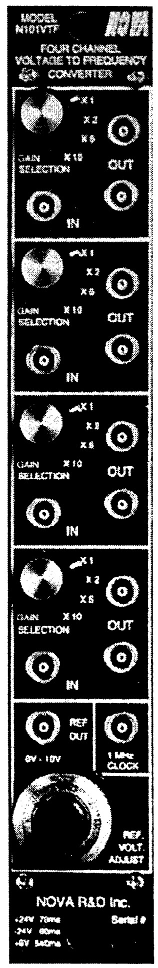
FOUR CHANNEL ULTRA HIGH LINEARITY VOLTAGE-TO-FREQUENCY CONVERTER

USER MANUAL
MODEL N101VTF
Ver. 1. Rev. C.



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MODEL N101VTF

WARRANTY

NOVA R&D, Inc. warrants its instruments to be free from defects in material and workmanship for a period of one year from the date of shipment. This warranty does not apply to equipment that has been subjected to misuse or has been repaired or altered in any way by the user. *NOVA R&D, Inc.* is responsible only for the cost of materials and labor to repair or replace, FOB our facility, products proven to be defective during the warranty period. *NOVA R&D, Inc.* is not liable for consequential damages incurred due to failure of the equipment. No other warranty is expressed or implied. All products returned under warranty must be shipped prepaid to the factory with documentation describing the malfunction noted. It is recommended that *NOVA R&D, Inc.* be notified and a Return Authorization Number obtained prior to shipment. The equipment will be evaluated, then repaired or replaced and promptly returned if the warranty claims are found to be substantiated. A nominal service charge will be made for any unsubstantiated claims. Include the *NOVA R&D, Inc.* Model and Serial number in all correspondence with *NOVA*.

SPECIAL CALIBRATION SERVICE

A special calibration service for the default settings listed in this manual is provided with a schedule of one day service and overnight delivery for a nominal fee. Other calibration options with specific instructions require a minimum of two day service and overnight delivery.

FOUR CHANNEL ULTRA HIGH LINEARITY VOLTAGE TO FREQUENCY CONVERTER

MODEL N101VTF

SECTION I: FEATURES, SPECIFICATIONS & CALIBRATION

I. 1. FEATURES

- Ultra high linearity, ≤ 50 PPM FS @ 1 MHz range for Voltage-to-Frequency (VTF) converter.
- Ultra high linearity, ≤ 50 PPM FS @ Gain = 1, for Instrumentation Amplifier (IA).
- Measured linearity of some typical channels ≤ 30 Hz in the mid range.
- Four fully decoupled independent channels.
- Undetectable crosstalk between channels.
- Immunity to feedback from large and fast rising voltage swings in different channels.
- Two outputs per channel.
- 0 to 10 volt (or internal switch selectable 0 to 5 Volt) input range.
- Four selectable gains; x1 (accurate calibrated default), x2, x5 & x10 (≤ 3% accuracy).
- Accepts positive (default) or negative (internal switch selectable) input polarities.
- Accurate 1 MHz clock output from internal 4 MHz common clock circuit.
- Ultra high stability 0 to 10 V reference voltage output, (on board pad for 5 V output).
- TTL output frequency range 0 to 1 MHz (2 MHz output is internal jumper selectable).
- All frequency outputs, including the 1 MHz clock, can drive a 50 Ω cable.
- Independent potentiometers for calibrating VTF & IA modules on each channel.
- Highest rated IA and VTF chips are used.
- Digital Output of gain selection, for use with driving TTL logic.

I. 2. DESCRIPTION

The four channel voltage-to-frequency converter provides an output frequency proportional to the input voltage. The output frequency range is 0 to 1 MHz (can be changed to 2 MHz). The input voltage range can be selected between 0 to 10 and 0 to 5 Volts. The polarity of the input voltage can also be set to either positive or negative. The output frequency can be directly correlated to the input voltage (unity gain) or the frequency can be a multiple of the input voltage (gain = x2, x5 and x10).

Each channel contains a single input and two outputs. Each channel also contains a four position switch which controls the voltage gain for that channel.

A highly stable reference voltage is available on the front panel. The voltage can be adjusted between 0 and 10 V with a 10 turn potentiometer located on the front panel. A clock output (TTL) of 1 MHz is also provided.

The approximate size of the unit is 11 1/4 in. long, 8 5/8 in. high and 1 3/8 in. wide. The total weight of the NIM module is 2lbs.

I. 3. INPUT CHARACTERISTICS: Instrumentation Amplifier

Input	Default 0 to 10 V (or 0 to 5 V internal switch selectable at the input of the VTF). There is no internal termination provided.
Nonlinearity	Ultra low nonlinearity, ≤ ± 0.001% @ gain = 1 to 256
Gain range	1 to 10,000
Gain error	≤ ± 0.02% (External resistor network must also be considered).
Gain change with temp.	≤ 5 PPM/°C
Noise	Ultra low noise, 4nV/√HZ @ 1 kHz RTI
Gain bandwidth product	25 MHz
Slew rate	5 V/µs (Typical)
Settling time to 0.01%	15 µs @ gain = 1 to 200 (Typical) for 20 Vstep
Input offset voltage	≤ 25 µV (Nulled during calibration)
Input offset V vs temp.	≤ 0.25 µV/°C
Input polarity	Default is positive input referenced to ground. Negative input can be selected through an internal switch.
Input connector	LEMO
Input impedance	10^9 Ω (Typical)
Input gain	A front panel switch controls the voltage gain of the instrumentation amplifier. The gains can be selected from the front panel to be x1, x2, x5, or x10. The x1 gain is fully calibrated. The other gains are supplied to ≤ 3% accuracy by using three 1% resistors for the gain circuit for gains larger than x1. The resistors are further selected to be better than 1% accuracy which produces an overall gain accuracy better than 1%. (Higher gain accuracies can be provided on special order.)
Input range	The VTF voltage ranges are 0 to 10 V (default); 0 to -10 V; 0 to 5 V; or 0 to -5 V. The VTF maximum range limit (10 or 5 V) is set with an internal switch. The input range is the voltage range divided by the input gain setting. The default x1 range is fully calibrated before shipment. Another range can be calibrated if specially ordered.
Protection	Inputs are protected through four low voltage drop clamping diodes and two high quality current limiting input FET transistors.
Temperature range	-25 to +85 °C

I. 4. OUTPUT CHARACTERISTICS: Voltage-to-Frequency Converter

Output	Two independent but identical outputs per channel.
Output frequency range	Up to 2 MHz. (1 MHz range recommended for accurate work.)
Nonlinearity	Extremely low linearity error (≤ ± 0.005% @ 1 MHz Full Scale, and ≤ ± 0.02% @ 2 MHz Full Scale)
Gain error	≤ ± 0.5% @ 0.5 MHz Full Scale, and ≤ ± 0.75% @ 2 MHz Full Scale
Gain temperature coeff.	≤ ± 25 PPM/°C @ 0.5 MHz range (≤ ± 50 PPM/°C @ 2 MHz range)
Offset	≤ ± 2 mV (Nulled during calibration)
Offset temperature coeff	≤ ± 25 μV/°C
Response time	One period of new output frequency + One clock period.
Output rise & fall times	≈ 3 ns with or without 50 Ω termination.
Output logic	TTL (Active high when there is no input to the VTF converter.)
Output level	All frequency outputs including 1 MHz clock are 0 to 2.9 V with 50 Ω terminator and 0 to 5.3 V without terminator.
Output pulse width	≈ 0.2 μs @ 1 MHz output.
Output connector	Two LEMO connectors per channel.
Output drive capability	VTF outputs can drive a 50 ohm coaxial cable. Termination is important if cables longer than 30 cm are used.
Output frequency range	0 - 1 MHz (An internal jumper is provided for 0 - 2 MHz range). Output remains at 1 MHz (or 2 MHz) even if input exceeds 10 V (or 5 V) for positive and -10 V (or -5 V) for negative input ranges.
Temperature range	0 to 70 °C for the VTF chip

Other outputs

1 MHz clock output	High stability (≤ 2 PPM Aging & ≤ 5 PPM Temperature) output from an internal 4 MHz clock with 50 Ω drive capability. Can be used as time base clock for accurate measurements.
Voltage reference output	An ultra stable voltage reference output is supplied with an accurate calibrated dial. It has low drift ≤ ± 1.5 PPM/°C, low initial error ≤ ± 1 mV, Output noise 6 μV p-p and both + 10 & + 5 V outputs. Provided for testing and calibration. Low output current, should only be used to supply calibration input to the VTF and a high impedance input volt meter.
8 Bit Digital Output	An 8-Bit encoded digital output is available, which corresponds to the gain selection of the four V-to-F channels. This can be used to drive any standard TTL logic device. The shunt resistance between the output of the NIM module and the TTL chip must be at least 150Ω or higher in order to properly drive the logic chip.

The following digital outputs should be seen based on the gain selection for the four channels:

If all channels are set to gain selection x1: output is 0000 0000

Channel 1	gain selection x2:	output is 0000 0001
Channel 1	gain selection x5:	output is 0000 0010
Channel 1	gain selection x10:	output is 0000 0011
Channel 2	gain selection x2:	output is 0000 0100
Channel 2	gain selection x5:	output is 0000 1000
Channel 2	gain selection x10:	output is 0000 1100
Channel 3	gain selection x2:	output is 0001 0000
Channel 3	gain selection x5:	output is 0010 0000
Channel 3	gain selection x10:	output is 0011 0000
Channel 4	gain selection x2:	output is 0100 0000
Channel 4	gain selection x5:	output is 1000 0000
Channel 4	gain selection x10:	output is 1100 0000

I. 5. CALIBRATION

IA input offset	An internal 25 turn potentiometer (**Figure 1**) can be used to adjust the input offset of the instrumentation amplifier.
IA output offset	An internal 25 turn potentiometer (**Figure 1**) can be used to adjust the output offset of the instrumentation amplifier. This potentiometer is not always supplied. It is only needed for large gain applications.

VTF input offset	An internal 25 turn potentiometer (**Figure 1**) can be used to adjust the input offset within a few Hz of the expected frequency.
VTF gain	Two internal 25 turn potentiometers (**Figure 1**) can be used independently to adjust the voltage-to-frequency gain of the 0 to 10 V (default) and 0 to 5 V ranges. The adjustment of each range effects each other somewhat. Therefore, the module comes with the 0 to 10 V range adjusted fully and 0 to 5 V range adjusted partially unless requested otherwise. If the unit is switched to 0 to 5 V range it must be recalibrated if accurate measurements need to be made. This adjustment can be carried out at *NOVA*.

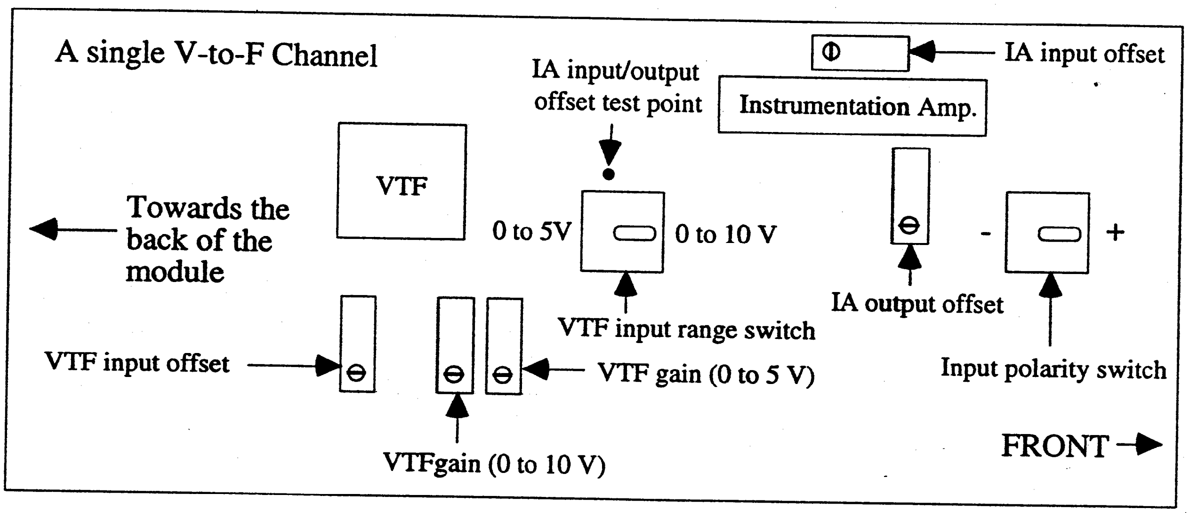


Figure 1. The position of the 25 turn calibration potentiometers. One channel is shown.

I. 6. GENERAL PERFORMANCE

Linearity accuracy	≤ ± 0.005% at Full Scale (≤ 50 Hz Nominal or ≤ 30 Hz Measured)
Stability	Less than 50 PPM.
Power requirements	+ 6 V @ ≤ 540 mA; + 24 V @ ≤ 70 mA, - 24 V @ ≤ 60 mA

SECTION II: OPERATION

II. 1. INSTALLATION

The N101VTF voltage-to-frequency converter is designed as a NIM module and operates with power furnished from a standard NIM crate. (Stand alone version is also available.) If the equipment is to be rack mounted, be sure that there is forced ventilation to prevent any localized heating of the components used in the N101VTF. The inside temperature of the module should not exceed 50 °C for normal and 22 °C for accurate measurements.

WARNING: Do not force the unit into the NIM socket. It may damage the connector. Gently rock the module until it slides into the NIM crate power connector.

II. 2. INPUT VOLTAGE POLARITY

The input polarity for each channel is adjusted by an internal switch (the nearest switches to the front panel at each channel) (**Figure 1**). The switches are labelled for channels one, two, three, and four are labeled S1, S1A, S1B, and S1C respectively. With the switch set toward the front panel the input voltage should be positive. Default setting is for positive input unless specifically requested otherwise.

II. 3. OFFSET ADJUSTMENTS OF THE INSTRUMENTATION AMPLIFIER

The instrumentation amplifier (IA) offset potentiometers (**Figure 1**) must be adjusted for proper performance of the N101VTF. There are two offset potentiometers for each channel. One potentiometer controls the input offset (R11, R11A, R11B and R11C) while the other controls the output offset (R10, R10A, R10B and R10C). (Please note: A, B, C stand for channels 2, 3, 4, respectively.) The input offset should be adjusted at low voltage gains, such as x1, and the output offset should be adjusted when high voltage gains are used. Since the maximum gain is x10 the adjustment of the output offset is not significant and this potentiometer may be omitted if not specifically requested.

The IA input offset can be adjusted by first setting the gain switch to the required level, normally x1 and applying a few mV to the input of the channel required to be calibrated. The input voltage applied must be very stable and the voltmeter meter used should be accurate to ≥ 6 digits. The 0 to 10 V reference output can be used for this adjustment. Adjust the input offset potentiometer so that the input and output voltages from the IA is same or as close as possible. The output voltage of the instrumentation amplifier can be probed at the provided test point.

The output offset can be adjusted similarly with the gain set to the maximum level. The output in this case will be equal to the gain setting x input voltage. The input and output offset adjustments can effect each other, therefore, recheck adjustments until a uniform setting can be achieved.

II. 4. OFFSET ADJUSTMENT OF VOLTAGE-TO-FREQUENCY CONVERTER

The voltage-to-frequency (VTF) converter offset potentiometer (**Figure 1**) must be adjusted for proper performance of the N101VTF. There is only one offset potentiometer (R13, R13A, R13B and R13C) for each channel. The input offset is normally adjusted for x1 gain setting unless specifically requested otherwise.

The VTF input offset can be adjusted by first setting the gain switch to the required level, normally x1 and applying a few mV to the input of the channel required to be calibrated. The input voltage applied must be very stable and the volt meter used should be accurate to ≥ 6 digits. The 0 to 10 V reference output can be used for this adjustment. The frequency output should be observed on an accurate counter with an accurate and stable time base or the 1 MHz output should be used as the time base. Adjust the input offset potentiometer so that the frequency out is equal or very close to the input voltage x 100,000 for the 0 to 1 MHz range (or 100 kHz/volt for unity gain in 0 to 10 V input voltage range). Similarly, 200 kHz/volt for the 0 to 2 MHz range.

II. 5. VTF INPUT VOLTAGE RANGE ADJUSTMENT

In order to ensure proper linearity and offset in the output frequency two potentiometers need to be adjusted for each channel. The two potentiometers control the voltage to frequency gain. One potentiometer controls the gain of the 0 to 10 V range (R19, R19A, R19B and R19C) while the other controls the gain of the 0 to 5 V range (R17, R17A, R17B and R17C). These potentiometers should be adjusted independently. The input voltage should be ≈ 90% of full scale. (The input should not be equal to the full scale value). The potentiometer should then be adjusted so that the output frequency is equal to the desired output for the input voltage applied. The frequency should then be checked for other input voltages to test whether proper linearity is achieved. Rechecking the calibration is important for accurate measurements as the calibration may drift in time.

For default the 0 to 5 V range is adjusted first then the 0 to 10 V range is calibrated. All outputs are terminated by 50 Ω resistors unless requested otherwise. The output is stable and reproducible. Therefore, it is possible to carry out measurements accurate to a few PPM if calibration is continuously monitored and the results are corrected accordingly. Calibration curves obtained for each channel at *NOVA* are attached to this manual.

II. 6. GENERAL COMMENTS ON CALIBRATION

All units are burned in before calibration. After the calibration is carried out it is periodically checked. It is found that the calibration can drift by time. The measurements done at *NOVA* indicate that the linearity is not affected but the offset changes. Warming up brings the unit back close to the calibrated settings. Therefore, it is recommended that the unit should be warmed up for about 20 to 30 minutes before accurate measurements are started. The temperature variations can also affect the calibration slightly.

NOTE: FOR HIGH ACCURACY CALIBRATION & MEASUREMENTS.

1. For accurate calibration and measurements the 1 MHz output supplied on the N101VTF module should be used as the external clock for the frequency measuring instrument. This will eliminate time base inaccuracy and drift. The 1 MHz output from the front panel is derived from the internal high accuracy (≤ 2 PPM) 4 MHz crystal clock.
2. Calibrate with 50 Ω terminator connected to the end of the coaxial cable if the output will be carried to distances longer than ≈ 30 cm. Use 50 Ω coaxial cable. If both outputs will be used with 50 Ω cables terminate both outputs during calibration.
3. Adjust the final potentiometer to slightly less than the 90% of full scale value by a few Hz to achieve slightly better accuracy at the top of the frequency range.
4. If high accuracy needed near the full output frequency 1 MHz (or 2 MHz) then calibrate the upper end of the frequency range between 95% to 98% of full scale value compared to 90% as recommended above.
5. Warm unit for 20 to 30 minutes before attempting high accuracy measurements.
6. Keep temperature inside the unit constant. Forced ventilation is recommended. Good quality NIM crates normally come with powerful fans. Care must be taken not to obstruct the path of the flowing air through the V-to-F Converter(s).
7. For ultra high accuracy measurements regularly monitor the calibration of the channels used and apply corrections to the data obtained as necessary. This procedure will also need continuous monitoring of the output frequency as the data is acquired.

II. 7. VOLTAGE GAIN ADJUSTMENT

Each channel has a voltage gain switch on the front panel. The voltage gain can be set to x1, x2, x5, or x10. Each channel can be adjusted separately. At x1 voltage gain the frequency output is equal to 100 kHz/volt (for 10 V voltage and 1 MHz frequency ranges). The frequency output is equal to the voltage gain set multiplied by 100 kHz/volt for a 10 V voltage range and equal to the voltage gain multiplied by 200 kHz for a 5 V voltage range. These numbers also need to be multiplied by a factor 2 if the 2 MHz frequency range is selected instead of the default 1 MHz.

The x1 gain is the default and is accurately calibrated. The x2, x5 and x10 ranges are ≤ 3% accurate as three 1% resistors are used to set the gain. These resistors can be specially selected to improve accuracy to < 1% on special order.

There is provision on the board at each channel for a potentiometer which can enable a variable voltage gain of up to x1000. This potentiometer and series resistor is not normally supplied. It requires special order.

II. 8. INPUT VOLTAGE RANGE ADJUSTMENT

The voltage range of the input can be either 0 to 10 volts (default) or 0 to 5 volts. The range is set by an internal switch labeled S2 for channel one (**Figure 1**). For channel two, three and four, the switch is labeled S2A, S2B and S2C, respectively. For both voltage ranges the output frequency will be 1 MHz at full scale (10 V or 5 V). The maximum input voltage is the range voltage divided by the voltage gain. For a gain of x10 and the input range set to 10 V the maximum input voltage would be 1 V. For overrange input voltages the output will remain at the maximum output frequency (1 MHz).

The default input is set for 10 V. If it is changed for 5 V the unit must be recalibrated for accurate work. The same is true if it is switched back to 10 V input again. It is not recommended to use the 5 V input unless there is test equipment available for recalibration. Units can be shipped calibrated for 5 V input.

II. 9. REFERENCE VOLTAGE OUTPUT

An ultra high precision reference voltage is supplied on the front panel of the instrument. The reference voltage is adjusted by the 10 turn potentiometer through an accurate calibrated dial on the front panel. The voltage range is 0 to 10 V. This voltage can be used as the input to any of the channels.

A 5 V reference output pad is available on the PC board located below the voltage reference chip near the power connector. The 5 V reference output can be used as a fixed reference if needed.

II. 10. CHANGING OUTPUT FREQUENCY RANGE

The N101VTF contains a 4 MHz crystal oscillator which is used to supply the clock input of the voltage-to-frequency converter. The output of the oscillator is sent to a digital counter. This chip provides several outputs which can be used as clocks for the VTF. In normal operation the 2 MHz output (default) of this chip is used for the VTF clock input since the maximum output of the VTF chip is one half of the clock frequency. It is possible with the N101VTF to change the clock frequency to 4 MHz since the maximum clock frequency accepted by the VTF chip is 4 MHz which in turn changes the output full scale frequency range to 2 MHz from 1 MHz.

An internal jumper is provided which selects the clock frequency between 2 and 4 MHz. It is located to the right of the 74LS393 binary counter chip. This adjustment affects all the channels. If the clock frequency is changed then the voltage-to-frequency gain pots must be readjusted. Using 0 to 2 MHz frequency output range decreases the output linearity and not recommended for accurate measurements. If requested, N101VTF can be supplied calibrated to 0 to 2 MHz frequency output range. Other ranges such as 500 kHz can be custom designed if requested.

II. 11. THE 1 MHz REFERENCE OUTPUT

A 1 MHz reference clock output is supplied at the front panel. This output is derived from the high accuracy (≈ 2 PPM) internal clock generator which is also used as the clock input of each VTF channel. It can drive 50 Ω coaxial cables. If used to drive long cables the end of the cable must be terminated with a 50 Ω resistor to eliminate reflections similar to the other outputs.

PLEASE NOTE: This output is recommended to be used as the clock to the data acquisition system for accurate measurements. This is because the VTF frequency outputs from each channel are directly related to this clock.

II. 12. DIGITAL OUTPUT FOR FRONT PANEL GAIN SELECTION SETTING

A 10 pin digital output connector is located on the back panel providing encoded information on front panel gain switch settings. The output pins supply TTL logic levels to drive standard TTL devices. Pins 1 to 8 gives bits 0 to 7 for the encoded switch settings. Pins 1 and 2 are the lowest and highest significant bits for the Channel 1 Gain Switch settings, respectively. Two bit encoded numbers give the switch position for 4 gain selections x1, x2, x5 and x10. Similarly the other pins provide encoded switch setting for the other channels. A +5 V power is provided at Pin 9 if external electronics need to be built. The supply use should be limited to about 100 mA. Excessive damage to the module will occur if excessive current is drawn from this pin. Pin 10 is the return ground for the signal pins and the +5 V supply.

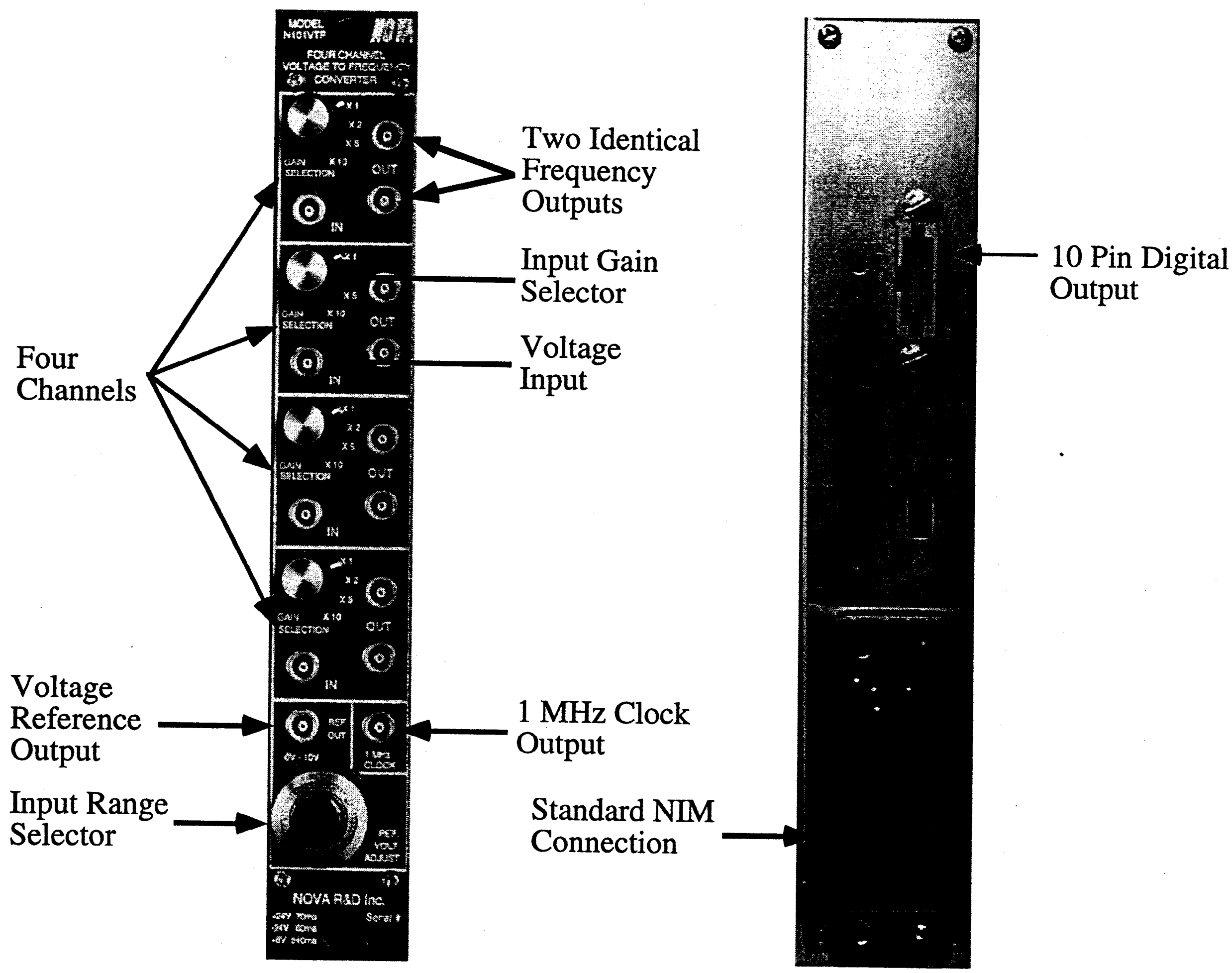
II. 13. THE CROSSTALK BETWEEN CHANNELS

Crosstalk between channels is measured in three ways. Tests and results are provided below.

1. While an input is supplied to any one channel and varied through its full range the other channels are observed for any output. No effect was seen.

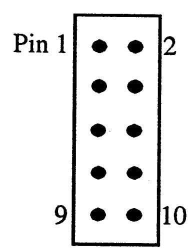
2. Nearly equal voltage inputs are supplied to any two channel and one of them is varied to cross over the value of the other channel. Changes on the stationary channel output is observed. No effect was seen beyond the normal fluctuations (a few Hz).

3. A rapidly rising and falling signal is applied to the input of one channel. The amplitude was made equal or larger than the full range (10 V). The rising and falling edges were changed from about 5 ns to 10 ms. Other channels were supplied with about 0.100 V input one by one and their output was observed for any changes related to the rapidly changing input voltage in the first channel. No changes were seen on the output of the channel supplied with a stationary input of 0.100 V beyond normal statistical fluctuations (a few Hz).



Front Panel

Back Panel



Pins 1-8	bit 0 to 7
Pin 9	+5 Volts
Pin 10	GND

Difference = measured(Hz) - ideal(Hz)
V-to-F Serial No. VF0231