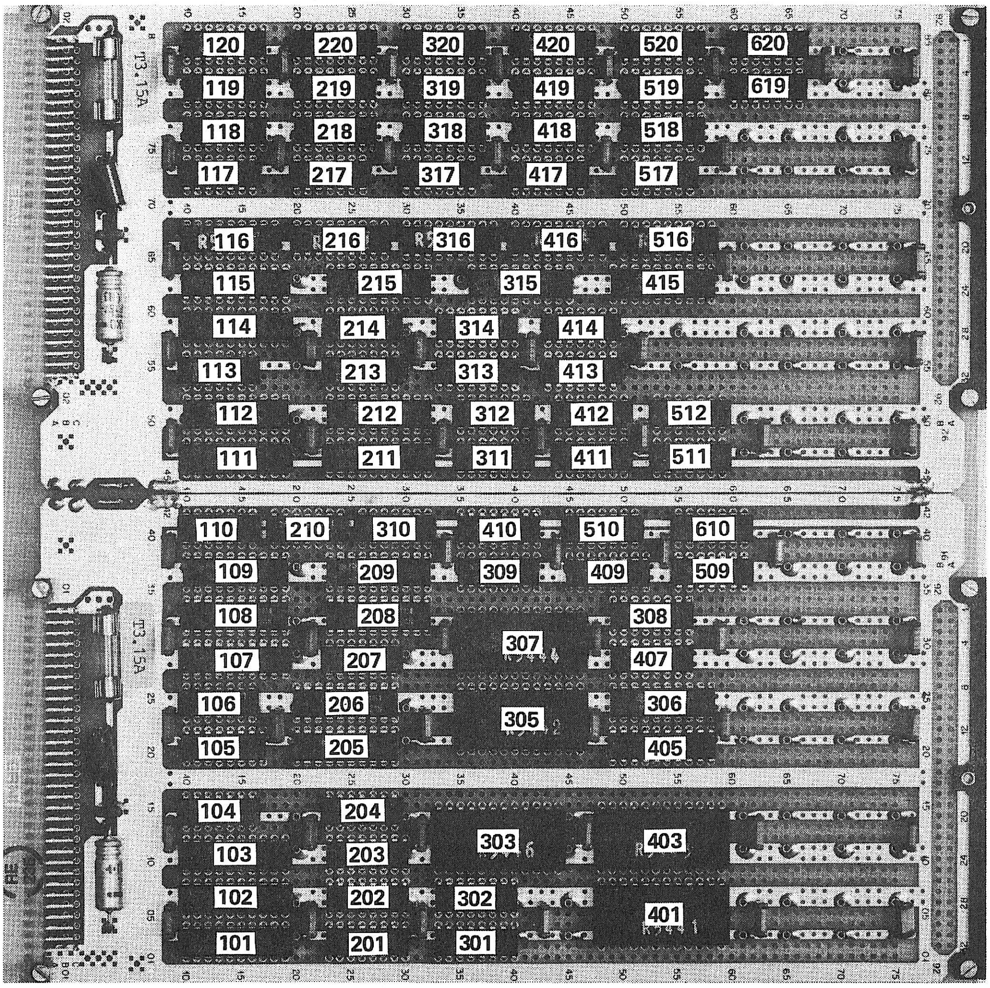


Fig. 6.6

IND.	POS.NO.	PART NO.	VALUE	SPECIFICATIONS / EQUIVALENT	MANUF.
	C..1001	59.25.3470	47u	-50%, 10V, ELECTROLYTIC	QUANTITY: 2
	C..1002	59.99.0205	68n	-20%, 63v, CERAMIC	QUANTITY: 2
	C..1003	59.99.0267	68n	-50%, 20V, CERAMIC	QUANTITY: 61
	F..1001	51.01.0122		FUSE, T3.15/250V, 5*20mm	QUANTITY: 2
	IC.0101	50.06.0273		SN 74 LS 273 N TTL	
	IC.0102	50.06.0273		SN 74 LS 273 N TTL	
	IC.0103	50.06.0273		SN 74 LS 273 N TTL	
	IC.0104	50.06.0086		SN 74 LS 86 N TTL	
	IC.0105	50.06.0395		SN 74 LS 395 AN,	
	IC.0106	50.06.0004		SN 74 LS 04 N TTL	
	IC.0107	50.06.0385		SN 74 LS 385 N,	
	IC.0108	50.06.0322		SN 74 LS 322 AN, -P	
	IC.0109	50.06.0374		SN 74 LS 374 N TTL	
	IC.0110	50.06.0164		SN 74 LS 164 N TTL	
	IC.0111	50.06.0273		SN 74 LS 273 N TTL	
	IC.0112	50.06.0244		SN 74 LS 244 N TTL-3	
	IC.0113	50.06.0030		SN 74 LS 30 N TTL	
	IC.0114	50.06.0273		SN 74 LS 273 N TTL	
	IC.0115	50.06.0240		SN 74 LS 240 N TTL-3	

IND.	POS.NO.	PART NO.	VALUE	SPECIFICATIONS / EQUIVALENT	MANUF.
	IC.0116	50.14.0111		N82 S185 N,	
	IC.0117	50.12.0002		SN 74S 86 N, 74 S86 DC,	
	IC.0118	50.12.0004		SN 74S 283 N,DM 74S 283 N,	
	IC.0119	50.06.0395		SN 74 LS 395 AN,	
	IC.0120	50.06.0395		SN 74 LS 395 AN,	
	IC.0201	50.06.0384		SN 74 LS 384 CD,-N,	
	IC.0202	50.06.0384		SN 74 LS 384 CD,-N,	
	IC.0203	50.06.0384		SN 74 LS 384 CD,-N,	
	IC.0204	50.06.0086		SN 74 LS 86 N TTL	
	IC.0205	50.06.0322		SN 74 LS 322 AN, -P	
	IC.0206	50.06.0322		SN 74 LS 322 AN, -P	
	IC.0207	50.06.0164		SN 74 LS 164 N TTL	
	IC.0208	50.06.0322		SN 74 LS 322 AN, -P	
	IC.0209	50.06.0374		SN 74 LS 374 N TTL	
	IC.0210	50.06.0004		SN 74 LS 04 N TTL	
	IC.0211	50.06.0273		SN 74 LS 273 N TTL	
	IC.0212	50.06.0244		SN 74 LS 244 N TTL-3	
	IC.0213	50.06.0030		SN 74 LS 30 N TTL	
	IC.0214	50.06.0004		SN 74 LS 04 N TTL	
	IC.0215	50.06.0244		SN 74 LS 244 N TTL-3	
	IC.0216	50.14.0111		N82 S185 N,	
	IC.0217	50.12.0002		SN 74S 86 N, 74 S86 DC,	
	IC.0218	50.12.0004		SN 74S 283 N,DM 74S 283 N,	
	IC.0219	50.06.0395		SN 74 LS 395 AN,	
	IC.0220	50.06.0395		SN 74 LS 395 AN,	
	IC.0301	50.06.0157		SN 74 LS 157 N TTL	
	IC.0302	50.06.0384		SN 74 LS 384 CD,-N,	
	IC.0303	50.14.0110		N82 S114 N,	
	IC.0305	50.14.0110		N82 S114 N,	
	IC.0306	50.06.0244		SN 74 LS 244 N TTL-3	
	IC.0307	50.14.0110		N82 S114 N,	
	IC.0308	50.12.0003		SN 74S 169 N, N74 S 169N,	
	IC.0309	50.05.0236		N 8T97B . ,TTL-3	
	IC.0310	50.06.0164		SN 74 LS 164 N TTL	
	IC.0311	50.06.0164		SN 74 LS 164 N TTL	
	IC.0312	50.06.0164		SN 74 LS 164 N TTL	
	IC.0313	50.06.0283		SN 74 LS 283 N TTL	
	IC.0314	50.06.0283		SN 74 LS 283 N TTL	
	IC.0315	50.06.0244		SN 74 LS 244 N TTL-3	
	IC.0316	50.14.0111		N82 S185 N,	
	IC.0317	50.12.0002		SN 74S 86 N, 74 S86 DC,	
	IC.0318	50.12.0004		SN 74S 283 N,DM 74S 283 N,	
	IC.0319	50.06.0395		SN 74 LS 395 AN,	
	IC.0320	50.06.0395		SN 74 LS 395 AN,	
	IC.0401	50.14.0110		N82 S114 N,	
	IC.0403	50.14.0110		N82 S114 N,	
	IC.0405	50.06.0240		SN 74 LS 240 N TTL-3	
	IC.0407	50.12.0003		SN 74S 169 N, N74 S 169N,	
	IC.0409	50.15.0109		AM26 LS33 PC,DS26 LS33 CN	
	IC.0410	50.06.0157		SN 74 LS 157 N TTL	
	IC.0411	50.06.0164		SN 74 LS 164 N TTL	
	IC.0412	50.06.0164		SN 74 LS 164 N TTL	
	IC.0413	50.05.0197		SN74S04N 74S04 PC , TTL	

IND.	POS.NO.	PART NO.	VALUE	SPECIFICATIONS / EQUIVALENT	MANUF.
	IC.0414	50.06.0032		SN 74 LS 32 N TTL	
	IC.0415	50.06.0244		SN 74 LS 244 N TTL-3	
	IC.0416	50.14.0111		N82 S185 N,	
	IC.0417	50.12.0002		SN 74S 86 N, 74 S86 DC,	
	IC.0418	50.12.0004		SN 74S 283 N,DM 74S 283 N,	
	IC.0419	50.06.0395		SN 74 LS 395 AN,	
	IC.0420	50.06.0395		SN 74 LS 395 AN,	
	IC.0509	50.05.0197		SN74S04N 74S04 PC , TTL	
	IC.0510	50.06.0164		SN 74 LS 164 N TTL	
	IC.0511	50.06.0164		SN 74 LS 164 N TTL	
	IC.0512	50.06.0164		SN 74 LS 164 N TTL	
	IC.0516	50.14.0111		N82 S185 N,	
	IC.0517	50.12.0002		SN 74S 86 N, 74 S86 DC,	
	IC.0518	50.12.0004		SN 74S 283 N,DM 74S 283 N,	
	IC.0519	50.06.0395		SN 74 LS 395 AN,	
	IC.0520	50.06.0395		SN 74 LS 395 AN,	
	IC.0610	50.06.0164		SN 74 LS 164 N TTL	
	IC.0619	50.06.0008		SN 74 LS 08 N TTL	
	IC.0620	50.06.0074		SN 74 LS 74 N TTL	
	L..1001	62.01.0115		INDUCTOR, RF-SUPPRESSION QUANTITY: 2	
	MP.0018	1.610.030.01		NAME - PLATE	
	MP.0019	1.610.030.02		NUMBER - PLATE	
	MP.1001	1.010.100.49		INSULATOR, 233*219mm, HGW	
	MP.1002	1.010.101.49		SHEET METAL PLATE, 233*216mm	
	MP.1003	1.010.030.49		EUROCARD, DOUBLE SIZE, 2*CU .3/.6" WRAP	
	MP.1004	1.010.096.49		TRANSPARENT COVER QUANTITY: 2	
	MP.1005	1.010.128.49		POSITIONING PLATE QUANTITY: 2	
	MP.1006	1.010.006.33		MARKING HANDLE QUANTITY: 4	
	MP.1007	21.01.0280		SCREW, CYL. HEAD, M2.5*8 QUANTITY: 4	
	MP.1008	21.01.0282		SCREW, CYL. HEAD, M2.5*12 QUANTITY: 4	
	MP.1009	21.01.2278		SCREW, FLAT HEAD, M2.5*5 QUANTITY: 8	
	MP.1010	28.21.1380		TUBULAR RIVET, D2.25*6.5mm QUANTITY: 2	
	MP.1011	1.010.008.54		CONTACT PIN, WRAP-L= 8,00 QUANTITY: 1470	
	MP.1012	1.010.009.54		DUMMY PIN, WRAP-L= 8,00 QUANTITY: 280	
	MP.1013	1.010.074.27		STAND-OFF, M2.5*11.0 QUANTITY: 4	
	MP.1014	1.010.205.27		STAND-OFF, M2.5*13.0 QUANTITY: 4	
	MP.1015	23.01.1025		WASHER D 2.5/5 *0.5 QUANTITY: 4	
	MP.1016	24.16.1025		LOCK WASHER D 2.7/5 *0.5 QUANTITY: 8	
	MP.1017	64.01.0345		WIRE, GN, D .255 LENGHT: 96700 mm	
	P..1001	54.01.0354		CARD CONNECTOR, 3*32 WRAP QUANTITY: 2	
	XF.1001	53.03.0142		CLAMP, 5*20 QUANTITY: 4	

6.6.2 SFC selftest

Before executing the self test, it is necessary that all tests in section 6.6.1 have been successfully terminated.
Observe now the six binary coded red LEDs on the interface board.

In the tables below you will find all possible error configurations of the six binary coded red LEDs on the interface board.
Check all ICs, listed under the apparent combination.
Do not forget to take care of the advice given in section 6.6.1!

UP MODE

Error configuration (1≘LED lit, 0≘LED dark) LED 6 5 4 3 2 1 binary	decimal	possible defective ICs	ON PCB
0 0 0 0 0 0	0	no error	FILTER 1 BOARD
0 0 0 0 0 1	1	116, 117 216, 217 317 505 606, 608, 609, 610, 611, 612, 618 710, 711	
0 0 0 0 1 0	2	101, 102, 103, 104, 106, 107, 109 201, 202, 203, 204 301, 302, 303, 304, 305, 306, 307, 317 401, 402, 403, 404, 405, 503, 504, 507, 508, 509, 514 602, 603, 606, 612 702	
0 0 0 0 1 1	3	104, 106, 107, 109 204 304, 305, 306, 307, 317 404, 405	
0 0 0 1 0 0	4	104, 106, 107 204, 209 304, 305, 306, 307 404, 405 507	
0 0 0 1 0 1	5	see combination above	
0 0 0 1 1 0	6	104 204, 206, 207 304, 305, 309 404, 405, 406, 407 507	
0 0 0 1 1 1	7	see combination above	

UP MODE

Error configuration (1≙LED lit, 0≙LED dark) LED 6 5 4 3 2 1 binary	decimal	possible defective ICs	ON PCB
0 0 1 0 0 0	8	104, 204, 206, 207 304, 305 404, 405, 406, 407, 409 507	FILTER 1 BOARD
0 0 1 0 0 1	9	see combination above	FILTER 1 BOARD
0 0 1 0 1 0	10	110, 111, 112, 113, 114, 115 210, 211, 212, 213, 214, 215 310, 311, 312, 313, 314, 315, 316, 317 410, 411, 412, 413, 414, 415, 416, 417 505, 510, 511, 512, 513, 516, 608, 609, 612, 616, 618	FILTER 1 BOARD
		220 301 403, 404, 408 607	FILTER 2/BUFFER BOARD
0 0 1 0 1 1	11	101, 102, 103, 104 212 401 501	FILTER 2/BUFFER BOARD
0 0 1 1 0 0	12	201, 202, 203, 204	FILTER 2/BUFFER BOARD
0 0 1 1 0 1	13	106 205, 206, 212 303, 304, 306 501, 503	FILTER 2/BUFFER BOARD
0 0 1 1 1 0	14	105, 106, 107, 108, 109, 110 205, 206, 207, 208, 209, 210 303, 306, 307, 308, 309, 310 404, 406, 409, 410 503, 506, 507, 508, 509, 510 606, 609, 610 709	FILTER 2/BUFFER BOARD
0 0 1 1 1 1	15	212 305 404, 405, 406, 407 503, 505 605, 607	FILTER 2/BUFFER BOARD
0 1 0 0 0 0	16	111, 115, 116, 117 213, 216, 217, 219, 220 313 411, 412, 413 517 618, 619 717 Filter 3: 305, 409	FILTER 2/BUFFER BOARD
0 1 0 0 0 1	17	111 213, 216, 217 414, 415, 416 517 619 717 313	FILTER 2/BUFFER BOARD

UP MODE

Error configuration (1≙LED lit, 0≙LED dark) LED 6 5 4 3 2 1 binary	decimal	possible defective ICs	ON PCB
0 1 0 0 1 0	18	111 213, 216, 217 313 511, 512, 513, 517 619 718	FILTER 2/BUFFER BOARD
0 1 0 0 1 1	19	111 213, 216, 217 314 514, 515, 516, 517 619 718	
0 1 0 1 0 0	20	111 213, 216, 217 314 518 611, 612, 613, 619 719	
0 1 0 1 0 1	21	111 213, 216, 217 314 518 614, 615, 616, 619 719	
0 1 0 1 1 0	22	211, 213, 216, 217 315 518 619, 620 711, 712, 713	
0 1 0 1 1 1	23	211, 213, 216, 217 315 518 619, 620 714, 715, 716	
0 1 1 0 0 0	24	211, 218 320 420 Filter 3: 213, 413, 414, 415, 509	
0 1 1 0 0 1	25	211, 218 319 419 Filter 3: 415	
0 1 1 0 1 0	26	211, 218 318 418 Filter 3: 415	
0 1 1 0 1 1	27	211, 218 317 417 Filter 3: 415	
0 1 1 1 0 0	28	115 210, 215 306, 313, 314, 315 405	FILTER 3/4 BOARD

UP MODE

Error configuration (1≙LED lit, 0≙LED dark) LED 6 5 4 3 2 1 binary	decimal	possible defective ICs	ON PCB
0 1 1 1 0 1	29	115 210, 215 305, 306, 313, 314, 315, 316, 317, 318 401, 403, 405, 413, 416, 417, 418, 419, 420 516, 517, 518, 519, 520 619	FILTER 3/4 BOARD
0 1 1 1 1 0	30	116, 117, 118, 119, 120 205, 210, 216, 217, 218, 219, 220 320 413 620	
0 1 1 1 1 1	31	120 206, 210, 220 320 413 620	
1 0 0 0 0 0	32	103, 104, 106 203, 204 301, 302 401, 403	
1 0 0 0 0 1	33	106 303	
1 0 0 0 1 0	34	106, 107, 110, 112 207 301, 303 401 Filter 1: 118	

DOWN MODE

Error configuration (1≙LED lit, 0≙LED dark) LED 6 5 4 3 2 1 binary	decimal	possible defective ICs	ON PCB
0 0 0 0 0 0	0	no error	FILTER 3/4 BOARD
0 0 0 0 0 1	1	101, 102, 106, 108, 109 201, 202, 208, 209 301, 309 401, 403 509	
0 0 0 0 1 0	2	103, 104, 106 203, 204 301, 309 401	
0 0 0 0 1 1	3	114, 115 210, 215 301, 306, 315 401, 405	
0 0 0 1 0 0	4	210 301, 302, 303, 307, 311, 312 401, 410, 411, 412, 413, 414, 415 510, 511, 512 610 Filter 2: 218, 220	
0 0 0 1 0 1	5	114, 115 210, 215 305, 307, 315, 316, 317, 318, 320 401, 403, 405, 415, 416, 417, 418, 419, 420 516, 517, 518, 519, 520 619 Filter 2: 218	
0 0 0 1 1 0	6	116, 117, 118, 119, 120 206, 210, 216, 217, 218, 219, 220 305, 306, 319, 320 405, 413, 420 520 619	
0 0 0 1 1 1	7	119 205, 210, 413	
0 0 1 0 0 0	8	106 307 405 509	
		111, 114, 116, 117 217, 220 313, 315 411, 412, 413 517, 519 618, 619 717	FILTER 2/BUFFER BOARD

DOWN MODE

Error configuration (1≙LED lit, 0≙LED dark) LED 6 5 4 3 2 1 binary	decimal	possible defective ICs	ON PCB
0 0 1 0 0 1	9	111 313 414, 415, 416 517, 519 619 717	FILTER 2/BUFFER BOARD
0 0 1 0 1 0	10	111 313 511, 512, 513, 517, 519 619 718	
0 0 1 0 1 1	11	111 314 514, 515, 516, 517, 519 619 718	
0 0 1 1 0 0	12	111 314 518, 520 611, 612, 613, 619 719	
0 0 1 1 0 1	13	111 314 518, 520 614, 615, 616, 619 719	
0 0 1 1 1 0	14	211 315 518, 520 619, 620 711, 712, 713	
0 0 1 1 1 1	15	211 315 518, 520 619, 620 714, 715, 716	
0 1 0 0 0 0 0 1 0 0 0 1 0 1 0 0 1 0 0 1 0 0 1 1	16 17 18 19	not used	
0 1 0 1 0 0	20	212, 214	
0 1 0 1 0 1	21	101, 102, 103, 104 202, 212 301 401 501	
0 1 0 1 1 0	22	102, 201, 202, 203, 204, 212	
0 1 0 1 1 1	23	106 205, 206, 212 303, 304, 306 501, 503	

DOWN MODE

Error configuration (1≙LED lit, 0≙LED dark) LED 6 5 4 3 2 1		possible defective ICs	ON PCB
binary	decimal		
0 1 1 0 0 0	24	105, 106, 107, 108, 109, 110 205, 206, 207, 208, 209, 210, 212 303, 304, 306, 307, 308, 309, 310 406, 409, 410 503, 506, 507, 508, 509, 510 606, 609, 610 709	FILTER 2/BUFFER BOARD
0 1 1 0 0 1	25	212 305 404, 405, 407 503, 505 605, 607	
0 1 1 0 1 0	26	317 418, 419 504, 516, 518, 519 606, 609, 610, 611, 618 710, 711	FILTER 1 BOARD
0 1 1 0 1 1	27	101, 102, 103, 104, 105, 106, 107, 108, 109 201, 202, 203, 204, 205 301, 302, 303, 304, 305, 306, 307, 308, 317 401, 402, 403, 404, 405 502, 503, 504, 506, 508, 509 602, 603, 606, 609, 612, 618	
0 1 1 1 0 0	28	104, 105, 106, 107, 108, 109 204, 205 304, 305, 306, 307, 308, 317 404, 405 505	
0 1 1 1 0 1	29	104, 105, 106, 107, 108 204, 205, 209 304, 305, 306, 307, 308 404, 405 507	
0 1 1 1 1 0	30	see combination above	
0 1 1 1 1 1	31	104, 105 204, 205, 206, 207, 208 304, 305, 309 404, 405, 406, 407, 408 507	
1 0 0 0 0 0	32	see combination above	
1 0 0 0 0 1	33	see combination above	
1 0 0 0 1 0	34	see combination above	
1 0 0 0 1 1	35	110, 111, 112, 113, 114, 115 210, 211, 212, 213, 214, 219 310, 311, 312, 313, 314, 317, 318, 319 410, 411, 412, 413 505, 510, 511, 512, 513 608, 609, 612, 616, 618	

Do not forget to toggle the switch on the interface board back to its middle position after having executed the self test!