OPERATING MANUAL

8100 RUGGEDIZED RUBIDIUM OSCILLATOR

#14829-201, Rev A

8100 Ruggedized Rubidium Oscillator

datum

Timing, Test & Measurement

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8100 Ruggedized Rubidium Oscillator

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Chapter One

INTRODUCTION/PRODUCT OVERVIEW

The Model 8100 is a ruggedized version of the Datum LPRO Rubidium Frequency Standard. The environmental capabilities of the Model 8100 are enhanced by conformal coating, staking down of internal parts, hard wiring of option jumpers, and other means that improve its moisture resistance and mechanical ruggedness. The Model 8100 also uses standard SMA RF and sub-miniature "D" power/monitor connectors.

OPERATING MANUAL SUMMARY

This Operating Manual is divided into the following chapters:

A. CHAPTER ONE – INTRODUCTION/PRODUCT OVERVIEW
This chapter includes a general description of the Datum 8100 and provides some basic product information.

B. CHAPTER TWO – INSTALLATION AND OPERATION
Describes initial inspection, installation and operation of the Datum 8100.

C. CHAPTER THREE – FREQUENCY ADJUSTMENT
Describes the procedure for adjusting the output frequency of the Datum 8100.

C. CHAPTER FOUR – DESIGN INTEGRATION CONSIDERATIONS
Describes how to integrate the Datum 8100 into the design of an instrument.

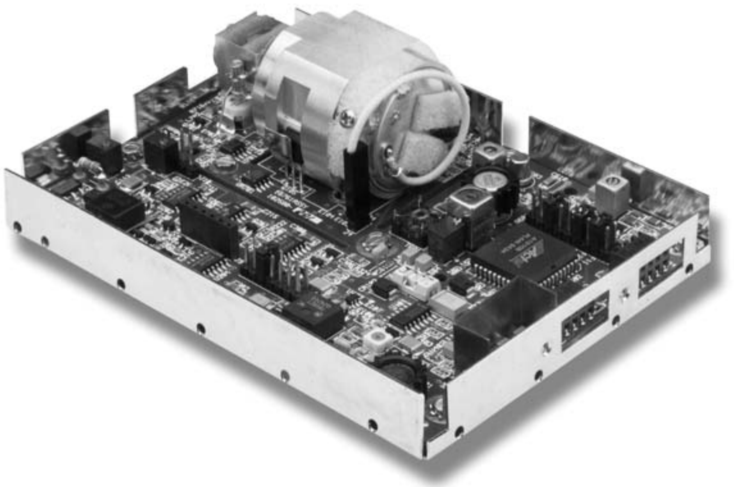
D. CHAPTER FIVE – SPECIFICATIONS
Describes the detailed performance, mechanical and environmental specifications.

E. APPENDIX – REFERENCES
Reference material relevant to atomic frequency standards are provided.

PURPOSE OF EQUIPMENT

The Model 8100 is a product that Datum offers for those requiring the high accuracy of a rubidium atomic frequency standard in their system design, but at a price that is competitive with high performance crystal oscillators. The 8100 is designed for ease of integration into time and frequency systems because of its low profile and single circuit board design. The height and footprint are designed to accommodate a 1U VME application, or a 3U VME application. Great care has been taken in the design to minimize EMI emissions and susceptibility, including the use of both a filtered connector for I/O signals and an outer mumetal cover. The 8100 complies with FCC Article 47, Code of Federal Rules, Part 15, class A. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation. The 8100 also complies with EN55022B and EN50082-1. The 8100 is designed for long operating periods without maintenance (long life Rb lamp, extended crystal control range) with a goal to exceed 10 years. The design provides a stable frequency with good short and long term stability, and excellent spur performance. The 8100 provides a 5 V CMOS-compatible alarm signal derived from the basic physics operation which indicates when the output frequency is outside roughly ±5E - 8 of absolute frequency offset.

FIGURE 1-1. 8100 RUGGEDIZED RUBIDIUM OSCILLATOR (SHOWN WITH COVER REMOVED)



PREPARATION FOR SHIPMENT

To turn off the Datum 8100 prior to shipment, remove the connector from J1 and J2. Package the instrument in its original packing if possible. If the original packing materials are not available, pack in a reinforced cardboard carton using foam to take up any space inside the carton. Do not use foam popcorn or crushed paper for packing.

If the instrument is being returned to Datum, contact the Service Department at (800) 938-9888 to advise of the product return.

TYPOGRAPHICAL AND OTHER CONVENTIONS

This Operating Manual uses the following conventions:

Acronyms and Abbreviations – Terms are spelled out the first time they appear in this Operating Manual. Thereafter, only the acronym or abbreviation is used.

Table 1-1 describes the typographical conventions that this Operating Manual uses to distinguish between the different types of information according to how they are used.

TABLE 1-1. TYPOGRAPHICAL CONVENTIONS

WHEN TEXT APPEARS THIS WAY...	IT MEANS...
8100 Operating Manual	The title of a document or the name of a product
CRITICAL PORT-1 J1	An operating mode, alarm state, status, or chassis label.
Press the **Enter** key. Press the **Print Scrn** key.	An named keyboard key. The key name is shown as it appears on the keyboard. An explanation of the key's acronym or function immediately follows the first reference to the key, if required.
A re-timing application...	A term or a word being emphasized.
Datum does not recommend...	A word or term given special emphasis so that you do not miss the idea being presented.

WARNINGS, CAUTIONS, RECOMMENDATIONS, AND NOTES

Warnings, Cautions, Recommendations, and Notes attract attention to essential or critical information in this Operating Manual. The types of information included in each are explained as follows:

WARNING …

All warnings have this symbol. Do not disregard warnings. They are installation, operation, or maintenance procedures, practices, or statements that if not strictly observed, may result in personal injury or loss of life.

ELECTRICAL SHOCK HAZARD …

All electrical shock hazard warnings have this symbol. To avoid serious personal injury or death, do not disregard electrical shock hazard warnings. They are installation, operation, or maintenance procedures, practices, or statements that if not strictly observed, may result in personal injury or loss of life.

CAUTION …

All cautions have this symbol. Do not disregard cautions. They are installation, operation, or maintenance procedures, practices, conditions, or statements that if not strictly observed, may result in damage to or destruction of equipment or may cause a long-term health hazard.

CAUTION …

All Electrostatic Discharge (ESD) cautions have this symbol. They are installation, operation, or maintenance procedures, practices, conditions, or statements that if not strictly observed, may result in electrostatic discharge damage to, or destruction of, static sensitive components of the equipment.

RECOMMENDATION …

All recommendations have this symbol. Recommendations indicate manufacturer-tested methods or known functionality. They contain installation, operation, or maintenance procedures, practices, conditions, or statements that provide you with important information for optimum performance results.

NOTE …

All notes have this symbol. Notes contain installation, operation, or maintenance procedures, practices, conditions, or statements that alert you to important information which may make your task easier or increase your understanding.

WHERE TO FIND ANSWERS TO PRODUCT AND DOCUMENT QUESTIONS

If you believe that this product is not performing as expected, or if you have comments about this Operating Manual, please contact your Datum representative or sales office.

We appreciate your suggestions on ways to improve this Operating Manual. Please mark or write your suggestions on a copy of the page and mail or fax it to …

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34 Tozer Road
Beverly, MA 01915-5510
US Toll Free: 1-800-544-0233
Phone: +1-978-927-8220
Fax: +1-978-927-4099
E-mail: ttmsales@datum.com

Thank you for providing the information.

NOTE …

Datum offers a number of applicable training courses designed to enhance product usability. Contact your Datum representative or sales office for a complete list of courses and outlines.

Chapter Two

INSTALLATION/OPERATION

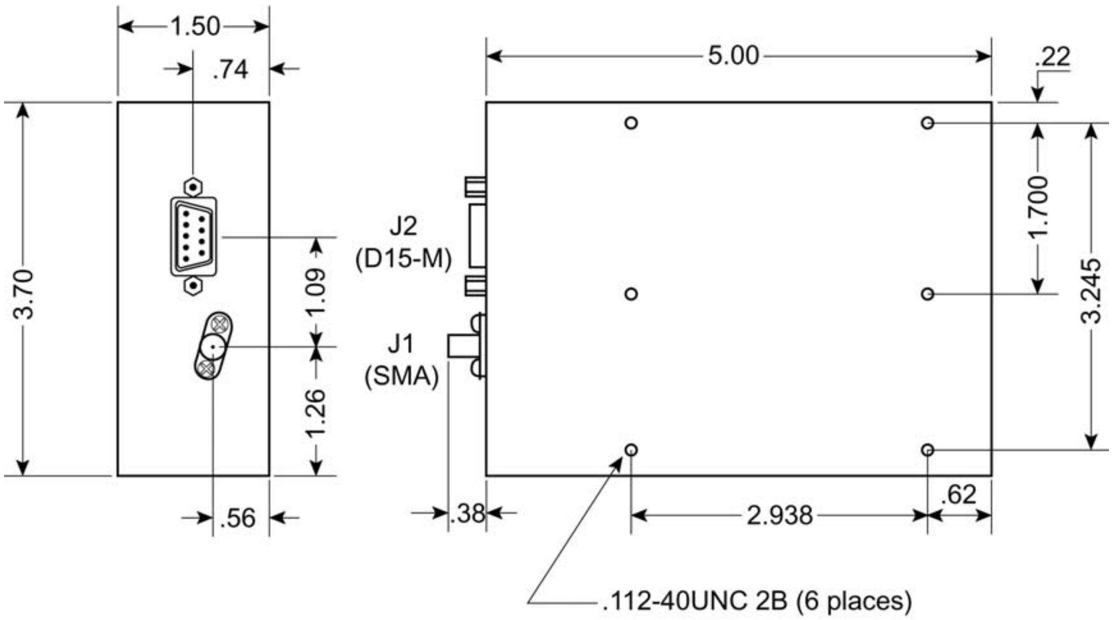
SITE SELECTION

The Datum 8100 installation site should be selected to maintain supply voltage and baseplate temperatures in the range of the specification of Chapter Five.

The user should ensure that there are no strong magnetic fields at the site since the 8100 is sensitive to external DC and AC magnetic fields (refer to specification). An external magnetic field under 2 gauss should not result in measurable permanent frequency offsets for the 8100.

See Figure 2-1 for mounting dimensions and hole locations.

FIGURE 2-1. DATUM 8100 OUTLINE DRAWING



See Table 2-1 for pin assignments of the J2 connector interface.

TABLE 2-1. J2 CONNECTOR INTERFACE

Pin	Pin Function - Standard DB-9 Male
1	DC Power [1] [2]
2	VCXO Control Voltage Monitor
3	No Connection
4	Lock Monitor (BITE) [3]
5	External C-Field Voltage [4]
6	Lamp (Light) Monitor
7	DC Power [1] [2]
8	DC Return (Ground) [5]
9	DC Return (Ground) [5]

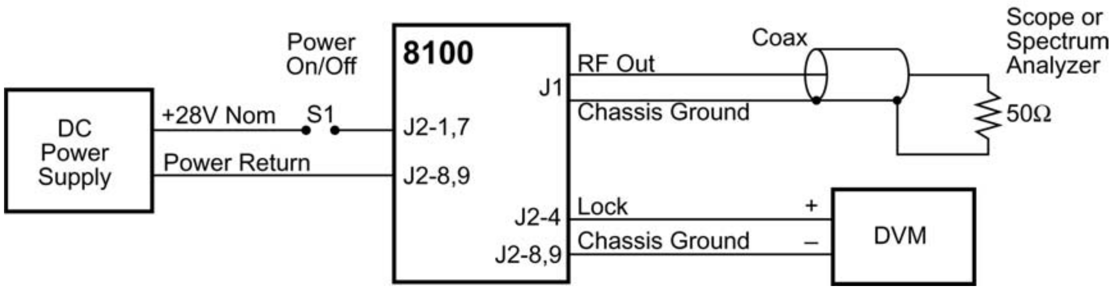
NOTES …

1. The electronic and heater power leads are common.
2. The electronic and heater voltage is +22 to +33 Vdc (+28 Vdc nominal).
3. H (4.2 to 4.8 V) = Unlock; L (>50 mV) = Lock.
4. Tuning range ±1.5x10-9 for 0 to +5 V.
5. The DC returns are common, apply to all signals, and are connected to the chassis ground.

TURN-ON PROCEDURE

The 8100 does not have an ON-OFF switch. The unit is powered up by plugging in the unit's J2 connector to a properly terminated cable or the user's interface board. Refer to Figure 2-1 for a block diagram of a suggested hook-up.

FIGURE 2-2. SUGGESTED CONNECTIONS FOR 8100, INITIAL TURN-ON



The mating connector must provide power (+19V to +32V, +28Vdc nominal) to J2-1& 7 and power return to J2-8 & 9. The user's system power supply must be capable of providing a peak source of 1.7 amperes during the warm-up period. After warm-up, this power requirement drops to ~0.5 amperes (at room temperature).

If the user's power supply is unable to provide the required peak amperage (1.7 A), the 8100 warm-up times will be degraded. If insufficient power is provided, the unit may be unable to complete warm-up and a latch-up condition will result. This does not overstress the electronics of the unit. However, it prevents the unit from achieving lock.

CAUTION ...

If the power source cannot provide the required minimum of 1.7 A, this can cause rubidium migration in the lamp, which could prevent the unit from operating properly. This would require that the unit be returned to Datum for service.

Connect the RF load to J1 (sine 10 MHz RF out) .

Monitor the BITE signal at J2-4 with respect to chassis ground at J2-8 or J2-9, using a high impedance meter (recommended >1 megohm input resistance).

Once the 8100 is plugged in and is receiving power, wait 3 to 4 minutes while the unit achieves atomic lock. During this period, the monitored BITE signal should be HIGH (4.2 to 4.8 Vdc). Once the unit achieves atomic lock, the BITE signal goes LOW (<50mV with respect to GND). At this point, the output frequency should be approximately ±5E-8 of absolute frequency.

Thirty minutes after applying power to the 8100 the RF output frequency will be very close to full accuracy (refer to 8100 specifications in Chapter Five, or Reference 1 for information about accuracy versus time from turn-on).

NOTE ...

The output frequency of the 8100 is more accurate than most counters. See Reference 2 for a discussion of methods that allow the verification of atomic frequency standards similar to the 8100.

Chapter Three

FREQUENCY ADJUSTMENT

There are two primary reasons to adjust the external frequency output of the 8100. The first is to compensate for aging over time, and the second is to syntonize the rubidium oscillator to a more accurate primary frequency source. The 8100 is considered to be a secondary frequency standard (i.e., much more accurate than a quartz frequency standard, but not as accurate as a cesium standard, which is considered to be a primary standard). By syntonizing the 8100 rubidium oscillator to an external cesium clock, or GPS satellite, it can be readjusted periodically to match the primary standard's slower aging rate and greater accuracy.

There are two mechanisms to adjust the output frequency by the user. Both methods result in a change in the current through a coil (the unit's "C-field" coil, which is wrapped around the resonance cell of the frequency standard, in turn adjusting the internal magnetic field of the resonator). There are two ways to manipulate the strength of the C-field coil effect. The first is electromechanical, by adjusting the external C-field potentiometer accessible through a small hole in the top cover of the unit. Rotation of the slotted adjustment screw of the potentiometer produces frequency change (use of a small straight edge can accomplish this task). A screwdriver is adequate.

CAUTION …

Do not force rotation. Damage to the potentiometer can result.

The second method of adjustment is electronic, using the External C-field control signal at pin J2-5. The unit is set to a nominal 2.5Vdc signal at the factory through this pin. Increasing the voltage will increase the output frequency. The allowable correction range is 0 to +5 Vdc, although positive voltages up to 36Vdc can be applied without causing damage or latch-up. Operating with negative voltages at J2-5 is not recommended, as latchup of the internal op amp can result when a voltage more negative than -8 Vdc is applied.

Using an external counter suitable for the task (this operation requires a measurement accuracy that exceeds most counters), adjust the unit so that the output RF frequency is 10,000,000.000 Hz.

NOTE …

If the output signal frequency of the 8100 must be changed, this can be done electronically by connecting the positive voltage of a low output impedance voltage reference to J2-5 and its return to J2-8. The recommended output impedance is <1K for the reference voltage, although a higher output impedance can be tolerated (the input impedance for this signal is approximately 151K). Increasing the positive voltage provides an increasingly positive frequency offset. The correction voltage range is 0 to +5 Vdc, where no external frequency offset correction is nominally at +2.5 Vdc.

Chapter Four

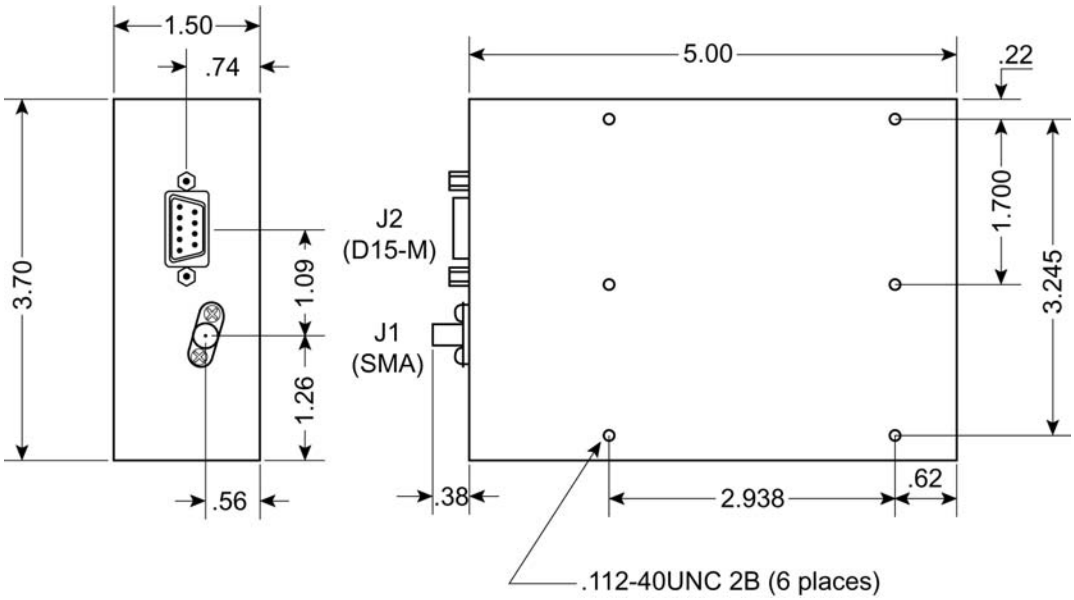
DESIGN INTEGRATION CONSIDERATIONS

MECHANICAL ISSUES

Mounting Guidelines

The 8100 has six mounting hole locations on its bottom cover that require a #4-40 screw with a minimum penetration depth of 1/8". The bottom cover can accept a maximum screw penetration depth of 1.25" without damage (a longer screw will hit the top cover). Torque each screw to 4.5 inch pounds minimum, 5 inch pounds nominal when using the recommended stainless steel screw.

FIGURE 4-1. DATUM 8100 OUTLINE DRAWING



THERMAL CONSIDERATIONS

Use of Thermal Tape

It is critical to obtain a good thermal contact from the bottom ("baseplate") of the 8100 to the mounting surface in order to achieve the highest ambient operating temperature for the specified 8100 operating baseplate temperature. It is also very important to maintain a uniform heat sink temperature because of uneven heat flow into the baseplate of the 8100 through its various mounting points.

TEST HEAT SINK

A heat sink or mounting base plate is required to keep the baseplate temperature under 70ºC. Internal self heating of the 8100 will cause local internal temperatures to exceed Datum's part derating guidelines when used without a heat sink or forced air. (although the maximum manufacturer's operating temperature ratings will not be exceeded). A heat sink with thermal resistance to ambient of less than 2ºC/W is required for ambient of 50ºC maximum. For test purposes, an optional heat sink is available. Order P/N 102518-001 from Datum.

Impact of External Ambient Air Temperature on Unit Operation

The behavior is dominated by three mechanisms; the resonator heater power, the lamp heater power, and the electronics power. The resonator heater power is determined primarily by the resonator control temperature of +78ºC, the baseplate temperature, and the 15.3 C/W thermal resistance from the resonator to baseplate. The lamp heater power is determined primarily by the lamp control temperature of +110ºC, the baseplate temperature, and the 53 C/W thermal resistance from the lamp to baseplate. The electronics power reflects nearly a fixed electronic current that is independent of input voltage due to the unit's internal 17 V regulator and is roughly independent of baseplate temperature. The heater powers are roughly independent of input voltage.

An equation to approximate quiescent input power consumption for the unit is:

$$PQ \sim \{VPS * (280\ mA)\} + \{[(78^\circ C - TBP) / (15.3^\circ C/W)]\} + \{[(110^\circ C - TBP) / (53^\circ C/W)]\}$$

{electronics pwr} {resn htr pwr} {lamp htr pwr}

This equation is only an approximation, since it does not account for effects like internal self-heating, power losses from the heater reverse protection diode, and power losses from the heater current sense resistors.

The 8100 maximum baseplate temperature described in the specifications was based on a model where the unit was covered on five sides with one inch foam to simulate free convection in air as the heat sink/baseplate was exposed to forced air.

The maximum operating baseplate temperature will be lower by several degrees C if the external air is hotter than the baseplate mounting. An example is a situation where the baseplate is being cooled by a thermoelectric cooler, but is exposed to nearby heat-producing equipment.

If there is air flow over the unit's top cover, the 8100's maximum operating baseplate temperature will increase by 1 or 2 degrees C and its power consumption at a given baseplate temperature will also increase by a few tens of milliwatts.

UNIT OPERATING TEMPERATURE RANGE

There are three scenarios of interest concerning the operating temperature range for 8100. The three scenarios are differentiated by performance for conditions including the turn-on / warm-up period, standard operation after warm-up is completed, and emergency operation after warm-up is completed.

The turn-on / warm-up period includes the time for the internal heater circuits to obtain thermal equilibrium, for the lamp to ignite into a plasma discharge, for the standard to achieve atomic lock, and for the crystal operating temperatures to reach its normal operating temperature range.

The three scenarios are:

Scenario 1. The operating temperature range below the normal temperature range without guaranteed warm-up, but with full frequency control

Scenario 2. The normal temperature range with full performance, including warm-up

Scenario 3. The operating temperature range above the normal temperature range, excluding guaranteed warm-up, but without loss of lock.

All scenarios are defined in terms of the unit's baseplate temperature (the bottom surface of the bottom cover) and are described below.

1. Temperature range -35ºC baseplate to -20ºC baseplate. This operating temperature range allows full frequency control, but excludes normal warm-up. The cold temperature limit is based on the use of a -30ºC/+85ºC unheated crystal, and an internal temperature rise at the crystal of ~6ºC. The hot temperature limit is based on staying under the maximum operating temperature of the crystal, avoiding loss of thermal control of the resonator heater, and not exceeding the operating derating guidelines of selected 8100 components.

2. Temperature range -30ºC to +70ºC. The normal operating temperature range with specified warm-up capability included. This temperature range excludes that of scenario 1, because of the unheated crystal used in the 8100. The unit will not be damaged when operated between -35ºC and -30ºC, but a guaranteed performance cannot be ensured until the circuit board near the crystal begins to warm; a 6ºC rise occurs thirty minutes to one hour after turn-on.

3. Temperature range from 70ºC to 75ºC baseplate. This is the emergency operating temperature range that maintains lock (but has no guaranteed warm-up period). The upper limitation is derived by staying under the upper operating temperature of the crystal as well as avoiding the loss of thermal control of the resonator. This condition is not recommended for long operating period because once heater control is lost, the unit may take on a frequency offset (typically parts in 10^{-11}) that will be present for many days of operation while the unit returns to equilibrium. Also, DATUM part derating guidelines are exceeded under this condition, although the component manufacturer's maximum part rating guidelines are not, provided the baseplate temperature is kept below 75ºC.

ELECTRICAL INTERFACE

CONVERSION OF 10 MHZ SINE TO 10 MHZ TTL

The 8100 was designed for a 10 MHz sine output with a 50 ohm source impedance at 10 MHz and for a 50 ohm load.

Transmitting RF output signals over long distances is less of an EMI issue for the user when the signal is a sine wave instead of a square wave because a sine wave lacks harmonics. In addition, the power consumption of the sine wave driver into 50 ohms is lower than for a square wave driver into 50 ohms, especially when providing short circuit protection.

Because some users require a square wave for their application, this section identifies a number of potential methods for the conversion. Keep in mind that any circuitry shown must be verified by the user in their particular application. No endorsement of any specific manufacturer's product is intended.

Refer to Table 4-1 for a comparison of the phase noise resulting for each of the circuits based on a test sample of one. Note that with the low noise source used there was no degradation in phase noise performance seen for the circuits illustrated in Figure 4-2 and only mild degradation for the circuit in Figure 4-3.

TABLE 4-1. MEASURED PHASE NOISE, SINE-TO-TTL CIRCUITS

Figure	1 Hz -dBc/Hz	10 Hz -dBc/Hz	100 Hz -dBc/Hz	1 kHz -dBc/Hz	10 kHz -dBc/Hz	100 kHz -dBc/Hz	Test Notes
4-2 (74AC04)	99	130	149	158	159	161	2
4-3 (74AC04)	102	130	149	155	157	159	2
4-4 (MC10ELT21D)	101	129	134	135	135	135	2, 3
4-5 (LT1016)	98	118	118	119	119	120	2, 4
Typical **8100**	86	96	138	152	156	158	1
FRK LN	103	130	149	158	160	161	1

NOTES …

1. The Wenzel oscillator was used as a reference source for the phase noise test set.
2. The FRK-LN oscillator was used as a driving source for the sine-to-TTL circuit.
3. Test Figure 3-4 with Figure 3-3 used as a buffer, since Figure 3-4 cannot drive the low 50 test.
4. Test Figure 3-5 with Figure 3-3 used as a buffer, since Figure 3-5 cannot drive the low 50 test.

FIGURE 4-2. SINE-TO-TTL CONVERSION, USING C-MOS LOGIC, RECOMMENDED APPROACH

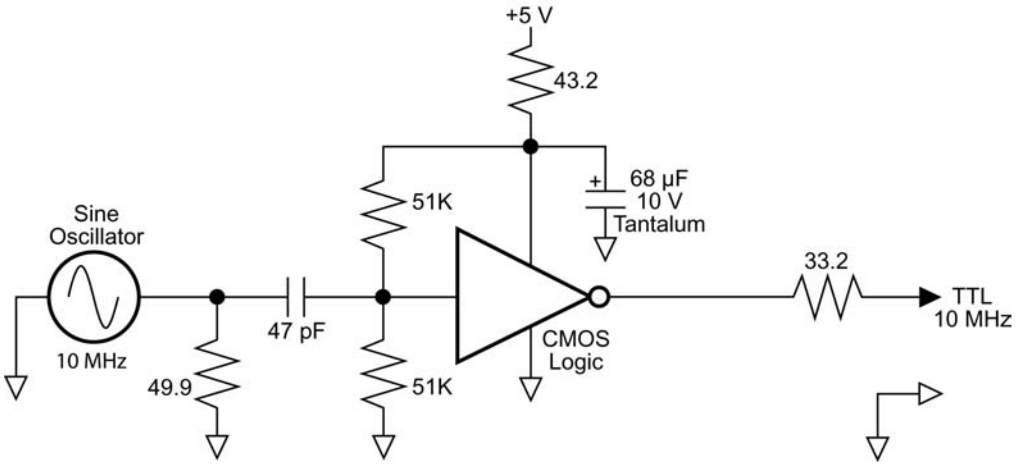


FIGURE 4-3. SINE-TO-TTL CONVERSION, USING C-MOS LOGIC, SELF-BIAS APPROACH

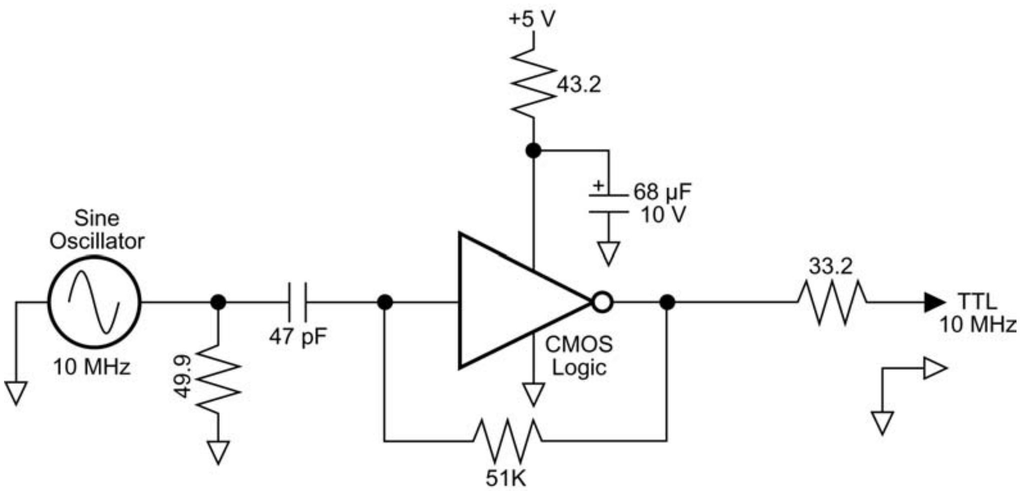
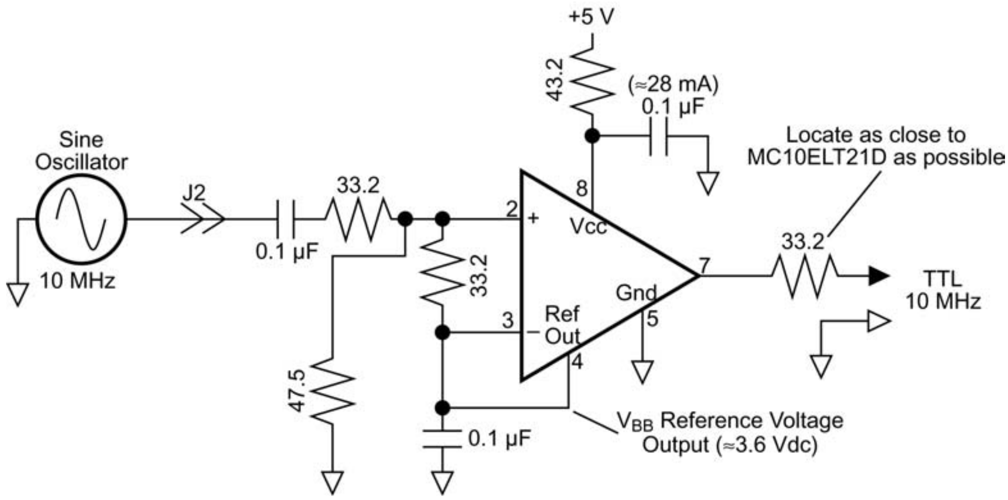


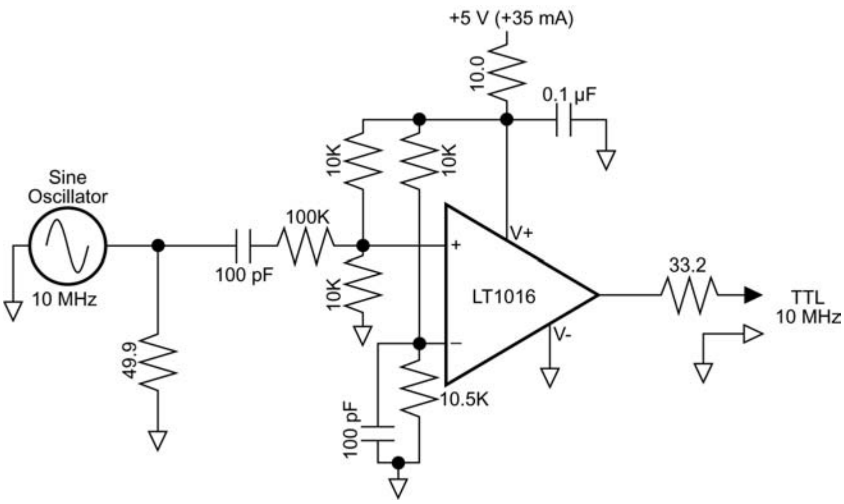
FIGURE 4-4. SINE-TO-TTL CONVERSION CIRCUIT, USING POSITIVE ECL CONVERTER



Use of an LT1016 Comparator

Figure 4-5 shows a sine to TTL converter using a high speed comparator. The advantage of this approach is the lower supply and ground noise compared to the ac-couple, high speed CMOS approach. The disadvantages are the higher phase noise and cost (compared to the AC-couple, CMOS approach), and the extra power dissipation (~24-29 mA more at 5 V).

FIGURE 4-5. SINE-TO-TTL CONVERSION CIRCUIT USING A HIGH SPEED COMPARATOR



AC-COUPLED RF LOAD

The 8100 is designed to tolerate an AC-coupled RF load without waveform distortion provided the coupling capacitor is low impedance at 10 MHz (for example, a 0.01 uF capacitor has an XC of 1.6 , which is small compared to the fifty ohm nominal output impedance). The RF output stage of the 8100 uses an AC coupled design. It is recommended that the coupling capacitor be ceramic, with a X7R or NPO dielectric.

TRANSFORMER-COUPLED RF LOAD

The transformer-coupled RF load is used to break up ground loops. It can also be used to provide some band pass filtering. However, it also attenuates the RF signal, making it difficult to provide a tight tolerance on the RF output level. It is also difficult to obtain an inexpensive, off-the-shelf wide operating temperature range SMT RF transformer.

ISOLATION OF CHASSIS

The 8100 can be electrically isolated from the user's chassis via a thermally conductive insulator and with the use of insulating shoulder washers for the baseplate insulation.

Shorted Output, Open Output Cases

The 8100 is designed to tolerate a short to ground of the RF output without damage, providing a RF output signal amplitude at approximately twice the normal output level of that from a fifty ohm load. This condition actually provides the worst case stress on the RF output driver stage transistor, but the derating guidelines are still followed for this part (less than 125°C junction temperature at the maximum operating baseplate temperature).

BUILT IN TEST EQUIPMENT (BITE) SIGNAL

The 8100 provides an indication that the internal Voltage Controlled Crystal Oscillator (VCXO) is locked to the atomic transition via the BITE signal. As long as the BITE signal is LOW once warm-up is completed, the user can be assured that the output frequency is within roughly ±5E-8 of absolute frequency.

If the BITE signal is high, atomic lock has been lost and the VCXO will go into sweep mode to reacquire lock. The sweep ranges approximately from -17 ppm to +18 ppm in approximately a 20 second period. Note that during this lock acquisition period a cumulative time error can be expected. The resulting overall time error will average out during the sweep period to that obtained from a constant frequency offset at roughly the net difference between the sweep endpoints (although nonlinearity of the sweep will give further errors).

Recommended Customer Interface to BITE

The internal 8100 BITE signal interface includes components for EMI filtering and ESD protection. The internal filtering impedance and response times must be taken into account by the user when utilizing the BITE signal. Standard TTL and LS-TTL draws too much current for the interface series output resistance of 2 K used by the 8100, while standard CMOS circuitry may oscillate during the slow transition through the active region during BITE level changes.

It is recommended that either Schmitt trigger CMOS logic (for example, 74HCT14A, MM74HC14, 74ACT14, and CD40106) or a high input impedance (FET input) comparator with hysteresis are used for the interface to the BITE signal.

C-FIELD FREQUENCY CONTROL

Greater than ±1E-9 Internal or External Control

The C-field control circuitry is designed to independently sum the contributions of the C-field control potentiometer and the external C-field control signal. Each control signal gives greater than ±1.5E-9 frequency offset correction capability.

The external C-field control circuitry is designed so that with no voltage applied at J1-7, the voltage will self bias to mid-range, or 2.5 V.

Time Response of External C-Field Control

The external C-field control has a response time that is dominated by the rubidium servo loop bandwidth, which yields a typical time constant of 23 mS. There are several other time constraints present, but they are all more than a factor of 10 faster.

TEMPERATURE COMPENSATION OF FREQUENCY USING C-FIELD CONTROL

One of the key specifications for an atomic frequency standard is the temperature coefficient. The 8100 is designed for a low temperature coefficient without the need for temperature correction. However, in applications where the user requires a tighter temperature coefficient, a common practice is to monitor the baseplate temperature of the 8100 and apply a correction signal via the External C-field Adjust (pin 5 on connector J2).

This method can be successfully used for moderate correction, for example to bring the maximum frequency change over the full operating temperature range to less than 1E-10. Applying more correction is possible, but there are limits without issues for both yield loss and the test time required for correction, as one runs into the inherent problems of subtracting two large numbers to accurately and consistently obtain a small difference.

Compensation using this scheme is suitable only for steady state conditions. This is because of inherent mismatches between the thermal time constants of the mechanisms that cause temperature coefficient errors, and because of the thermal time constant of the monitoring circuitry. Transients from time constant mismatches will show up; these transients are minimized if temperature ramp rates are limited. Changing less than +2ºC/minute baseplate temperature should result in negligible transients from mismatches.

There are issues with changing the C-field current in atomic frequency standards for the impact on aging and other parameters, but this is more of an issue for expensive laboratory frequency standards with significantly tighter aging specifications than a 8100 unit.

EMI CONSIDERATIONS

Outer Mu-Metal Cover

The resonator packages of rubidium frequency standards have significant frequency offsets due to external magnetic fields. For this reason, it is customary to use a double mu-metal shield for the resonator housing in order to meet the magnetic susceptibility specification for the unit of parts in 10-11/gauss. The 8100 was designed so that the unit cover forms the second, outer magnetic shield. The cover is made of mu-metal, with overlapping edges that minimize problems with fringing fields. The advantage of this approach is the resulting magnetic shielding of the electronics outside of the resonator package.

8100 SUSCEPTIBILITY TO INPUT NOISE

When a user has an application where the output spectrum phase noise and spur integrity is crucial, the 8100 must be provided with comparatively clean source of DC power (free of spurious current or voltage noise). Connecting fans and other electromechanical devices to the DC supply powering the 8100 can result in degraded phase noise and spur performance. This is because motors with brushes can create a wide spectrum of noise. The frequency spectrum of the spurs will vary largely with the motor's speed and load conditions.

The Rubidium atomic frequency source uses a modulation/demodulation lock-in amplifier scheme with a modulation frequency of ~152 Hz. Inherent in this approach is sensitivity to noise at multiples of the modulation frequency. This noise is coupled through both the heater and electronic power lines to cause modulation spurs on the output frequency. Care should be taken to avoid the modulation frequency and its lower harmonics (roughly up to the tenth harmonic).

The 8100 has an internal linear regulator supplying power to the critical electronics, including the crystal oscillator, which is the source for the 10 MHz output. This regulator loses its ripple rejection attributes at frequencies greater than 100 kHz. The crystal oscillator in the unit has some filtering to minimize the conductive spurs from affecting the oscillator. It remains critical that a clean input supply is used if spur and phase noise performance is critical for the end user application. This topic is discussed further in the 8100 Data Manual.

MAINTENANCE

The 8100 is designed with a goal of ten years of maintenance-free operation. In order to accomplish this, the major mechanisms impacting the need for maintenance were addressed. Thus, each 8100 has been designed to have sufficient rubidium fill in the lamp to last for the required period, sufficient pulling range for the voltage controlled crystal oscillator, and sufficient dynamic range of the rubidium control loop.

As stated in Chapter Three, with the exception of frequency adjustment via the fine frequency control potentiometer, or the external C-field adjusting signal, there is no tuning that need be performed by the user. If problems arise in 8100 operation, contact Datum Customer Support for guidance. The 8100 is considered to be factory serviceable only.

Monitor signals are provided to allow the user to track indicators of pending end-of-life for the unit with sufficient warning to avoid a total and sudden failure of the unit. The key indicator of health for the operation of this atomic standard is the BITE signal. If the unit BITE output is high after the specified warm-up period has ended, a fault condition exists.

The LAMP V signal can also be monitored for inherent degradation of the internal pickup of the lamp light output by the photodiode (this is often called DC light voltage decay, or DCLV decay). If the LAMP V signal drops below 3 Vdc, the unit should be removed for maintenance. If the LAMP V signal exceeds 14 Vdc, the unit should be removed for service by DATUM, following the procedures described in Chapter Three, Maintenance and Repairs.

Similarly, the crystal voltage monitor (XTAL V MON) can be used to show if the crystal is drifting out of the available trim range once the warm-up period has been completed. If the XTAL V MON signal falls outside the range of 0.55 to 12.6 Vdc over the operating temperature range, the unit should be removed for service by DATUM, following the procedures described in Chapter Three, Repairs. This allows roughly a half volt of margin before the crystal oscillator will lose lock to the (stable) rubidium frequency. The crystal voltage will, during sweep mode, traverse through end points of (0.502 V ± .017 V) on the low end and (13.3 V ± 0.45 V) on the high end. These design values are used to ensure that the normal operating limits are covered by the sweep signal while minimizing the "wasted" oversweep voltage.

Chapter Five

SPECIFICATIONS

ELECTRICAL SPECIFICATIONS

Output Frequency:	10 MHz	
Output Waveform:	Sine wave	
Output Level:	0.55 Vrms ±0.05 Vrms into 50 (+7.8 ± 0.8 dBm)	
Output Impedance:	50 @ 10 MHz	
Phase Noise (SSB):		
1 Hz	-75 dBc/Hz	
10 Hz	-89 dBc/Hz	
100 Hz	-128 dBc/Hz	
1000 Hz	-140 dBc/Hz	
10000 Hz	-147 dBc/Hz	
Spurs:		
Harmonic	2nd	<-51 dBc
	Other	<-65 dBc
Non-Harmonic	1 Hz to 1 kHz	<-89 dBc
	1 kHz to 10 kHz	<-97 dBc
	10 kHz to 100 kHz	<-100 dBc
	>100 kHz to 1 GHz	<-68 dBc
Aging:		
Monthly (after 1 month)	<5E-11/month	
10 Years	<1E-9	
Frequency Accuracy (at shipment)	±5E-11 (25ºC)	
Frequency Retrace: (after 24 hours power on @ 25ºC and up to 48 hours power off)	<±2.5E-11	
Short Term Stability:	τ = 1 sec	<2.5E-11
	τ = 10 sec	<0.8E-11
	τ = 100 sec	<0.25E=11
Frequency Control:		
Internal trim range (trimpot)	±1.5E-9	
External trim range (electronic)	±1.5E-9 (0 V to +5 V)	

Warm-up:	at –20°C	at 25°C
Time to Lock	<8.7 min	<5.4 min
Time to <1E-9	<10.2 min	<7.3 min
Time to <4E-10	<12.7 min	<10.6 min
Max Input (Amps) @ 24 V	<1.45 A	<1.43 A

Input Voltage Range:	+19 to +32 Vdc
Voltage Sensitivity:	.72E-11/V (over the input voltage range)
Input Power, Quiescent:	+24 Vdc <13 W @ 25°C
	+19 Vdc <7 W @ 65°C
Status Monitor:	
Analog	VCXO lamps, lamp volts (20K impedance, filtered)
Digital	LOCK monitor: 5 V CMOS load
Lock	<0.2 V (CMOS low)
Unlock	>2.5 V (CMOS high)

ENVIRONMENTAL SPECIFICATIONS

Operating Temperature:
- Baseplate: -25 to +70°C
- Ambient: 0 to +50°C

Temperature Coefficient:
- | y (70°C) -y (-25°C) |: <6E-10
- | y (50°C) -y (0°C) |: <3E-10

Storage Temperature: -55 to +85°C

Altitude:
- Operating: -200 ft to 70,000 ft
- Non-Operating: -200 ft to 70,000 ft

Magnetic Field Sensitivity, DC: ±4E-11/GAUSS (±2 GAUSS)

Relative Humidity: 80%, non condensing; meet or exceed Bellcore TR-NWT-000063, Issue 5, Section 4.2.1 (over 1.7°C to 49°C ambient)

Vibration:
Non-Operating: MIL-STD-202, Method 214, Test Condition 1-3 7.6

EMI: Compliant to FCC Part 15 Class B (conducted and radiated emissions) and complies with EN55022B emissions (radiated and conducted) and EN50082-1 (immunity)

MTBF: Per Bellcore TR-NWT-00332, (Ground, Fixed, Controlled)

Ambient Temperature	20°C	25°C	30°C	40°C	50°C	60°C
MTBF (hours)	381,000	351,000	320,000	253,000	189,000	134,000

(RELEX software V5.1, part stress, MET 1 case 3)

Physical Specifications:
- Weight: 1.10 lbs. maximum
- Size: 3.7"W x 5.0"D x 1.5"H

Warranty: Two years

Extended Warranty: Consult factory

NOTE ...
Consult the factory for application support, test reports or special requirements.

References

1. NIST Technical Note 1337, "Characterization of Clocks and Oscillators," Sullivan, Allan, Howe, Walls, Editors, March 1990.

2. "Frequency Stability: Fundamentals and Measurement," V. Droupa, Editor, IEEE Press, 1983.

3. "General Considerations in the Metrology of the Environmental Sensitivities of Standard Frequency Generators," IEEE Frequency Control Symposium, 1992, pp 816-830.

4. NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results," 1994 Edition, B. Taylor and C. Kuyalt.

5. "The Use of Statistics for Specifying Commercial Atomic Frequency Standards," DeWatts etal, 1996, Frequency Control Symposium.

6502 TEN CHANNEL RF DISTRIBUTION MODULE

The DATUM 6502 Distribution Module is a ten channel, RF distribution amplifier packaged in a 1U rack mount chassis. It is comprised of ten low phase noise RF amplifiers that maintain high channel isolation (>100dB). Up to ten units can be daisy chained together to give up to 100 outputs or each output of one unit can be used as a source for other 6502 units to give almost infinite expansion capability with virtually no signal degradation

6512 MILITARIZED TEN CHANNEL RF DISTRIBUTION MODULE

The Datum 6512 Militarized Distribution Module is a ten channel, RF distribution amplifier packaged in a 1U rack mount chassis. It is comprised of ten low phase noise RF amplifiers that maintain high channel isolation (>100dB). Up to ten units can be daisy chained together to give up to 100 outputs or each output of one unit can be used as a source for other 6512 units to give almost infinite expansion capability with virtually no signal degradation.

6530 TEN CHANNEL FIBER OPTIC TRANSMITTER

The Datum 6530 Fiber Optic Distribution Module is a ten-channel fiber optic distribution amplifier packaged in a 1U rack mount chassis. The 6530 accepts input frequencies of 100kHz, 1MHz, 5MHz or 10MHz and provides ten, low noise optical outputs of the same frequency that can be distributed over distances up to 2km without degradation of signal integrity. Multiple 6530 modules can be daisy chained together to provide an infinite number of distribution channels with virtually no signal degradation. Each output and input has an alarm indicator that warns of either a loss of signal or a signal of insufficient amplitude.

6531 TEN CHANNEL FIBER OPTIC RECEIVER

The Datum 6531 Fiber Optic Receiver Module is a ten-channel fiber optic receiver packaged in a 1U rack mount chassis. The 6531 accepts 850nm amplitude modulated optical input signals and provides ten buffered, low noise RF signal outputs. Multiple 6531 modules can be daisy chained together to provide an infinite number of distribution channels with virtually no signal degradation. Each output and input has an alarm indicator that warns of either a loss of signal or a signal of insufficient amplitude.

6602 TEN CHANNEL PULSE DISTRIBUTION MODULE

The Datum 6602 Pulse Distribution Module is a ten- channel, pulse distribution amplifier packaged in a 1U rack mount chassis. The 6602 buffers and provides one pulse per second signal distribution to ten separate locations. The module's Summary Fault Alarm Output feature indicates an alarm whenever there is a single output fault condition. The Datum 6602 preserves input phase characteristics over a wide range of environmental conditions and is available with front or rear input and output connection access.

6612 MILITARIZED EIGHT CHANNEL PULSE DISTRIBUTION MODULE

The Datum 6612 Militarized Pulse Distribution Module is a eight channel pulse distribution amplifier packaged in a 1U rack mount chassis that is capable of withstanding tactical military environments. The 6612 buffers and provides one pulse per second signal distribution to eight separate locations. The module's Summary Fault Alarm Output feature indicates an alarm whenever there is a single output fault condition. The Datum 6612 preserves input phase characteristics over a wide range of environmental conditions.

Limited Warranty

DATUM - TT&M guarantees its products to be free from defects in material and workmanship for a period of one year from the date of shipment. Datum - TT&M shall, at its option, either repair or replace hardware products which prove to be defective.

DATUM - TT&M software and firmware products designed to be used and installed in Datum - TT&M hardware products are warranted not to fail to execute their programming instructions due to defects in material or workmanship. If Datum - TT&M receives notice of such defects during the warranty period, Datum - TT&M will repair or replace software media and firmware which do not execute their programming instructions due to such defects. Datum - TT&M does not warrant that operation of the software, firmware or hardware shall be uninterrupted or error free.

All warranty service will be carried out at the Datum - TT&M – TT&M facilities at 34 Tozer Rd, Beverly, MA 01915. The purchaser shall prepay shipping charges and shall pay all duties and taxes for products returned for warranty service. Datum - TT&M will pay for the return of products to the purchaser except for products returned from another country.

LIMITATION OF WARRANTY: The above warranty does not apply to defects of, or resulting from the following:

1. End items included as part of a system or product selected by, but not designed by, Datum - TT&M are subject only to warranty as may be obtained from the original manufacturers. Such items include, but are not limited to, test equipment, accessories, batteries, computers, printers, software, etc.
2. Items manufactured by Datum - TT&M pursuant to detailed designs furnished by purchaser or specific components, accessories, support equipment and software specified by purshaser.
3. Improper or inadequate maintenance by purchaser.
4. Unauthorized modifications, misuse or mishandling.
5. Operation outside of the environmental specifications of the product.
6. Purchaser's supplied software or interfacing.

THIS WARRANTY IS EXCLUSIVE AND NO OTHER WARRANTY, WHETHER WRITTEN OR ORAL, IS EXPRESSED OR IMPLIED. DATUM - TT&M SPECIFICALLY DISCLAIMS THE IMPLIED WARRANTIES OR MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

The remedies set forth above are the purchaser's sole and exclusive remedies. In no circumstances shall Datum - TT&M assume liability for loss, damage, or consequential expense (including loss of profits) whether based on contract, tort, or any other legal theory, arising directly or indirectly from the use of its equipment separately or in combination with other equipment.