

## 4. Theory of Operation

### 4.1 System Block Diagram

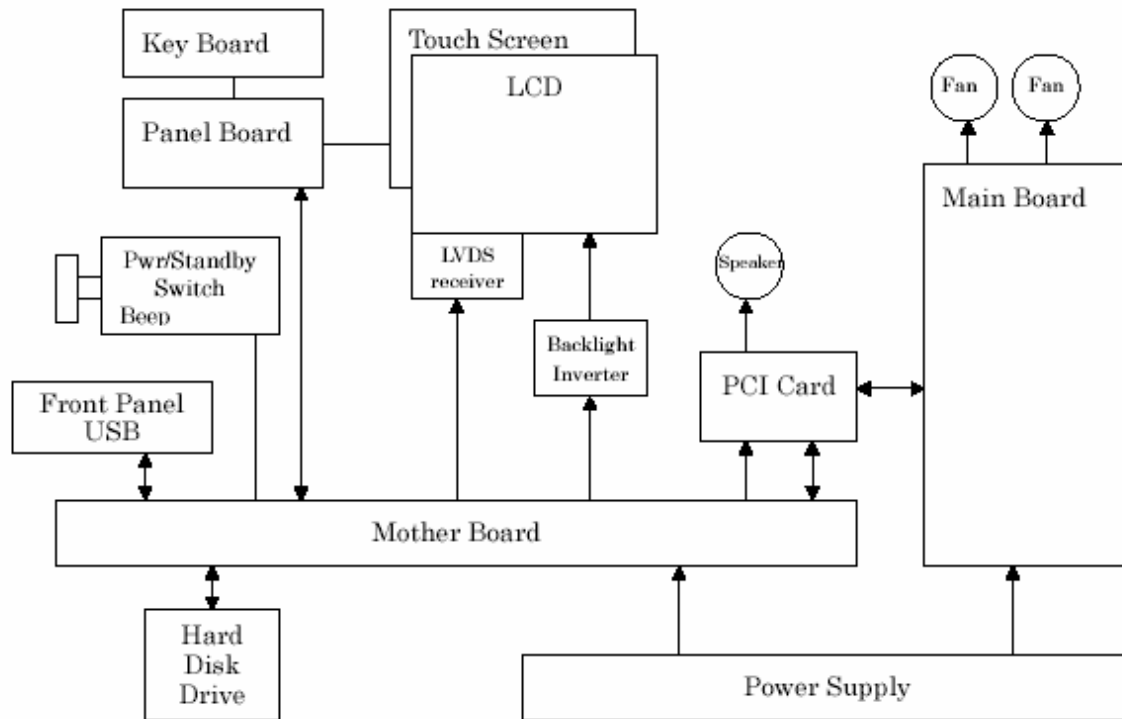


Figure 4-1 WaveSurfer Block Diagram



## 4.2.1 Front End

The front end processes an analog signal for ADC and trigger, consists of 1M ohms attenuators, high impedance buffer, 200 ohms attenuator, variable gain amplifier SA5209D and differential amplifiers.

The main functions of the Front end without the amplifiers are:

- Four channels operation, calibration with Software control.
- Input protection (clamp + thermal detection) and coupling (AC, DC, 1M $\Omega$ , 50 $\Omega$ ).
- Attenuator by 5, by 10, by 50, by 100 & by 500.
- Offset control of  $\pm 1V$ .
- Detection of 50 $\Omega$  over loading.
- Input of signal for DC calibration and skew calibration.

The main functions of SA5209D and differential amplifiers are:

- Amplitude normalization for the ADC system : at the BNC the dynamic range is 16 mV to 80V FS (full scale) and the ADC/TRIG system input is 500 mV differential.
- Fine adjustment of gain and variable control.
- Band width limiter of 20MHz, 200MHz.
- Switch for channel combine mode.

### Control

Relay control

The relay of the attenuator is set by selecting the input coupling and the gain as shown in the table below.

All relays are driven with +5V/0V.

Input coupling

Control port	Relay	GND	1M,DC	1M,AC	50,DC
CAL	RL2	H	L	L	L
1M/*50	RL1	H	H	H	L
AC/*DC	RL5	H	L	H	L
1/*10	RL3	H	X	X	X
1/*100	RL4	L	X	X	X

Switch of attenuator

Control port	Relay	2mV-49mV	50mV-0.49V	0.5V-10V
1/*10	RL3	H	L	L
1/*100	RL4	H	H	L



## Divide gain

The gain ratio in each block and input range is a table below.

At the BNC the dynamic range is 16 mV to 80V FS (full scale) and the output is 500 mV differential (HAD631 input).

Block	Range V/div											
	2mV	5mV	10mV	20mV	50mV	100mV	200mV	500mV	1V	2V	5V	10V
ATT 1/*10	1	1	1	1	1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
ATT 1/*100	1	1	1	1	1	1	1	1	0.1	0.1	0.1	0.1
ATT 1/5	1	1	1	0.2	1	1	0.2	1	1	0.2	0.2	0.2
SA5209D	31.25	12.5	6.25	15.62	1.25	6.25	15.62	1.25	6.25	15.62	6.25	3.125
Total(ratio)	31.25	12.5	6.25	3.125	1.25	0.625	0.3125	0.125	0.0625	0.03125	0.0125	0.00625

## Analog control voltage

Circuit name	signal level	Signal name
CHx OFFSET	+/-4V	Offset control signal for Front End
CHx GAIN	+/-4V	SA5209D gain control signal
CHx OS ADJ	0 to +4V	Offset control signal for differential amplifiers
INT CAL	-6V to +6V	Signal each CH commonness for calibration

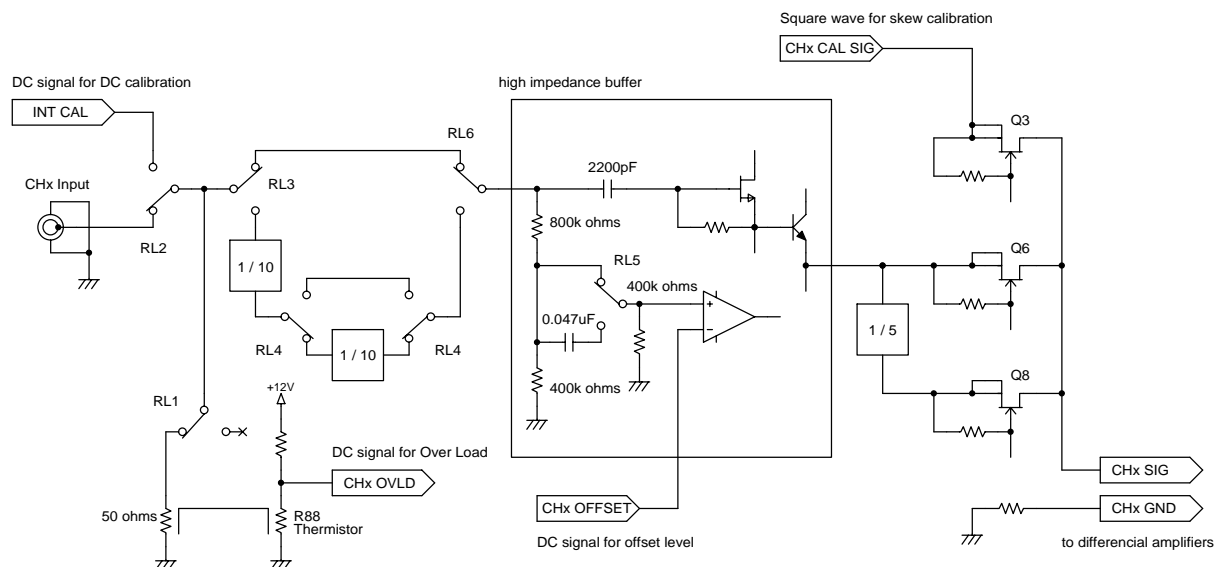


Figure 4-3 Front End Block Diagram 1

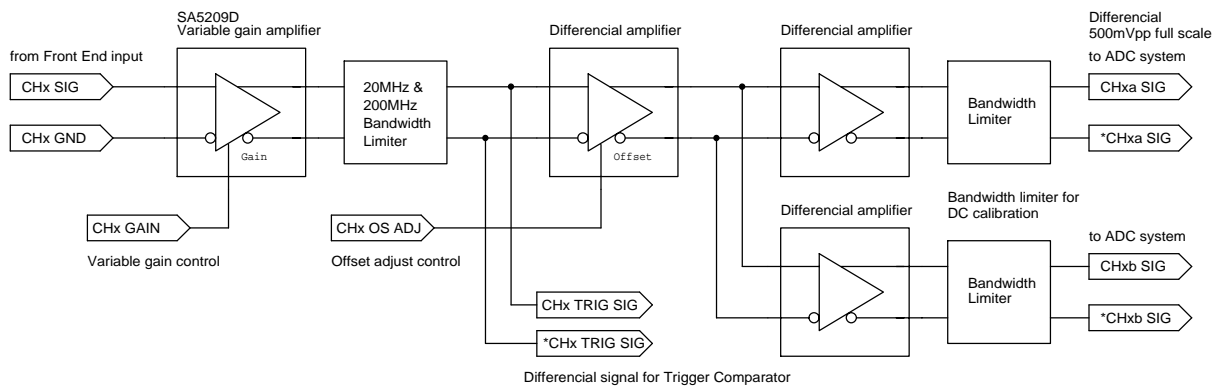


Figure 4-4 Front End Block Diagram 2

## 4.2.2 Analog to Digital Converter

The analog to digital converter system does the signal conversion to 8 bits, using the HAM631:

The system has the relay switchyard to combine the input channels.

- HAM631**

Hybrid ADC 1GS/s with 4Mb memory. It consists of MAD442 and MAM633.

Provide 83 MHz clock for memory and refresh for DRAM.

### Analog Control voltage

Circuit name	signal level	Signal name
CHx ADGAN	0 to +4V	Adjust ADC gain (+/-15%)
CHx ADOFS	0 to +4V	Adjust ADC offset (+/-100mV)
CHx ADDLY	0 to +4V	Adjust ADC sampling delay (+/-250ps)

These are mainly used on channel combine mode.

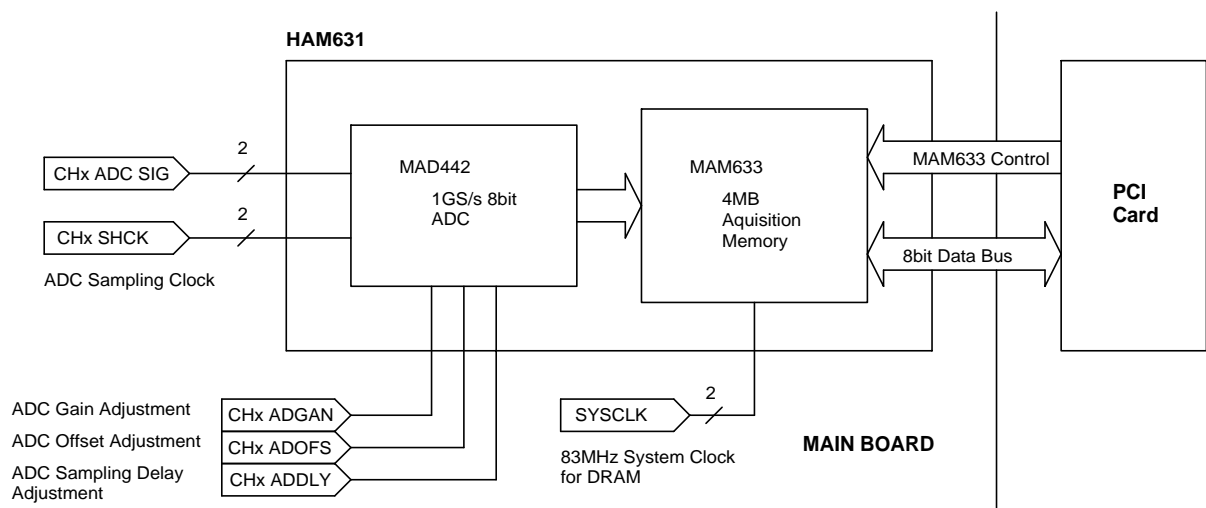
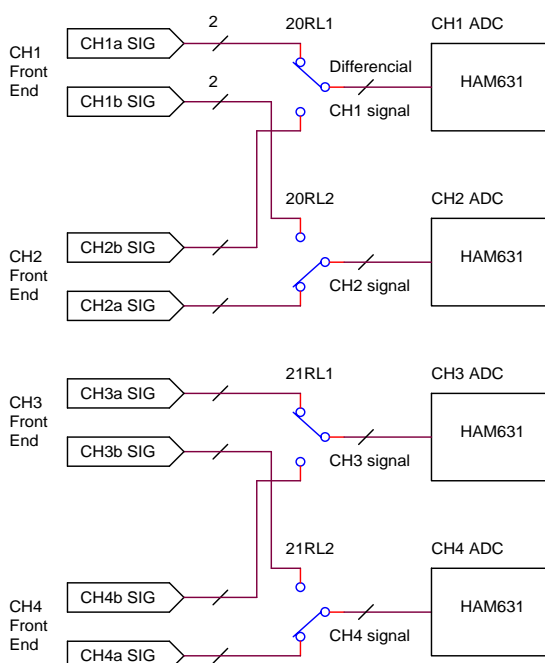


Figure 4-5 HAM631 System Architecture



#### 4 channels mode



#### Channel combine mode (CH1 & CH3)

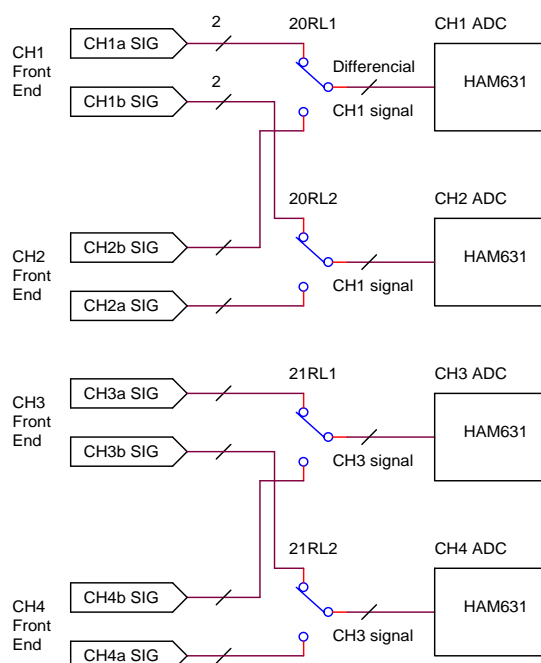


Figure 4-6 4 & 2 Channel Mode

### 4.2.3 Trigger

#### HTR420

The main function of HFE420 are:

- Generation of trigger signal (analog input and digital output) with comparator
- Setting of trigger level (TRIG, VALIDATE)
- Setting of trigger coupling (DC, AC, LFREJ, HFREJ, HF)
- Setting of slope (+, -, WINDOW)

The different trigger couplings using HTR420 are :

- DC
- AC : cut off frequency is almost 7.5 Hz.
- LF REJ : single pole high pass filter with a cut off frequency at 50 kHz.
- HF REJ : single pole low pass filter with a cut off frequency at 50 kHz.
- HF : frequency divider by four for high frequency signal.

#### TV Trigger

Each channel has a pick-off after the HTR420. Selected trigger source goes to commercial chip (LM1881) via AGC amplifier and provides three outputs (Composite Sync. Output, Vertical Sync. Output, and ODD/EVEN output) to the MST429A.

---

### **MST429A**

The main function of MST429A are:

- generates main trigger signal for Time Base system

The trigger function of MST429A are:

- Single source trigger,
  - Standard trigger,
  - Hold off by Time
  - Hold off by Events,
  - Pulse width
  - Interval
- Multiple source trigger,
  - State qualified,
  - Edge qualified

### **Analog Control voltage**

Circuit name	signal level	Signal name
CHx TRIG LVL1	+/-4V	Trigger level control signal
CHx TRIG LVL2	+/-4V	Trigger level control signal for smart trigger/window
CHx HYST	0 to +4V	Trigger hysteresis control signal

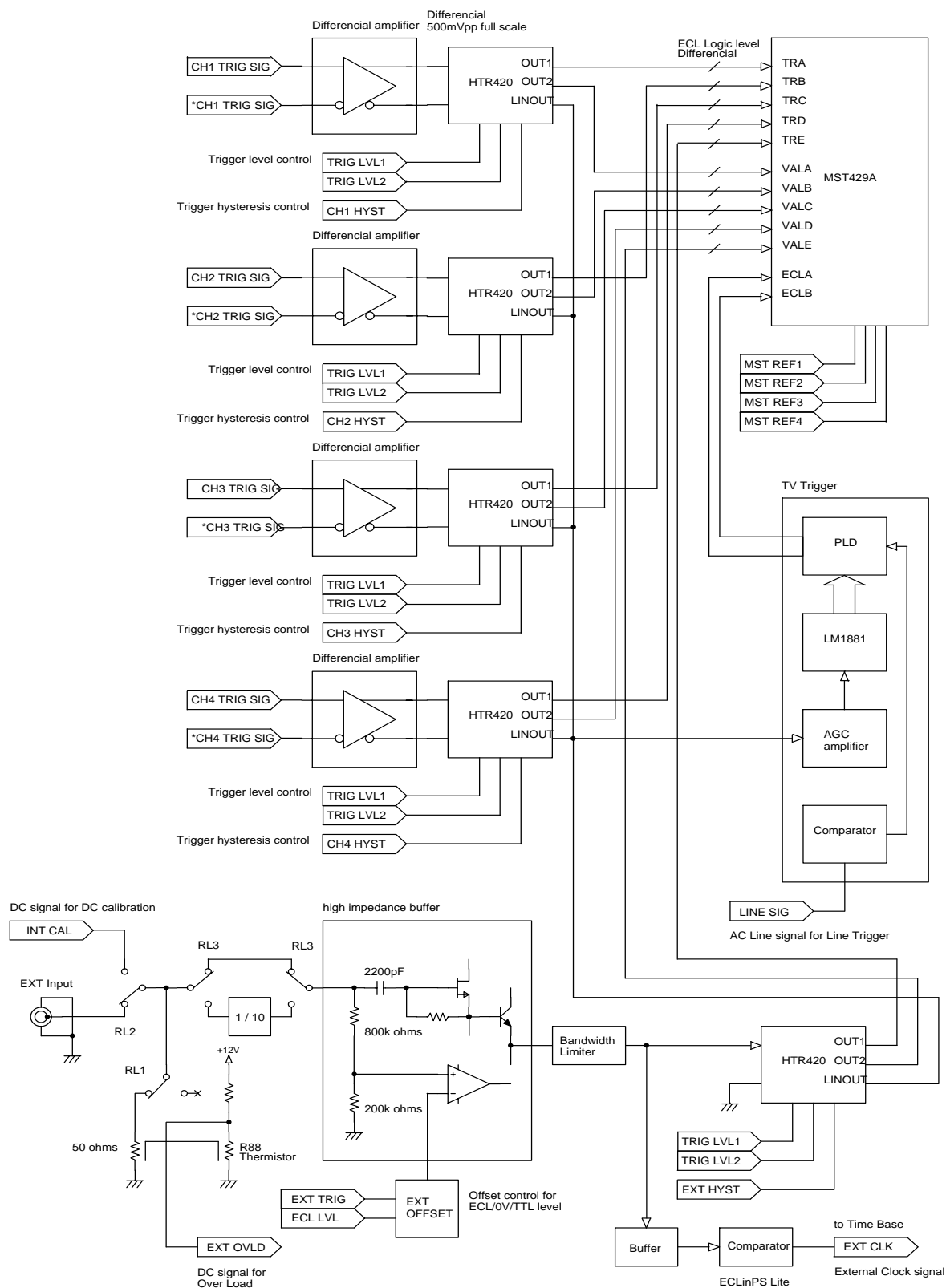


Figure 4-7 Trigger Block Diagram



## 4.2.4 Time Base

The time base includes four circuits:

- **MCG426:** generates sampling clocks: 12.5 MHz up to 2GHz  
generates clocks for the MTB411  
interleaves sampling clocks to increase sampling rate and memory depth.
- **MTB411A:** Time Base System  
Trigger circuitry  
Main oscillator circuitry  
Frequency divider for a Probe Calibrator
- **TDC:** Time to Digital Converter interpolator and Real Time computation
- **MST429A:** generates main trigger signal for Time Base system.

### Analog Control voltage

Circuit name	signal level	Signal name
MST REF1	+/-4V	Reference signal for analog time of Smart trigger
MST REF2	+/-4V	Reference signal for analog time of Smart trigger
MST REF3	+/-4V	Reference signal for analog time of Smart trigger
MST REF4	+/-4V	Reference signal for analog time of Smart trigger
TDC ADJ	0 to +4V	TDC gain control signal

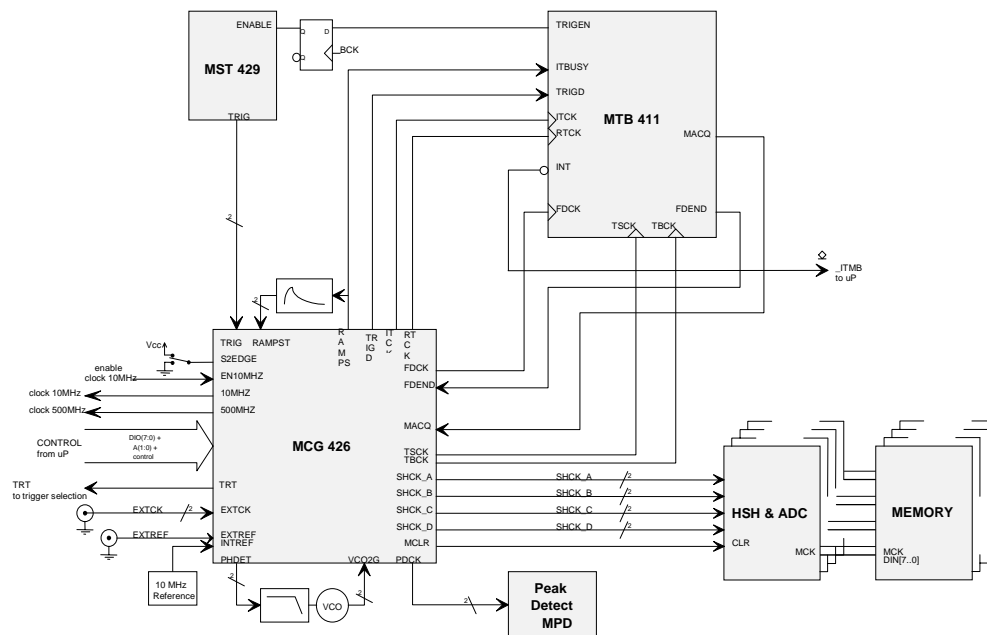


Figure 4-8 Time Base Block Diagram



## 4.2.5 Calibrator

The main functions of the Calibrator are:

- Probe calibration signal output.
- DC calibration signal output.
- Skew calibration signal output.

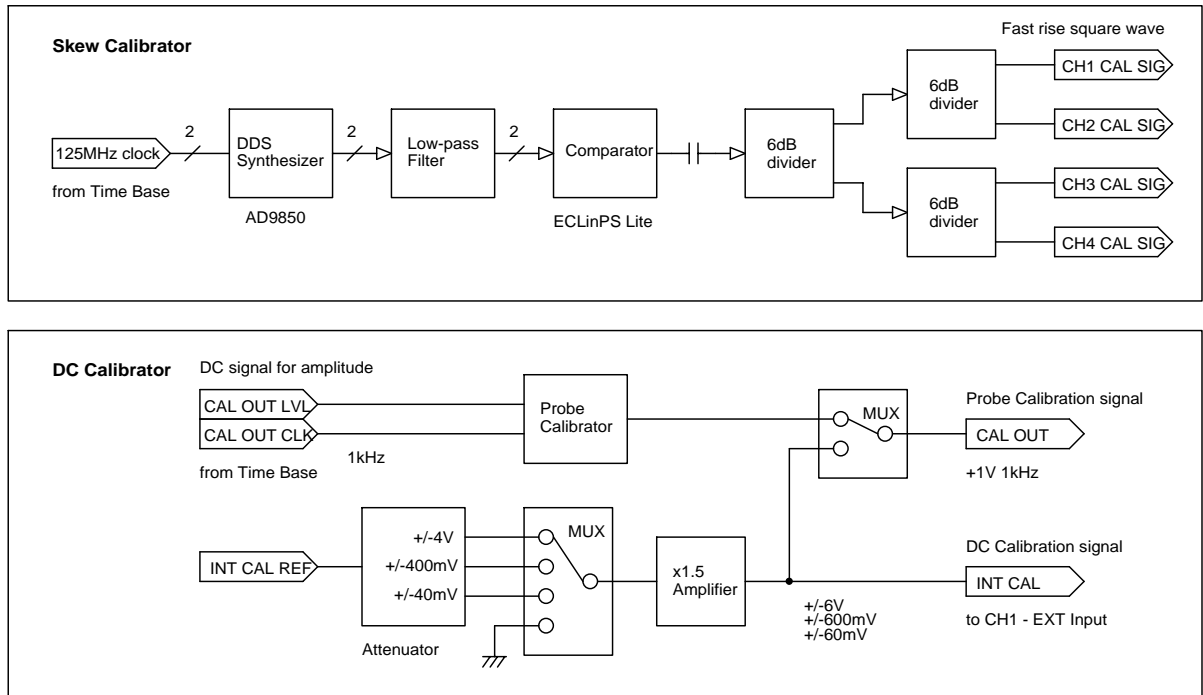


Figure 4-9 Calibrator Block Diagram

## 4.2.6 SCAN DAC

The main functions of the SCAN DAC are:

- 16 bit precision DAC with uP system.
- 24 analog control signal outputs.
- +/-4V dynamic range outputs.
- 16 ADC inputs for Probe sense, overload detection and so on.

## 4.2.7 MAIN BOARD CONTROL

The main functions of MAIN BOARD CONTROL are:

- 3 wire Serial Bus for serial device control.
- IIC Bus for EEPROM, Thermometer and ProBus system.
- 16 Analog control outputs using 10 bit DAC.
- 12 Analog control outputs using 8 bit DAC.
- Interface between Main Board and PIC Card.

---

## **4.3 Computer**

The WaveSurfer processor is an 850 MHz Intel Celeron processor. This motherboard was designed for embedded system.

### **4.3.1 Operating System**

The system uses Microsoft Windows XP embedded as the operating system. The operating system license can be found on the rear panel of the instrument.

### **4.3.2 Memory**

The standard memory configuration for a WaveSurfer is 256MB, consisting of 1 piece of 32M x64 Bit PC-2100 DDR DIMM.

### **4.3.3 Interfaces**

The standard interfaces provided by the Motherboard to external are SVGA, Audio, Ethernet, RS-232, Centronics, three USBs(side 2, front 1), PS/2 Keyboard and PS/2 Mouse. Also one USB and IDE port provided by the Motherboard are used inside the unit for Front panel and HDD.

### **4.3.4 Storage Devices**

The system has an internal hard drive of at least 30 GB in size. 10 GB is allocated for LeCroy use, 16 GB is in a user partition for the saving of panel setups, waveform memory, hard copies, application programs, user data, etc. The balance is allocated as invisible partition for system recovery data

### **4.3.5 Video port**

The Mother board has an on-board video display processor with a LVDS output as well as the ability to drive a rear panel external display. This external port is enabled on power up if it an external monitor is sensed. If the monitor is connected after the initial power on, the power to the instrument must be cycled in order for this monitor to operate.



## 4.4 PCI Card

The PCI card is the interface between the PCI bus on the processor card and the rest of the system (acquisition system and amplifier for speaker). It has the following interfaces:

- PCI interface (32 bit 33MHz bus with bus mastering capability)
- Acquisition data interface using 32bit local bus.
- Acquisition control interface using 8bit local bus.
- Dallas OneWire interface and chip for scope id.
- Audio amplifier for internal speaker.

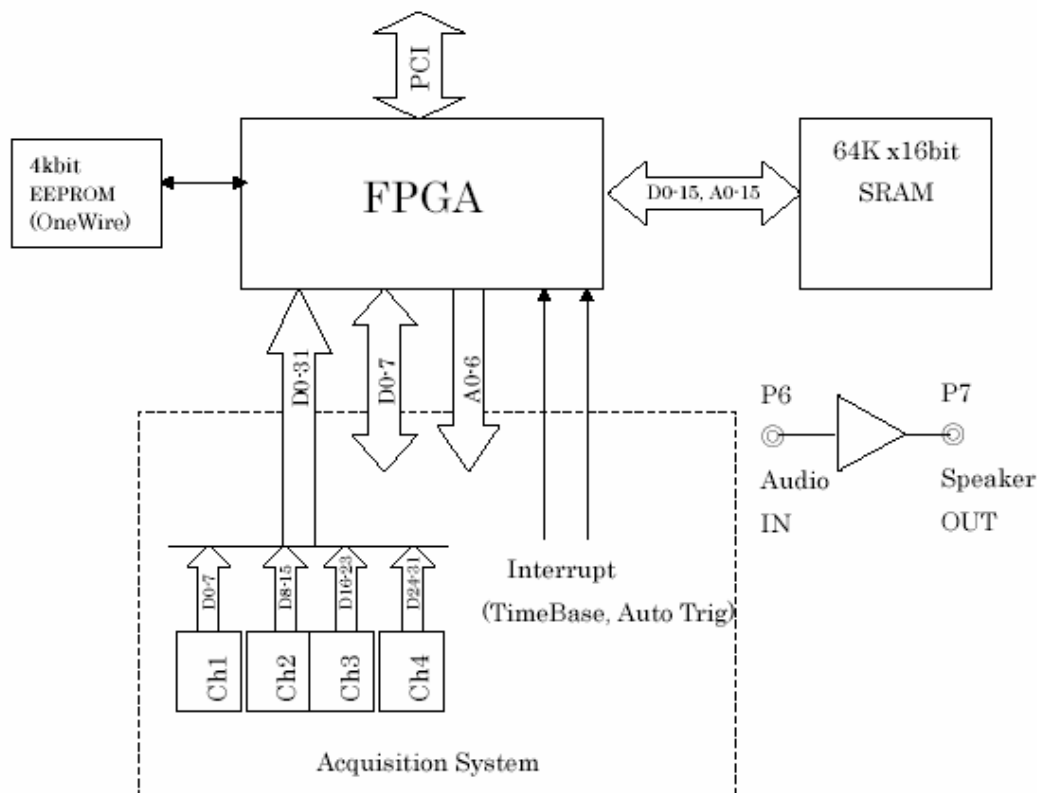


Figure 4-10 PCI Card Block Diagram

### 4.4.1 PCI Interface

The PCI interface is implemented with a Xilinx FPGA. It is a 32 bit, 33 MHz bus master that allows the PCI card to take control of the PCI bus and push data directly into the processor memory without requiring the direct involvement of the processor. In readout mode, the FPGA reads the data and puts it in the correct time order for the processor memory. The FPGA also has a special readout mode to access the acquisition data in roll mode, store the data, and then transfer this data in blocks to the processor memory. This implementation is the most complicated but is needed in order to maximize the PCI throughput.

#### 4.4.2 Local bus for acquisition

The acquisition interface consists of 2 local buses to read out acquisition data and to control the main board.

##### 4.4.2.1 Control

All resource on main board is controlled through 8bit local bus.

##### 4.4.2.2 Acquisition Data

32bit local bus is used to access the acquisition memories. Each 8bit is connected to each channel's memories directly. (bit0-7 is connected to ch1, bit8-15 is connected to ch2, bit16-23 is connected to ch3 and bit24-31 is connected to ch4)

#### 4.4.3 Dallas OneWire Interface

The Dallas onewire interface is controlled by FPGA. The 4kbits EEPROM is connected to this interface. This device has unique id to generate scope id.

#### 4.4.4 Audio amplifire

The audio amplifier to drive internal speaker is on PCI board. This is independent from other PCI function.

#### 4.5 Front Panel

The front panel consists of two assemblies, the panel board and the key board assembly.

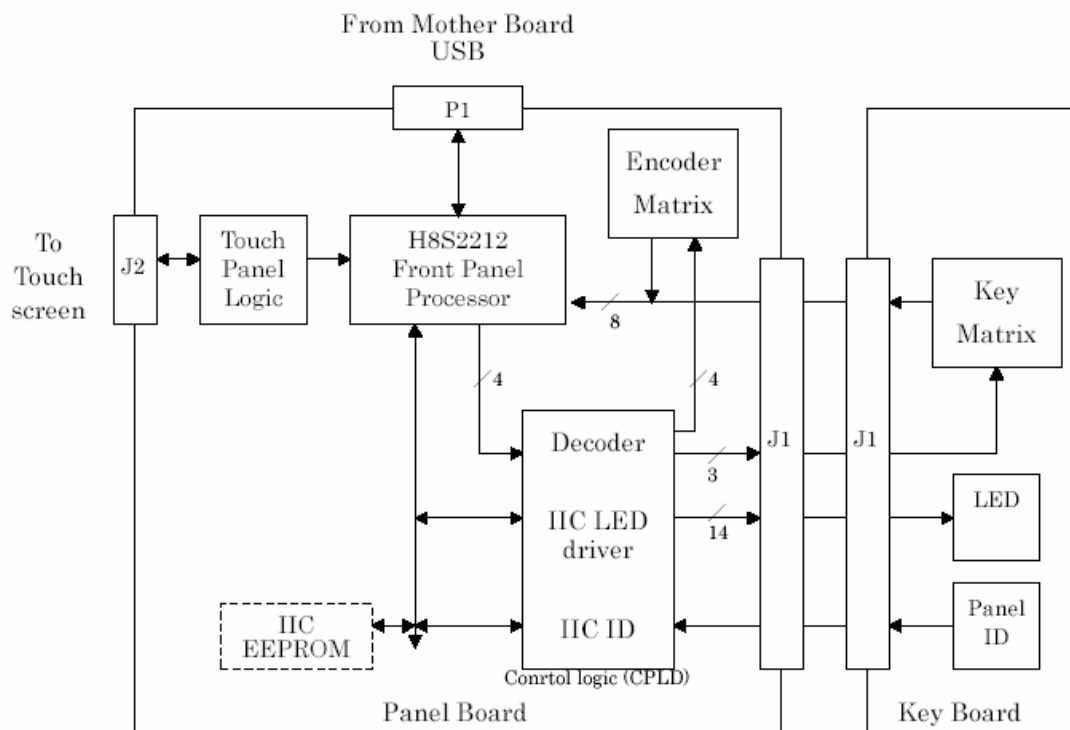


Figure 4-11 Front Panel Block Diagram



#### **4.5.1 Key board**

The front panel assembly consists of the panel board PCB, the panel board metal, the elastomeric keypad and the key board PCB. The key board PCB connects to the panel board assembly which is connected to the mother board by USB. The key board has the LED's which illuminate some of the front panel buttons and has trace patterns which act as switches when the elastomeric keypad shorts the traces together in response to a key press.

The key board has configuration jumper which must be selected based on the identification of the front panel (2 channel model or 4 channel model).

#### **4.5.2 Panel Board**

Panel board consists of rotary encoder function and touchscreen function.

The encoder status, the front panel key status and the touch panel status is read by the front panel processor, the H8S2212. Power for the panel board comes from the cable of the USB.

##### **4.5.2.1 Encoders**

The panel board contains all of the rotary encoders. There are two different types of encoders on this assembly, some have a push switch, others do not. The V/Div and timebase use encoders that do not have push switch, the rest of the encoders have a push switch. The encoders contain two switches, they are not potentiometers. The software can determine the direction and speed the encoder is turning based on the order and frequency of make and break connections of these internal switches.

##### **4.5.2.2 Touchscreen Interface**

Provides a control interface to a 4-wire resistive touchscreen. The pointing location is measured by 4 A/D convertors in the front panel processor.

## 4.6 Display and Touchscreen

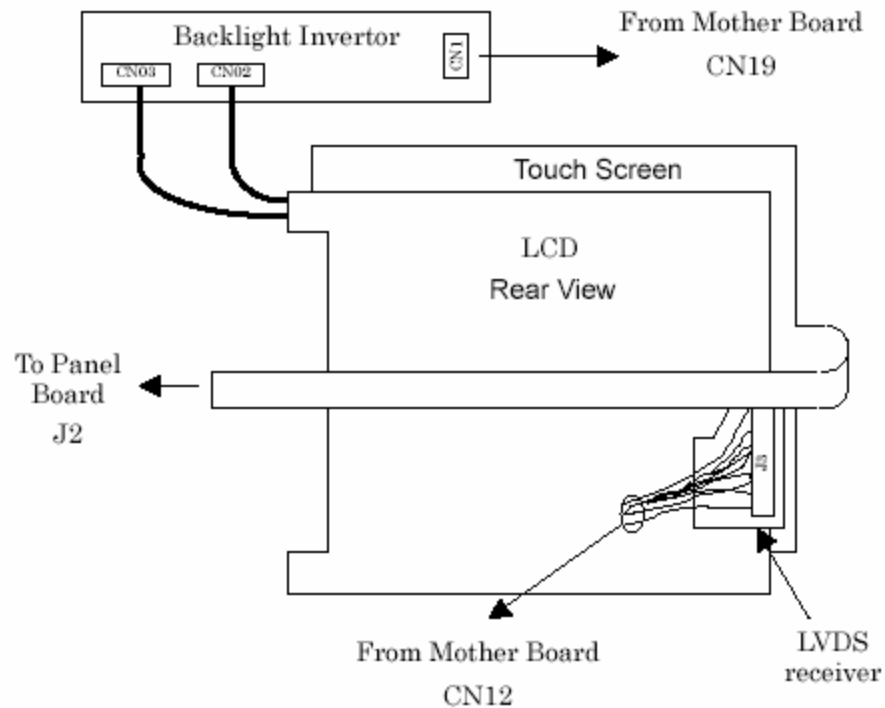


Figure 4-12 Display & Touchscreen Block Diagram

### 4.6.1 Color LCD Module

The display module is an SHARP TFT (thin film transistor) active matrix color liquid crystal display (LCD) module comprising amorphous silicon TFT attached to each signal electrode, a driving circuit and a backlight. The 26cm diagonal display area contains 800x600 pixels (SVGA) and can display 262144 colors simultaneously.

### 4.6.2 Backlight Inverter

The inverter which supplies power to the LCD's backlight is supplied with +12V from the Mother board, it then converts this to 1000-2000V AC to drive the CCFT (Cold Cathode Fluorescent Tube). There is also a signal from the Mother board which controls the On/Off of the backlight.

### 4.6.3 Touch Screen

The touch screen is a 4 wire resistive touch screen. It must be calibrated so that software can determine where a touch corresponds to a position on the screen. This calibration is done at four points and can be invoked through the Utilities menu.

### 4.6.4 LVDS receiver

Mother board has LVDS output for LCD. LVDS receiver receive the LVDS signal from Mother board, it then converts this to 18bits RGB (each color has 6bits depth) for input type of LCD module.



## 4.7 Power Supply



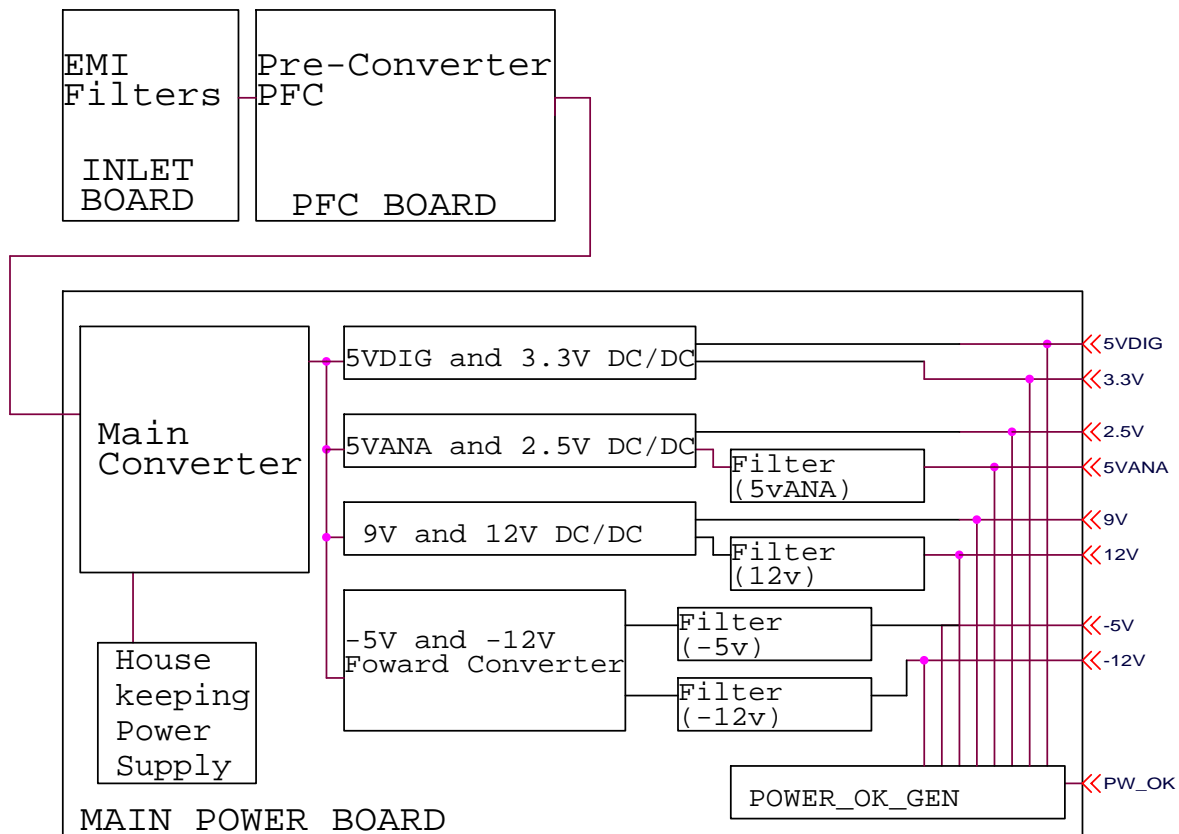
Do not touch any electric parts inside the power supplies during operation as the primary side of the power unit has many high voltage portions to ground.

Power Supply Unit comprises of INLET BOARD, PFC BOARD and MAIN BOARD.

The INLET BOARD includes EMI Filters.

The PFC BOARD includes Pre-converter, which is operated Power Factor Correction.

The MAIN BOARD includes Main Converter (off line), House Keeping Power Supply, Post Converters, Filters, Power OK Generator circuit and internal Bias Supply Circuits.



Solid Line Blocks represent Daughter Boards.

Figure 4-13 Power Supply Block Diagram

### 4.7.1 Input Voltages

The power supply supports a wide ranges of inputs, 90-132 V AC (45-65HZ, 360-440Hz) and 90-264V AC (45-65Hz) are allowed.



## 4.7.2 Output Voltages

The power supply makes several output voltages:

OUTPUT VOLTAGE	“TOTAL” REGULATION BAND	Min. Load	Typ. Load	Max. Load	CAPACITIVE LOADING	
					Minimum Capacitance	Maximum Capacitance
+5.0Vana (RS)	+/-1%	0.1A	4.0A	4.2A	1200μF	1800μF
-5.0V (RS)	+/-1%	1.0A	5.0A	5.25A	1200μF	1600μF
+9.0V	+/-2%	0.1A	0.4A	0.5A	330μF	390μF
+2.5V	+/-5%	0.1A	1.0A	1.4A	1400μF	2000μF
+12.0Vana	+/-1%	0.1A	0.16A	1.16A	330μF	560μF
-12.0V	+/-2%	0.1A	0.62A	1.7A	330μF	560μF
+5.0Vdig	+/-5%	0.1A	3.1A	5.5A	2400μF	10000μF
+12Vdig	+/-5%	0.1A	1.0A	1.24A	500μF	1000μF
3.3V	+/-5%	0.1A	2.0A	3.0A	4000uF	6000uF
5.0V(stand)	+/-5%	0.1A	0.1A	1.0A		

Note: RS represent Remote Sense.

## 4.7.3 Basic Operation

The power supply utilizes 5 converter, 5 synchronous step- down switching regulator and step-down switching regulator.

### 4.7.3.1 Pre-converter

Power Factor Correction (PFC) circuit. It uses a Critical Mode Boost Converter topology switching and using MosFETs as the primary switches. The output of the PFC Converter is regulated to 385VDC.

### 4.7.3.2 Main Converter

The converters are like dual-switch half-bridge converters switching at approximately 88KHz and utilizing the module integrated controller and two MosFETs as the primary switches. Output is regulated using a post switching regulation scheme. The output has its own raw voltage provided on its own separate winding on the transformers. The output is regulated to 24V secondary bus voltage,.

### 4.7.3.3 House Keeping Power Supply

It is a fly back converter switching at approximately 80 kHz. The bias supply also provides other voltages for internal housekeeping. The bias supply is “ON” whenever AC is present. +5VSB is provided from an step-down switching regulator.

### 4.7.3.4 +5VDIG and 3.3V DC/DC(Daughter Board)

Dual 2-phase synchronous step-down switching regulator is used for the +5Vdig and +3.3V supply.



#### 4.7.3.5 +5VANA and 2.5V DC/DC (Daughter Board)

Dual 2-phase synchronous step-down switching regulator is used for the +5.0Vana and 2.5V supply.

#### 4.7.3.6 +9 and 12V DC/DC (Daughter Board)

Step-down switching regulator is used for the +9.0V supply. Synchronous step-down switching regulator is used for the +12V supply.

#### 4.7.3.7 -5V and -12V Forward converter

This converter is used for the -5.0V supply. There is also a linear regulator which supplies the -12V supply.

#### 4.7.3.8 Filter Circuits (Daughter Boards)

The Filter circuits are implemented for analog outputs ;+5.0V,+12.0V,-5.0V and -12.0V.

### 4.7.4 Connector Assignments

The power supply connectors are arranged as follows:

#### INLET BOARD

Reference	Supplied BOARD	Connector	Pin#	Voltage /Function	Comment
1CN2	PFC BOARD	5566-2A	Total 2	Input AC Line	

#### PFC BOARD

2CN2	INLET BOARD	5566-2A	Total 2	Input AC Line	
------	-------------	---------	---------	---------------	--

2CN3	MAIN BOARD	5566-2A	1	385VDC	
			2	Primary Return	

2CN1	MAIN BOARD	5267-3A	1	18.5VDC	
			2	Primary Return	
			3	Traiac Bias	

2CN4	MAIN BOARD	5267-2A	1	Line	
			2	GND	

## MAIN BOARD

### Primary

3CN1	PFC BOARD	5267-3A	1	18.5VDC	
			2	Primary Return	
			3	Triac Bias	

5CN2	PFC BOARD	5566-2A	1	385VDC	
			2	Primary Return	

### Secondary

Reference	Supplied BOARD	Connector	Pin#	Voltage /Function	Comment
CN9	EXT BOARD	5566-2A	1	24V	Bus Voltage
			2	GND	

5CN1	EXT BOARD	5267-3A	1	24V	To printer
			2	N.C	
			3	GND	

CN2	Main Board	51067	1,2	+5.0V	
			3,6	GND	
			4,5	-5.0V	
			7,8	+2.5V	

CN3	Main Board	51067	1	+12.0V	
			2,4	GND	
			3	+9.0V	
			5	-12.0V	



CN4	Main Board	5268-07A	1	-12.0V	F.B -12.0V
			2	+12.0V	F.B +12.0V
			3	-5.0V	F.B -5.0V
			4	+5.0V	F.B +5..0V
			5	LINE	Line tiger Signal
			6	BAT EN	Battery EN.
			7	BAT VS	Battery V.S.

CN5	Main Board FAN MOTOR	5568-02A	1	+12Vdig	
			2	GND	

Reference	Supplied BOARD	Connector	Pin#	Voltage /Function	Comment
CN6	UATX-Board	5566-20A	1,2,11	3.3Vdig	
			3	GND	
			4	5.0Vdig	
			5,7,13	GND	
			6,19,20	5.0Vdig	
			8	PWR_OK	TTL level
			9	+5.0Vstb	Standby Power
			10	+12.0Vdig	
			12	-12Vdig	
			15,16,17	GND	
			14	PS_ON#	<0.8V:ON/>2V:OFF
			18	-5.0Vdig	

CN11	PFC BOARD	5267-02A	1	LINE	
			2	GND	

CN7	EXT Board	5267-06A	1	GND	
			2	REMOTE_ON	
			3	BAT VS	
			4	BAT EN	
			5	Vaux	
			6	5Vstd	

CN10	EXT Board	5267-02A	1	24V	External OUT
			2	GND	

#### 4.7.5 Output Voltage Adjustment Range

Each output voltage has an adjustment range of the nominal Vset voltage as specified in the table. The adjustments are clearly labeled and accessible from the top of the Power Supply. Turning adjustment potentiometers clockwise increases the absolute value of output voltages.

#### 4.7.6 +5VSB Standby Supply Rail

+5VSB is a standby supply output that is active whenever the AC power is present. It provides a power source for the processor standby circuits that must remain operational when the other main DC output rails are in a disabled state. The 5VSB output is capable of delivering up to 0.5A continuously with the fan not operating.

#### 4.7.7 Control

The following control signals are required.

##### 4.7.7.1 Output Enable OUTPUT-EN/ (active low)

This is an active low signal which comes from the processor board that turns on (enables) all of the power supply DC outputs.

##### 4.7.7.2 Line Frequency Synchronization Output Signal (LFS)

The LFS signal is safety-isolated from the primary circuits of the power supply. The LFS signal is a digital signal (TTL levels) that toggles at each zero-crossing of the AC line input.

##### 4.7.7.3 PWR\_OK signal

PWR\_OK is a "power good" signal. It is asserted high by the power supply a minimum of 100ms after all Secondary Outputs are above the minimum voltage as specified by the lower limit of the regulation band and the AC line is present. The PWR\_OK rise time is  $\leq 10\text{ms}$ . In the case of AC line disconnection or drop-out, the PWR\_OK signal goes low when at least one of Secondary Outputs drop out of regulation.



#### **4.7.8 Over-Current Protection**

All outputs are protected against damage due to overloads or short circuits. Short circuit current levels for any output, unless specified below, will not exceed 125% of maximum current for that output.

Each output has independent current limiting, that is the over-current of any of these outputs will not cause any other output except -5.0V Output. If -5.0V output will short, -12.0V output reduces output voltage. The over current circuitry is latch type. Whenever Over-Current protection occur, all Outputs shut down to protect Circuitry damage. -5V output only have over-current adjustment value(6A) and adjustment potentiometer.

#### **4.7.9 Over-Temperature Protection**

The power supply will shut down before any damage occurs from over-temperature. This is true independent of the cause of the over-temperature condition (i.e. blocked power supply cooling fan, excessive ambient temperature, etc.) When the power supply restart, the power supply must remove AC Line for a few minutes and remove the cause of the over-temperature condition.

#### **4.7.10 Over-Voltage Protection**

Over-voltage protection is required to reduce the likelihood of damage to system components in the event of a single point fault within the power supply. All outputs incorporate an over-voltage protection limited to less than 135% of the nominal Vset values. When the power supply restart, the power supply must remove AC Line for a few minutes and remove the cause of the over-Voltage condition.