Operator's Manual

Frequency Standard Auxiliary Output Generator

Model 110

Part Number 85001-201
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Technical Support

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1.0. Product Overview

The Auxiliary Output Generator (AOG) provides a highly stable 5 MHz output, available on three buffer-isolated outputs that are programmable in frequency and phase with extremely high resolution and a minimum of added noise. In addition to the 5 MHz outputs, the AOG provides a one pulse per second (1PPS) output capable of being synchronized to an external 1PPS reference and a real time clock; both the clock and the 1PPS output are derived from the AOG output.

The AOG is designed for use with an external frequency standard as a reference input, providing flexible use of the standard without disturbing the standard's controls. The buffered 5 MHz outputs are derived from a high performance, low phase noise crystal oscillator that is phase-locked to the external reference using heterodyne techniques developed from the Symmetricom-Sigma Tau atomic hydrogen maser receiver-synthesizer system. Figure 1.0 on the following page illustrates the heterodyne system used to develop the 5 MHz AOG output given by Equation 1.0 on the following page. The 1PPS output is also included in Figure 1.0.

The AOG is controlled locally through a menu-driven keypad interface on the front panel and remotely via an RS-232C serial link. A programmable option allows control to be shared between local and remote, exclusively local or exclusively remote. Other programmable options include: baud rate, parity and data format; unit identification number; VCO phase-locked loop (PLL) bandwidth and real time clock format. These options may be stored in a nonvolatile memory so they will be retained after power is removed and restored.

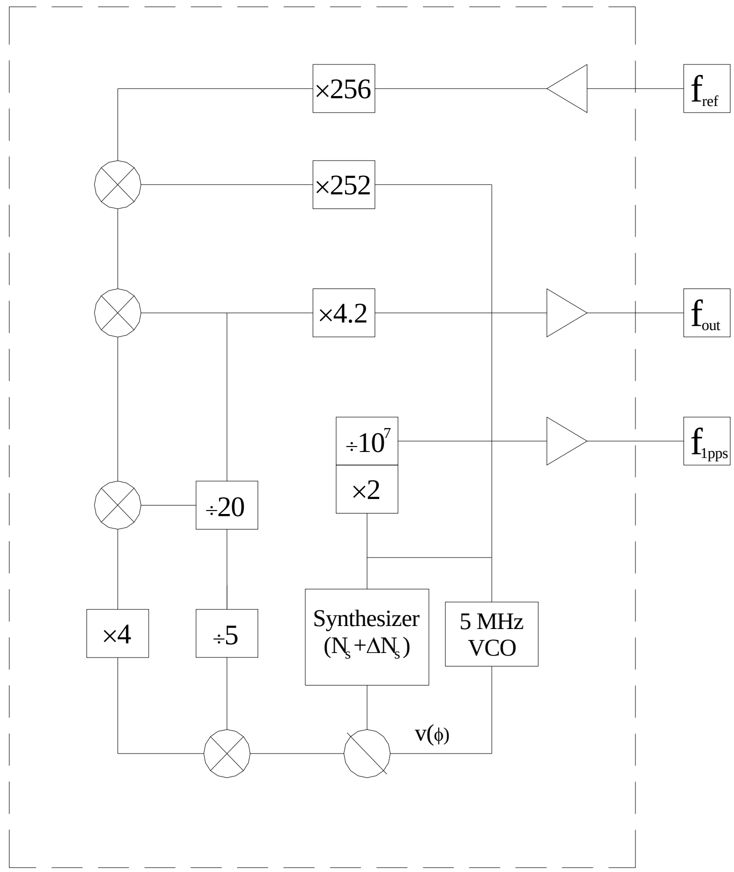


Figure 1.0. AOG Heterodyne System

1.1. Frequency Control System

The 5 MHz crystal oscillator (VCO) is offset using a very high resolution synthesizer phase-locked to the last IF frequency of the AOG heterodyne electronics. The synthesizer's numerical resolution is ±1 X 10^{-19} fractionally, referred to the AOG output. The relationship between the output frequency, f_{out}, and the input reference, f_{ref}, is given by Equation 1.0 where ΔN_S is the selected frequency offset number displayed on the front panel.

$$f_{out} \equiv f_{ref} \cdot \left(1 - \frac{\Delta N_s}{10^{19}}\right)^{-1}$$

Equation 1.0

The output range is $5x10^{-8}$ fractionally and is limited by the bandwidth of the VCO phase locked loop to frequency modulation rates lower than 10^{-8}/second. The range may be centered anywhere within the VCO coarse control adjustment range, typically greater than $\pm 10^{-6}$ fractionally. The frequency changes may be designated as absolute offsets or as incremental adjustments to an existing offset. Because of the input-output relationship defined in Equation 1.0, fractional frequency changes about a non-zero frequency offset will produce an output frequency error proportional to the square of the fractional frequency change with respect to the output. This second order effect is only significant for frequency changes greater than 10^{-9} fractionally.

All programmed changes in output frequency are performed under microprocessor control and are phase continuous within the bandwidth of the VCO/ PLL. Figure 1.1 illustrates the implementation of the frequency offset where f_1 is the initial AOG output frequency and f_2 is the desired new frequency offset. A corresponding phase plot is also provided and shows the phase-frequency relationship that is exploited for the phase offset feature.

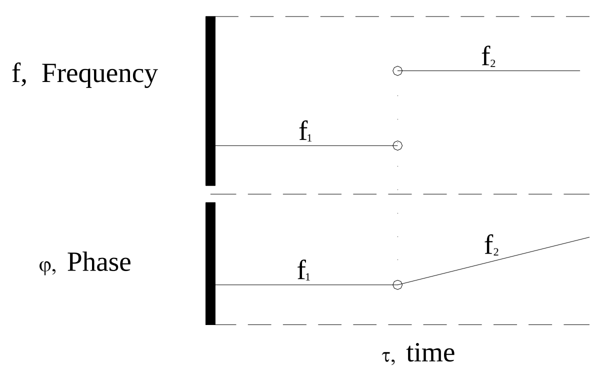


Figure 1.1. Implementation of the Phase Continuous Frequency Offset

1.2. Output Phase Control

Phase changes to the AOG output are accomplished under microprocessor control by offsetting the synthesizer over a precisely timed interval. Output phase is digitally variable with 1 picosecond resolution over a range of ±1 microsecond and changes are measured with respect to the AOG output. The interval over which the offset may occur is selectable over a range of 10^6 seconds in 0.1 second increments. The interval time base resolution is 0.5 milliseconds with ±35 microsecond full-scale error for all intervals; therefore, the error budget for a phase offset requiring a 10^{-9} fractional frequency offset (the worst case) is less than 0.5 picoseconds.

Provided that the input reference may be considered stable over the phase offset interval, the result at the end of the offset interval is as if the phase had been changed instantaneously at the *beginning* of the phase interval. This concept is illustrated in Figure 1.2 where f_1 is the AOG output frequency, $\Delta\phi$ is the desired phase offset and $\Delta\tau$ is the offset interval used.

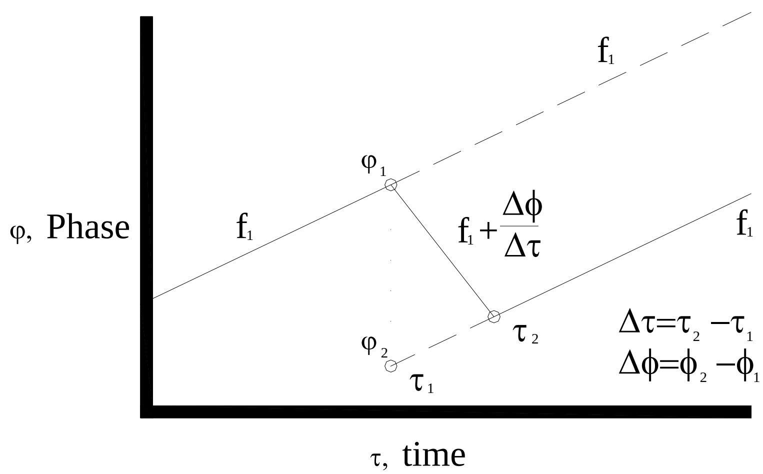


Figure 1.2. Implementation of the Phase Offset

1.3. Frequency and Phase

Some applications may require a change in the AOG output frequency and phase using a single command. In this coordinated change, the user defines the phase offset, the offset interval and the frequency at the end of the interval. The result at the *end* of the offset interval is as if both the phase and frequency had been changed instantaneously at the *beginning* of the offset interval.

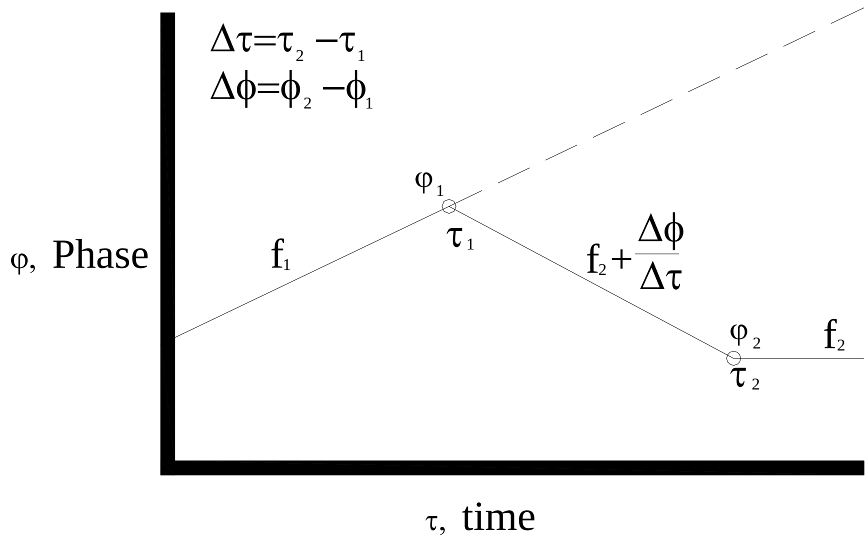


Figure 1.3. Phase and Frequency Offset

Figure 1.3 illustrates this change where f_1 is the AOG output frequency prior to the change, f_2 is the desired frequency at the end of the offset, $\Delta\phi$ is the desired phase offset and $\Delta\tau$ is the offset interval used.

2.0. Time Domain Stability

The maximum contribution of the AOG over the instability of the reference is $3x10^{-13}$ at one second, decreasing approximately as $1/\tau$ using a two sample variance.

2.1. Frequency Domain Stability

Typical phase noise specifications for the VCO phase-locked crystal oscillator:

Offset	Spectral Noise (dBc)
10 Hz	≤ -130
100 Hz	≤ -140
1 kHz	≤ -150
10 kHz	≤ -150
100 kHz	≤ -150

Output harmonics of second order and higher are below 45 dBc. Spurious noise, such as power line harmonics, do not exceed -100 dBc.

2.2. Reference Frequency Input

The reference input is a 5 MHz (nominal) sine wave with +10 to +13 dBm signal power when terminated to 50 ohms. The frequency range is $5x10^{-8}$ fractionally without adjustment of the internal VCO when the reference frequency is centered on the output frequency. With adjustment to the VCO coarse control, the input range is $\pm 9x10^{-8}$. The reference input uses a type-N female coaxial connector located on the back of the chassis.

2.3. Frequency Outputs

There are three (3) 5 MHz signal outputs with +13 dBm (±2dB) amplitude with a real source impedance of 50 ohms designed to drive matched 50 ohm impedance coaxial lines. Each output is isolated from the others by 80 dB, minimum and uses a type-N female coaxial connector located on the back of the chassis.

2.4. Reference 1PPS Sync Input

The 1PPS reference input should be a 1 Hz, pulse capable of delivering 3.0 volts or greater into a 50 ohm load, DC-coupled. The reference pulse rise time should not exceed 5 nanoseconds, 10% to 90% full scale, and the pulse duration should equal or exceed 20 microseconds at rated amplitude. The 1PPS input uses a type-N female coaxial connector located on the back of the chassis.

2.5. 1PPS Output

The 1PPS output is a DC coupled, positive pulse 20 microseconds long referenced to the 5 MHz AOG output. The output impedance is a real 50 ohm resistance capable of driving a 50 ohm load with >3 volts 0 to peak, 0 to 5 volts open circuit. Rise time is less than 5 nanoseconds.

The 1PPS output is derived from a 10 MHz clock frequency synchronized to the AOG output. Upon synchronization with the 1PPS reference, the output phase will be within 15 nanoseconds of the reference Sync Input. The 1PPS output uses a type-N female coaxial connector located on the back of the chassis.

2.6. Frequency Control

Using either a front panel keypad or a remote control terminal the output frequency may be offset digitally over a range of $\pm 9\times10^{-8}$ fractionally, with a resolution of $\pm10^{-19}$.

2.7. Phase Control

Using either a front panel keypad or a remote terminal the output phase may be offset over a range of 1 microsecond with 1 picosecond resolution. The maximum phase slew rate is limited by the microprocessor to 1,000 picoseconds/second with a total error budget of less than 0.5 picoseconds.

2.8. Microprocessor Control

The AOG analog instrumentation, display (liquid crystal), keypad, RS-232C serial port and system synthesizer are controlled by an 8-bit microcontroller. The microcontroller handles the phase-to-frequency calculations and the precision interval monitoring for the phase offset. All phase and frequency computations are accurate to 56-bits using a custom fixed-point math library.

2.9. Temperature Control

The RF electronics and the input and output buffer amplifiers are mounted within a temperature control enclosure stabilized at 50 degrees Celsius to minimize temperature dependent phase variation of the outputs. Power dissipation is limited such that cooling by a fan is not required. Operation in conditions where ambient temperatures exceed 35°C is possible provided ambient air circulation is not restricted.

2.10. Data and Alarms

All system critical data including frequency offset, phase offset, analog instrumentation, time of day and interval timing is displayed on the front panel LCD as well as provided on the serial port.

A VCO Lock Status indicator LED is present on the front panel:

The indicator is green when the VCO is locked, the VCO phase voltage is within the nominal range (indicated by a voltage reading of 1.5 to 3.75 volts of the VCO Phase on the system data screen), and the reference input level is above 7 dBm (also indicated by a Multiplier 1 voltage above 0.5 volts on the system data screen).

The indicator is amber when the reference input is below 7 dBm (also indicated by a Multiplier 1 voltage below 0.5 volts on the system data screen) and the VCO phase voltage is within the nominal range (indicated by a voltage reading of 1.25 to 3.75 volts on the VCO Phase on the system data screen).

The indicator is red when VCO is unlocked, or reference is absent.

An indicator on the LCD display (an asterisk adjacent to the Standard Time label, see Figure 3.1) signals that the reference has been removed or has failed since the last set-up. When the asterisk is present, the serial port also displays an "E" adjacent to the time reported to the serial port. To clear the indicator, reset the clock; see section 4.12.

2.11. System Power

The AOG may be powered from either AC line voltages (85-265 VAC, 47-440 Hz) or by an external DC source of 22 to 28 volts. The unit consumes approximately 20 watts continuously and peaks at 40 watts at start-up.

2.12. Mechanical

The unit is packaged in a 7.0" (17.8 cm) high, 16.8" (42.7 cm) wide and 21.875" (55.6 cm) deep chassis including power module with optional mounting brackets for a standard 19" rack. The total weight is approximately 52 pounds (24 kg).

3.0. Unpacking After Shipment

Before installing or rack-mounting the AOG, the following steps should be taken to insure that the unit has not been damaged in shipment

(1) If the AOG was received from a shipper, inspect it and the shipping container for signs of damage that might have occurred during shipment. Report any damage to the shipping container to the carrier and to Symmetricom-Sigma Tau.

(2) Carefully remove the AOG from its packaging and place it on a table or bench so that the controls are accessible, as in Figure 3.0, below.

(3) Apply power, connect a reference signal to the reference input and observe the messages displayed on the LCD display.

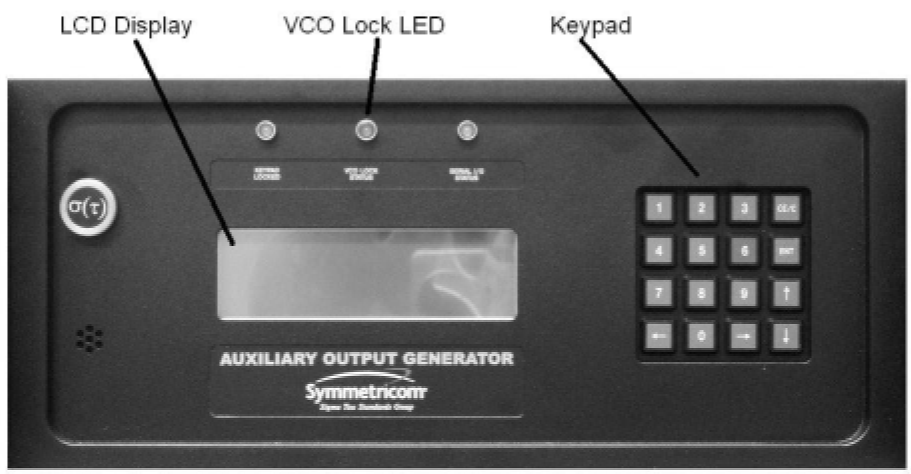


Figure 3.0. AOG Device, Front Panel Keypad Interface and VCO Lock Indicator.

(4) If the AOG is operating properly, the VCO Lock Status indicator may initially be red and a start-up message will appear on the display followed by a short burst of test tones from the front panel. If the 5 MHz reference signal frequency is within the lock range of the AOG and meets the frequency stability requirements of the system, the VCO should lock up within about 20 minutes and the VCO lock indicator should turn green.

(5) Approximately 15 seconds after starting, the standard screen should appear on the display. The screen should now resemble Figure 3.1 and the clock should be running. If the standard screen does not appear or

appears but is garbled, disconnect all input power for 15 seconds and repeat steps 3-5. If the standard screen fails to appear, contact Symmetricom-Sigma Tau at (205) 553-0038.

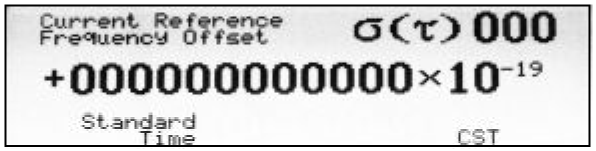


Figure 3.1. AOG Standard Screen.

3.1. Controls and Connections

The key operational features of the AOG device are identified in the following list and Figure 3.2.

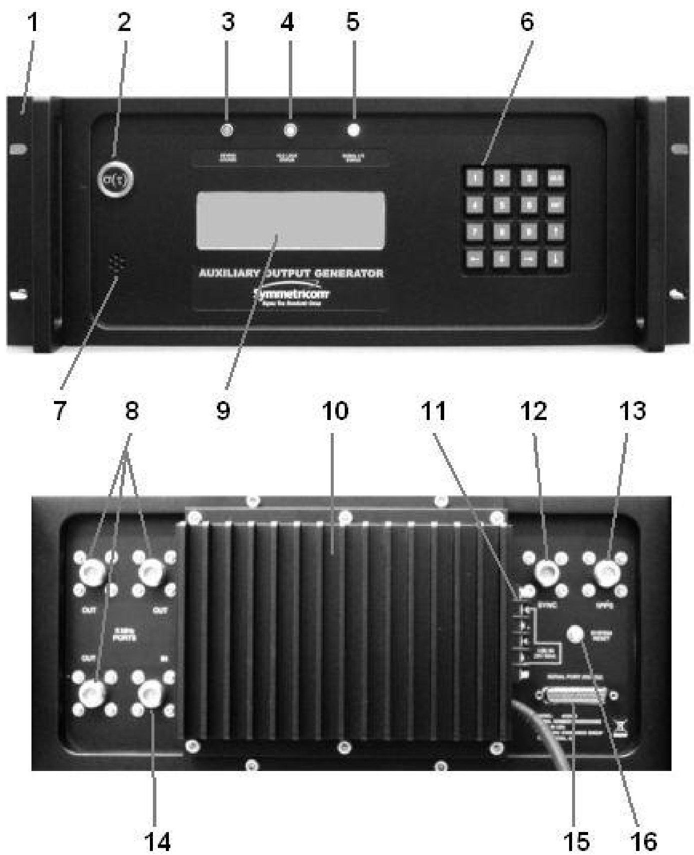


Figure 3.2. AOG Controls and Connectors

(1) Optional rack mounting brackets;
(2) Course Adjustment Access Port;

(3) Keyboard Lock indicator, normally off when keypad control is active;
(4) VCO Lock Status indicator, normally green when AOG is locked to external reference;
(5) Serial I/O Status indicator, normally green when serial port enabled;
(6) 16-key matrix keypad;
(7) Annunciator output;
(8) AOG outputs, 5 MHz plus offset;
(9) 40x8 LCD display panel;
(10) AOG power module;
(11) Battery Back-Up terminal;
(12) 1PPS reference input connector;
(13) 1PPS AOG output connector;
(14) AOG 5 MHz reference input connector;
(15) RS-232C serial port, DB-25 female;
(16) AOG Processor Reset.

3.2. Installation Checklist

To insure proper operation, complete the following checklist before continuing with the installation:

- Verify that the reference meets the specified input levels of the AOG as specified in Section 2.2. The frequency stability of the reference must be good enough that changes in the VCO lock voltage do not exceed the red light limits. High stability, rigid or semi-rigid 50 ohm coaxial cable and matched impedances for all inputs and outputs is mandatory for optimum performance.

- Check that the AOG output specifications match the target system input specifications.

- Before connecting to the serial port, verify that the communication protocol matches the requirements of the connecting terminal. A null cable or null modem may be required between the terminal and the AOG.

- If the unit is to be rack mounted with other devices, allow enough separation between devices to prevent overheating (1 inch or 2.5 cm minimum). Optimal ambient operating temperature is between 10 C and 35 C. Avoid locations with variable air circulation or vibration.

- To insure continuous operation, connect the AOG (and other devices connected to it) to an uninterruptible power source (UPS) and/or DC backup unit.

- Keep the AOG powered-up at all times, even when not connected to an input reference, to reduce the warm-up time.

3.3. Connecting the Reference Input

(1) If you have not already done so, plug the AOG into the proper power source.

(2) Connect the reference to the input port shown in Figure 3.2. Allow at least 20 minutes for the VCO to stabilize. If the VCO lock light is green and the VCO phase voltage is within ±0.25 volts of the nominal 2.25 volt center voltage, VCO coarse frequency adjustment will not be required.

(3) If the VCO lock indicator blinks or is still red after 20 minutes, or the VCO voltage is outside the desired range given above, the VCO coarse frequency will need to be adjusted as described in step (5) – (6); otherwise, proceed to step (4).

(4) The AOG temperature control station (TCS) requires about 4 hours to warm up and must be balanced to minimize thermally induced phase variations of the output. At saturation the voltage will be about 7.3 volts; when balanced and with the ambient temperature at about 22°C, the voltage will be within about 2 - 3 volts.

(5) If the VCO Lock Status indicates an unlock condition, select the widest bandwidth from the PLL Bandwidth menu. If the AOG locks, go to step (8); if not, select the Set Immediate option from the Frequency Menu (see Chapter 4 for details if you are not familiar with AOG menu operations before proceeding to step (6)).

(6) If the phase voltage indicates less than 1.25 volts or greater than 3.75 volts, select the digit representing 10^{-8} offset and increase or decrease this digit in steps of one until the VCO Lock Status turns green and the VCO voltage is between 1.25 and 3.75 volts. If the VCO will not lock to the reference input, the course frequency control may need to be adjusted or the stability or amplitude of the reference may need to be checked. See Section 6.1 for detailed VCO locking instructions.

(7) Select the PLL bandwidth that will be used for your system. If VCO lock is lost, go to steps (5) and (6) but use a smaller offset adjustment. Note that at narrow bandwidths the VCO may take some time before locking up. Also, the VCO lock light may flash when changing the first or second most significant digit.

(8) When TCS and VCO thermal controls are balanced and the VCO is

locked to the reference properly, the unit is ready for operation. See Chapter 4, Front Panel Operation or Chapter 5, Remote Control.

4.0. Basic Operation

Primary control of all AOG functions is provided by a liquid crystal display (LCD) and a 16 key matrix keypad. This combination of display and entry pad comprise the front panel keypad interface. Device control is designed around a system of menus that are navigable with a few keystrokes. The menus and operational information are displayed on the LCD and feedback tones from an internal speaker report on user progress with each key press. Although the standard interface is comprised of a complex hierarchy of status screens, command entry screens, menus and menu options, the menu structure makes operation of the AOG simple.

4.1. Menus and Sub-Menus

Menus are lists of commands or options related either in function or importance. Figure 4.0 is an example of an active menu and illustrates the AOG's Main Menu. Many menus have hierarchal menu separators, which split the menu into two distinct categories: separating either options from commands or options of one type from another. All AOG functions are available within a command or option menu. Menu options will either select a command entry screen, a new sub-menu or a new operational parameter.

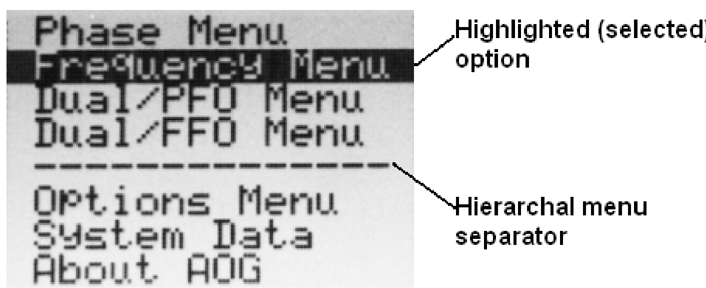


Figure 4.0. The Main Menu.

Command menu options will present the user with an entry screen appropriate to the command selected from the menu category. Some menu options present the user with another menu instead of a command: these subordinate menus are called sub-menus. A sub-menu contains specific options subordinate to a primary menu option or command. Sub-menus often have sub-menus of their own.

Menus or menu options that do not summon a submenu or command entry screen will allow the user to directly change operational parameters like serial baud rate or PLL bandwidth. These types of menus (or sub-menus) are known as selection menus.

Selecting an option from a selection menu immediately changes the related operational parameter of the AOG system: i.e. selecting 9600 from the Baud Rate Menu immediately changes the serial baud rate to 9600 baud.

4.2. The Keypad

The keypad is the only means of user input to the AOG without the use of a remote terminal. Of the 16 keys on the keypad, only four are used to navigate the menu structure: (1) the cancel key, (2) the enter key, (3) the up-arrow key and (4) the down-arrow key. Figure 4.1 illustrates the keypad layout and indicates these primary keys. The number keys are only used for numeric entry on command entry screens.

Each time a key is pressed the AOG will sound a tone. The frequency of the tone implies success or failure - a low tone signifies an error or invalid key press and a high tone signifies success or valid key press.

If a key press completes a command, successful completion of the command will be sounded by a sequence of two short high-tone beeps. Similarly, if the key press cancels a command operation, a two-tone sequence will sound: one short beep followed by a two low tones.

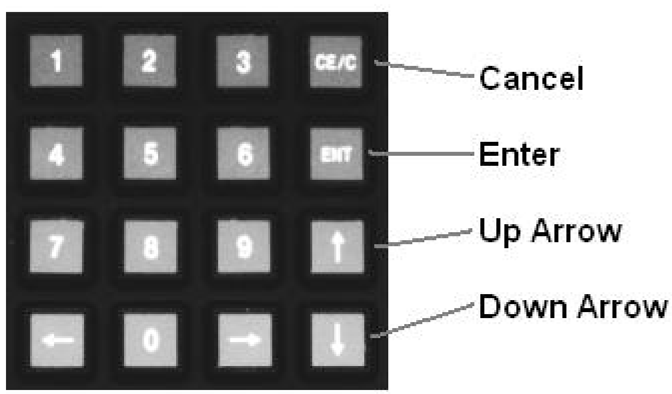


Figure 4.1. Keypad Interface

4.2.1. The Cancel Key

The cancel key is used to evoke the Main Menu from the Standard Screen. Once in a menu or sub-menu, the cancel key is used to go back one menu level. For entry screens and selection menus, the cancel key restores the previous value and returns the user to the previous menu or screen.

4.2.2. The Enter Key

The enter key is used to commit an operation or select a menu option. Menu items that are highlighted are selected when the enter key is pressed. If the selection is a command menu option, the command entry screen will appear. Otherwise, a sub-menu will be displayed. From a command entry screen, the enter key will complete the entry sequence and replace the old setting with the new one. The enter key can also be used to evoke the Main Menu from the Standard Screen.

4.2.3. The Arrow Keys

The up-arrow key is used to change the menu option that is highlighted for selection. Pressing the up-arrow key moves the menu highlight to the next higher option in a menu list. If the currently highlighted option is at the top of the menu, the bottom menu item will be highlighted on the next press of the up-arrow key. The down-arrow has the opposite effect of the up-arrow key, highlighting the next lower menu option in a list. Similarly to the up-arrow key, pressing the down-arrow key while the bottom-most menu option is highlighted moves the menu highlight to the top of the menu.

The left and right arrow keys are only used when editing values in command entry screens and in no way affect menu operations. Since command entry screens have not yet been formally introduced, discussion of the left and right arrow keys is left for that section.

4.3. Command Entry Screens

Command entry screens allow the user to modify numerical settings such as the frequency offset, time interval or phase magnitude. For instance, on the set frequency offset screen in Figure 4.2, the current frequency offset number is displayed and may be edited or replaced with a new offset. Entry is accomplished by either entering new numbers directly through the keypad or by using the arrow keys.

Figure 4.2. Frequency Offset, Command Entry Screen

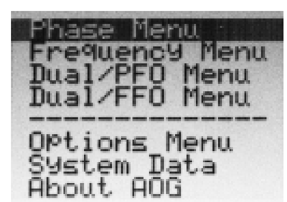
In a command entry screen, the arrow keys are used to select and modify the numeric object of the command (i.e. the frequency offset number, phase offset number, etc.) When modifying a multi-digit number, only one digit may be changed at a time. The left and right-arrow keys may be used to select which digit will be changed.

When selected, the digit will blink - signifying that it is ready to be changed. Pressing the up-arrow will add one to the selected digit place, adding one to the next digit of greater significance on nine-to-zero transitions. Pressing the down-arrow will subtract one from the selected digit place, subtracting one from the next digit of greater significance on zero-to-nine transitions.

Command entry screens make use of the digit keys as well. Pressing a digit key changes the selected digit to the value of the digit key pressed and selects the next digit place to the right of the one modified. This allows convenient entry of long numeric sequences without the use of the arrow keys.

Once the number has been changed, pressing the enter key saves the change and returns the user to either the Standard Screen or the last menu (depending on the command.) Any changes may be discarded prior to that time by pressing the cancel key. After three minutes without a key press within a command entry screen, all changes will be discarded and the AOG display will return to the Standard Screen.

4.4. The Main Menu



As indicated in a previous section, the Main Menu can be summoned by pressing either the cancel key or the enter key from the Standard Screen. This menu contains seven options and a hierarchal menu separator. The first four menu options evoke sub-menus that allow the user to make adjustments to the AOG phase and frequency control. The three remaining options are placed on the other side of the separator because their functions do not directly affect the frequency or phase of the AOG output. The first of these remaining options calls up sub-menus that allow the user to make changes to all other aspects of the AOG not covered by the previous options, the second evokes the system analog data display, and the third option recalls system firmware information for technical support.

To perform any one of the Main Menu options, use the arrow key to select the desired option and press the enter key. Pressing the cancel key at any time will return the user to the Standard Screen. After three minutes of delay without a key press, any menu operations not completed will be discarded and the AOG display will return to the Standard Screen.

4.4.1. System Data

To evoke the System Data display, select the System Data option on the Main Menu and press the enter key. The System Data display will now be active and will be continuously updated while active. All-important system monitoring information is identified directly on the display as in Figure 4.3.

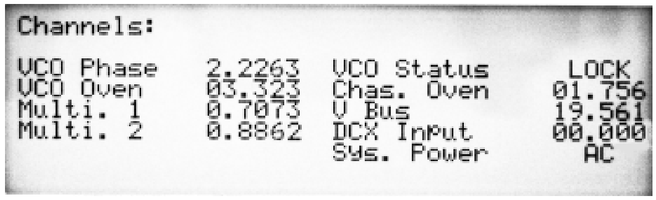
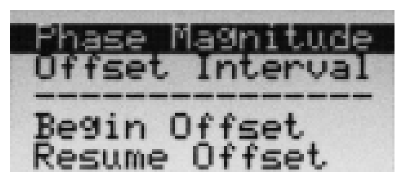


Figure 4.3. The System Data Screen

Of the nine channels listed on the System Data display, two are warning annunciators for the VCO Status and System Power. As long as the VCO remains phase-locked and the phase voltage is within the designated range, the VCO Status channel will indicate LOCK. If either condition fails, the indicator will blink the UNLOCK warning. The System Power indicator behaves the same way: AC reports AC power in use; blinking DC warns of AC power loss and fall-back to DC power.

4.5. The Phase Menu



To evoke the Phase Menu, select the Phase Menu option on the Main Menu and press the enter key. This menu contains the command options necessary to select and perform an AOG output phase offset. The magnitude of the phase change and the interval over which the change will take place can be edited independently. Changing the phase magnitude or time interval does not immediately change the output phase offset - the Begin Offset option must be selected before any change will occur.

4.5.1. Phase Magnitude

Selecting this option brings up the phase magnitude entry screen, shown in Figure 4.4.

The phase magnitude is a six digit signed integer that represents change in output phase in units of picoseconds. All six digits and the sign may be changed using the arrow and numeric keys. Pressing the enter key saves the change and returns the user to the Phase Menu.

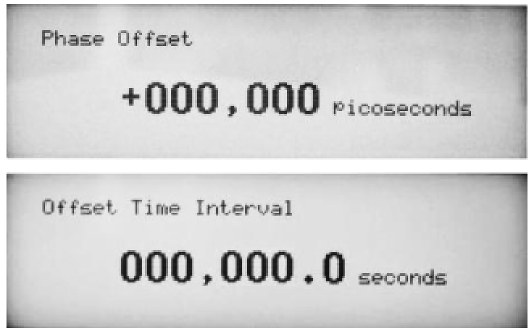


Figure 4.4. The Phase Magnitude Entry Screen,
top, and the Offset Interval Entry Screen.

4.5.2. Offset Interval

Selecting this option brings up the offset interval entry screen, shown in Figure 4.4. The offset interval is a seven digit unsigned integer that determines the time interval over which the output phase will be changed.

4.5.3. Begin Offset

This option initiates the phase offset interval. After selecting Begin Offset with the enter key, the microprocessor checks the offset parameters to determine that the requested offset does not exceed the maximum phase slew rate. If there is an error, the AOG will make an error sound and the Phase Menu will persist, signaling either that the phase magnitude must be reduced or that the time interval be extended.

At the start of a phase offset interval, the microprocessor synchronizes the offset clock to its internal time base. This takes a few milliseconds and should be imperceptible to the user. Once the interval has started, the display will return to the Target Screen (see Section 4.6) instead of the Standard Screen.

4.5.4. Resume Offset

This feature is only available after halting a phase or timed frequency offset (see Section 4.7.1, Halt Offset.) Modifying the phase offset number, time interval or timed frequency settings after halting a phase offset will disable this option.

4.6. The Target Screen

The Target Screen replaces the Standard Screen during a phase or timed frequency offset. This screen displays the target phase offset magnitude (when applicable), a count down timer for the offset interval and the adjusted frequency offset: the sum of the current frequency offset plus the frequency offset necessary to make the phase or frequency change. An example of the

Target Screen in illustrated in Figure 4.5, below. During a phase offset, the entire Main Menu is not available; however, the Target Menu is available (see the next section.)

Figure 4.5. The Target Screen.

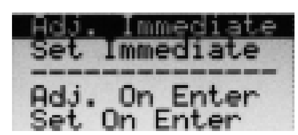
4.7. The Target Menu

The Target Menu allows access to the second hierarchal tier of the Main Menu plus an option to halt the current phase offset. When the offset interval reaches 0.2 seconds, the display timer will be disabled while the interval timer is synchronized to the internal time base. Caution: It is not recommended that the Save Settings option be used during the last two seconds of a phase offset. The precise timing requirements of the EEPROM programming waveform will supersede the timing of the interval timer and may interfere with clock synchronization.

4.7.1. Halt Offset

This command option terminates the current phase, phase-frequency or dual frequency offset. The halt operation is synchronized to the nearest tenth of a second. Total phase will be conserved if the offset is later resumed.

4.8. Frequency Menu



To evoke the Frequency Menu, select the Frequency Menu option on the Main Menu and press the enter key. This menu contains the command options necessary to select an AOG output frequency offset. The frequency offset may be changed absolutely or changed by a correction to preexisting setting. Changing the frequency offset number using the "Immediate" options interactively changes the output frequency each time a digit is changed - the other options require pressing the enter key before any change will take place. Examples of the frequency entry screens are given in Figures 4.6 and Figure 4.7.

4.8.1. Adjust Immediate

This command entry screen allows the user to make a change in the output frequency each time a frequency digit is changed. Every time this screen is displayed, the frequency augment number will be zero - this is because this number represents a positive or negative offset *in addition to* the current frequency offset. As the output frequency is changed, the VCO phase voltage will have a corresponding change. In order to monitor this change, the VCO voltage is displayed and updated continuously on the Adjust Immediate screen as shown in Figure 4.6.

Figure 4.6. The Adjust Immediate Screen, top, and the Set Immediate Screen

Figure 4.7. The Adjust On Enter Screen, top, and the Set On Enter Screen

This voltage indication is especially helpful when frequency offsets are made near the VCO/PLL bandwidth limit. The range of the frequency augment is limited depending on the current frequency offset such that the total frequency offset can not exceed the 10^{-7} offset limit.

After three minutes of delay without a keypress, *any changes made will remain in effect* and the AOG display will return to the Standard Screen.

4.8.2. Set Immediate

Like the Adjust Immediate command, this command entry screen allows the user to change the output frequency each time a frequency digit is changed. However in this case, each time this screen is displayed the frequency number will represent the current frequency offset. This command is especially useful when gradual changes in frequency are needed and the absolute frequency offset must be known. Note that care should be taken when toggling the sign of the offset to prevent accidental loss of lock when the frequency offset is sufficiently large.

After three minutes of delay without a key press, *any changes made will remain in effect* and the AOG display will return to the Standard Screen.

4.8.3. Adjust On Enter

The final result of this command is exactly like the Adjust Immediate command. However the implementation has two significant differences: the VCO phase voltage is not present on the entry screen (see Figure 4.7 on the previous page) and *the enter key must be pressed* before any change in output frequency will be made.

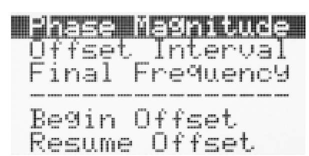
Unlike the immediate version, after three minutes of delay without a key press, *any changes made will be discarded* and the AOG display will return to the Standard Screen.

4.8.4. Set On Enter

The final result of this command is exactly like the Set Immediate command. However the implementation has two significant differences: the VCO phase voltage is not present and *the enter key must be pressed* before any change in output frequency will be made.

Unlike the immediate version, after three minutes of delay without a key press, *any changes made will be discarded* and the AOG display will return to the Standard Screen.

4.9. Dual/PFO Menu



The Dual/PFO option from the main menu allows the user to specify the phase and frequency offset together so that they will be issued simultaneously. This menu is similar to the Phase Menu with the addition of the Final Frequency setting. All other Dual/PFO Menu options work identically to their Phase Menu counterparts.

4.9.1. Final Frequency (PFO)

The Final Frequency Screen affects the frequency offset that will exist after the phase change occurs. As with the Phase Menu, the Begin Offset option must be selected for any changes to take effect. The digits representing 10^{-8} and 10^{-9} are not *directly* addressable when setting the Final Frequency; all higher order changes must be made with increments of the 10^{-10} digit (using the up and down arrow keys.)

When the Begin Offset option is selected, the frequency offset required for the desired phase offset will be computed then added to the final frequency selected (which will be the current frequency offset if no final frequency has been explicitly entered.) This composite frequency offset is then used over the phase offset interval to produce the desired phase offset. At the end of the phase offset interval the output frequency will be set to the final frequency.

Premature termination of the Dual / PFO offset will cause the frequency offset to revert to its original setting and not the final frequency. The Resume Offset option will restore the Dual/PFO operation after a halt.

4.10. Dual/FFO Menu

The Dual/FFO option from the main menu allows the user to specify the pair of frequencies and a time interval. This first frequency will be used over the period of the time interval, after which time the second frequency will take over.

4.10.1. Timed Frequency

The Timed Frequency Screen operates identically to the Set Frequency Screen with the exception that changes affect frequency offset that will exist during the defined time interval. As with the Phase Menu, the Begin Offset option must be selected for any changes to take effect. The digits representing 10^{-8} and 10^{-9} are not *directly* addressable when setting the Timed Frequency as with the previous Final Frequency setting.

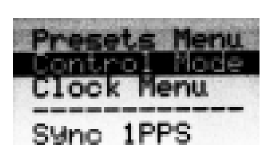
4.10.2. Final Frequency (FFO)

The Final Frequency Screen operates identically to the previous Final Frequency Screen with the exception that changes affect only the frequency offset that will exist at the end of the time interval.

Be aware that *premature termination of the Dual/ FFO offset will cause the frequency offset to revert to the Final Frequency setting* and not the original frequency. In such case, the Resume Offset option will remain valid until a change is made in the phase or frequency settings.

4.11. Options Menu

The Options Menu allows the user to change the



operational parameters of the AOG that are detailed in the remaining sections. One sub-menu allows the user to make some of these changes permanent. This menu also contains the synchronization function for the 1PPS output.

4.11.1. Control Mode

This option brings up a sub-menu allowing the user to select the control mode of the AOG. The control mode selects which of the two interfaces, keypad and serial, will be the source of control commands. There are three options: Serial/keypad, serial only and keypad only.

4.11.1.1 Serial/Keypad Mode

This is the normal operational mode of the AOG. Both the keypad and the serial port may generate commands for the AOG. In this mode, commands from the serial port may be interrupted by the keypad and vice versa.

4.11.1.2 Serial Mode

This is the most secure mode of operation of the AOG because control is limited to only a properly configured serial device. This mode may be entered by using the Serial Only option from the Control Mode Menu or by issuing the KEY_LOCK command from the serial port (see Section 5, Serial Commands for details on the key_lock command.)

Once this mode is entered, all control and monitoring commands must be issued from the serial port. No menu options will be available and the green Keypad Lock LED will be lighted. This condition persists until either the password is entered (see next section) or the system power is removed.

4.11.1.3 Restoring Keypad Control

A key code must be entered from the keypad to restore menu function while the AOG is in serial mode. The default key code may only be changed from the serial port and the new code made permanent at any time thereafter via the Presets Menu.

WARNING: If the key code is altered, write the new code in the space provided below or in some other more secure location. A power-down will not change a key code that has been made permanent; however, once menu operation has been restored, the Recall Factory option will restore the key code to the factory default.

4.11.1.4 Keypad Mode

In this mode, all serial port phase and frequency commands are disabled. However, the serial status and 1PPS sync function will remain available. Selecting either of the other two modes will restore serial function.

4.11.1.5 Default Key Code

The factory default key code is:

0 5 1 3 6 6

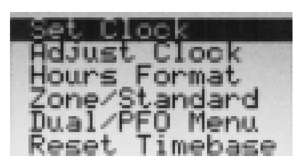
4.11.1.6 User Key Code

The preset user key code is:

4.11.2. Sync 1PPS

The 1PPS reference input has no effect on the 1PPS output circuit unless a Sync 1PPS option is given. This command option enables a 1.75 second sync window during which the positive leading edge of the 1PPS output will be synchronized to the reference input's positive edge - see Section 2.5, 1PPS Output. The time of day clock will also sync to the external reference - rounding up or down to the nearest second.

4.12. Clock Menu



The Clock Menu contains options that allow the user to change the way the system clock is displayed and make corrections to the time of day. The time of day function has no bearing on the operation of the AOG, but it serves as a reliable indicator that the system is running properly and a convenient source of time based upon the AOG output frequency. Available options allow the user to further customize the AOG for organizations that use the AOG output for time keeping.

4.12.1. Adjust Clock

Editing the system clock is similar to editing the phase and frequency numbers. The current time of day presented in 24-hour format and is updated once per second and/or following each key press while it is edited. Also, standard time limitations apply: 0.00-59.99 seconds, 0-59 minutes, and 0-23 hours with carries over to the appropriate units when these limits are exceeded.

4.12.2. Hours Format

This option presents the user with a sub-menu allowing the user to select between standard (12 hour, AM/PM) and 24 hour time. These options only affect the way the clock is displayed and do not affect the internal format or the serial status report.

4.12.2.1. 24 Hour

Selects 24-hour time format. The AM/PM annunciator is disabled and valid clock times are 0:00 to 23:59.

4.12.2.2. 12 Hour

Selects standard, 12-hour clock format. The first 12 hours in a day are signified by AM on the AM/PM annunciator- the second half of the day being denoted by PM.

4.12.3. Zone/Standard

This sub-menu allows customization of the clock display to accommodate different time zones and standards. The available standards and time zone indicators include: International Atomic Time (TIA), Eastern Standard Time (EST), Central Standard Time (CST), Mountain Standard Time (MST), Pacific Standard Time (PST), Bureau International des Poides et Mesures time (BIPM), and Universal Coordinated Time (UTC).

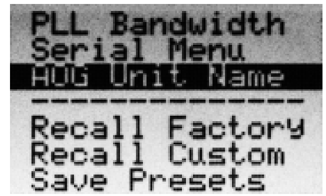
4.12.4. Reset Timebase

The microprocessor timebase that is used for the real time clock and the phase and frequency offset intervals is derived from the AOG synthesizer. If the link between the synthesizer and the microprocessor is broken, the microprocessor falls back to its internal clock to maintain these processes. At this point, the clock and intervals are no longer calibrated and do not represent the precision of the AOG.

After a failure has been discovered, the microprocessor will fall back to the internal reference and signals this condition by flashing the clock display on the front panel. A failure will result in a loss of several milliseconds on all AOG clock and timing resources. Resetting the timebase will add up to 200 microseconds to the error.

Once the timebase has been restored, the real time clock should be adjusted accordingly and optionally resynchronized with the 1PPS reference. Resetting the timebase will also stop the LCD clock from flashing provided the timebase is present.

4.13 Presets Menu



This menu contains initial setup options and preset programming and recall commands. In most cases, the AOG Unit Name and PLL Bandwidth will need to be set only once. After changing these settings, they may be made permanent via this menu so that the settings survive power cycling. This menu may also be used to recall the factory presets at any time.

4.13.1. AOG Unit Name

This option allows AOG units to be differentiated where multiple AOG systems are present in a single installation. This option presents the user with an entry screen and a configurable AOG Unit ID Code. The ID code is usually in the format σ(τ)xxx where xxx is a unique numeric identifier between 000 and 999. This ID code appears in the top right of the Standard Screen, and in the serial data report and may optionally be all numeric with up to seven digits. Note: When changing the ID code, some characters are not displayable and appear to be blank.

4.13.2. PLL Bandwidth

This menu option allows the user to change the VCO phase-locked loop bandwidth parameter. Caution: Under certain conditions, changing the PLL bandwidth may result in a change in output phase or in loss of lock if the VCO frequency is far offset from normal. Available bandwidth options are: 3.5, 7.0, 14.0 and 21.0 Hz.

4.13.3. Recall Factory

This option restores all user programmable parameters to the factory defaults - see Section 4.13.5 for a listing of settings affected by this command.

4.13.4. Recall Custom

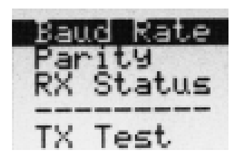
This option restores all programmable parameters to those programmed by the last Save Presets command - see Section 4.14.5 for a complete listing of settings affected by this command.

4.13.5. Save Presets

This option makes changes in programmable options permanent in microprocessor EEPROM. Once programmed, these values will be the default when the AOG is powered-up. Options made permanent by this command include: AOG Unit Name, PLL Bandwidth, Baud Rate, Parity, RX Status, Hours Format, Zone/Standard, Control Mode, the security pass code, the phase offset number, the phase offset interval number, and the frequency offset number. Caution: It is not recommended that the Save Settings option be used during the last two seconds of a phase offset. The precise timing requirements of the EEPROM programming waveform will supersede the timing of the interval timer and may interfere with clock synchronization. Also, the operation of the Save Presets command is irreversible - all previous changes will be permanently over-written.

4.14. Serial Menu

All options affecting the operational parameters of the serial port are available in this menu. These options should be changed only while the serial port is idle. Making parameter changes to an active serial port will cause a loss of serial data.



4.14.1. Baud Rate

Determines the baud rate used for serial commands. The available baud rates are: 1200, 2400, 4800, 9600, and 19200. The default baud rate is 9600 and should be adequate for most applications. Of course, response latency will be directly proportional to the selected baud rate.

4.14.2. Parity

Determines the parity, data size and bit structure of serial communications. Available parity settings include: odd, even and none. Selectable data sizes are 7-bit and 8-bit. The data bit structure can include 1-stop or 2-stop bits. Some older terminals using mark/space may require selection of 2-stop bits.

4.14.3. RX Status

Allows the user to select the serial receiver as online or offline. When offline is selected the Serial I/O Status LED is turned off, the serial receiver is disabled and the microprocessor will ignore all serial transmissions.

4.14.4. TX Test

This option generates a serial output that identifies the ROM version of the

AOG firmware used. It is not dependent upon valid serial input to activate. If the serial RX Status is offline, the transmitter will remain active and the Serial I/O Status will continue to flash when serial data is transmitted from the microprocessor.

4.15. About AOG

This option displays information about the version and production date of the embedded program (firmware) contained in the AOG. Any support questions relating to the operation of the user interface should refer to include this information. An example of the about screen is illustrated in Figure 4.8.

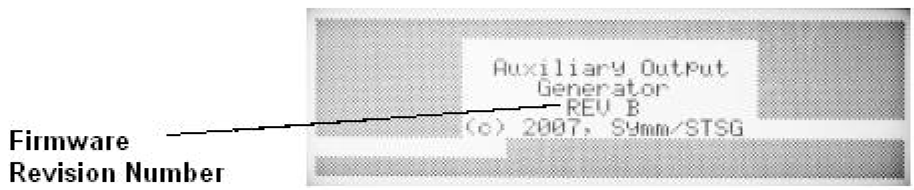


Figure 4.8. The About AOG Screen.

5.0. Overview

The RS-232 serial port on the AOG may be selected for primary or auxiliary control of the output phase and frequency (see Section 4, Menu Commands.) Status information, 1PPS synchronization and time of day control is available for the serial port as well. All serial commands are command line oriented commands - they return status information about the success or failure of each command only after the complete command has been received by the AOG.

Serial port execution is concurrent with the main AOG program: when enabled, all serial commands execute independently of the front panel interface or previously issued serial commands. If a conflict exists, serial phase and frequency commands will always supersede any pending phase offset without the need for a halt command from the front panel.

Activity over the serial port is alerted by the Serial I/O Status LED flashing up to 8 times per second as data enters or leaves the microcontroller. When the serial port is "offline" the Serial I/O Status LED will be off and all serial input will be ignored. In this state, serial data directed at the AOG will not cause the LED to blink - this should not be interpreted as a serial malfunction.

5.1. Error Reporting

All commands are checked for proper syntax by the microcontroller following the receipt of a return character (ASCII character 13.) This allows the user to edit the command line with the backspace key before pressing the return key from a remote terminal.

There are two types of general errors reported: Invalid Command and Invalid Argument(s). If a command contains unexpected characters, is improperly formatted or exceeds the bounds of the command an Invalid Argument(s) error will be signaled. If the command is misspelled or does not exist in the command set, an Invalid Command error is issued. Any time an error code is generated by a command sequence, the entire command will be ignored.

5.2. Command Set

There are a number of serial commands associated with monitor and control of the AOG. At any time while the serial port is online, the command set may be recalled by pressing the question mark key (?) followed by a return. The commands in this section adhere to the following syntax and rules:

(1) Serial commands are subject to the same parameter limits as their menu oriented counterparts.

(2) Serial commands are not case sensitive: upper and lower case letters can be mixed on the command line without affecting command execution.

(3) Valid serial commands that affect phase or frequency will result in a change in the front panel display that reflects the change: i.e. issuing a chg_phase command will cause the Target Screen to be displayed just as if the Begin Offset option had been selected.

(4) Command line options enclosed within curly braces, { }, are required for the command to be properly formatted.

(5) Options enclosed in square braces, [ ], are not needed to complete the command and may be ignored if their values are to remain unchanged.

(6) Command delimiters such as comma, period and space may be interchanged without affecting the command result.

(7) Commands requiring a signed value must not include a space (or other valid delimiter) between the sign and the qualifying integer.

5.3. Adjust Clock

Command: **adj_clock or ac**

Usage: **ac *{+|-}hh[:mm[:ss[.ss]]]***

Options: ***hh,***
Hours. Valid range is 0 to 23.

mm,
Minutes. Valid range is 0 to 59.

ss.ss,
Seconds. Valid range is 0.00 to 59.99.

Purpose: Adjusts the time of day by the amount given in the command line option(s). Options to the right of an option being changed may be omitted when the remaining options are also omitted. The time of day is returned if no arguments are passed.

5.4. Adjust Frequency Offset

Command: **adj_freq or af**

Usage: **af *{+|-}offset***

Options: ***offset,***
Frequency augment. Valid range is -9999999999 to +9999999999.

Purpose: Augment the current frequency offset by the amount given in the command line option. The offset amount is interpreted as a right justified, fractional frequency change in parts in 10^{19}. The maximum offset change is therefore limited to nearly 10^{-7}.

Note: Although offset changes greater than 10^{-10} may be used, doing so may result in a loss of signal lock.

5.5. Change Frequency

Command: **chg_freq or cf**

Usage: **cf *interval* {+ | *-}timed* {+ | *-}final***

Options: ***interval,***
Timed offset interval in tenths of seconds. Valid range is 0 to 9999999 tenths-seconds.

timed,
Timed frequency during interval.
Valid range:-9999999999 to +9999999999 and represents an offset from the current frequency offset.

final,
Final frequency after interval.
Valid range:-9999999999 to +9999999999 and represents an offset from the current frequency offset.

Purpose: This command will change the output frequency by *timed* over *iiiiii* tenths-seconds and return to a new frequency offset equal to the original frequency plus *final* after the interval.

Note: Although offset changes greater than 10^{-10} may be used, doing so may result in a loss of signal lock.

5.6. Change Phase

Command: **chg_phase or cp**

Usage: **cp *{+ | -}phase [interval] [{+ | -}final]***

Options: ***phase,***
Phase change in picoseconds.
Valid range is -999999 to +999999.

interval,
Phase offset interval in tenths of seconds. Valid range is 0 to 9999999 tenths-seconds.

final,
Final frequency after phase offset.
Valid range:-9999999999 to +9999999999 and represents an offset from the current frequency offset.

Purpose: This command will change the output phase by *phase* picoseconds (relative to the input) over *interval* tenths-seconds and return to a new frequency offset of final plus the original frequency offset. If the offset interval is not included, the last offset interval will be used. An offset interval must be specified if a frequency offset is required.

Note: Although offset changes greater than 10^{-10} may be used, doing so may result in a loss of signal lock.

5.7. Change Password

Command: **password or pw**

Usage: **pw *old new new***

Options: ***old,***
Current password code. Must be a string of one to six digits.

new,
New password code. Must be a string of one to six digits.

Purpose: This command will change the password used to defeat the keypad lock or serial only commands. Once the password command has been issued the Save Presets command must be used to make the change permanent. Otherwise, the new password will only remain valid until power is removed.

Note: Removing power is the only recourse when the password is unknown; see Section 4.11.1.3 for details.

5.8. Keypad Lock

Command: **key_lock or kl**

Usage: **kl {key}**

Options: ***key,***
Security code key.

Purpose: Forces the AOG into the Serial Only mode when the code key matches the code key stored in the AOG.

Note: The override for this command is discussed in Section 4.11.1.3 and may only be issued from the keypad.

5.9. Set Time of Day

Command: **set_clock or sc**

Usage: **sc *hh[:mm[:ss[.ss]]]***

Options: ***hh,***
Hours. Range 0 to 23.

mm,
Minutes. Range 0 to 59

ss.ss
Seconds. Range 0 to 59.99

Purpose: Set the AOG system real time clock to time given by *hh:mm:ss.ss.* Options not included with the command will be set to zero.

5.10. Set Frequency Offset

Command: **set_freq or sf**

Usage: **sf {+ | -}*ffffffffffff***

Options: ***ffffffffffff,***
Frequency offset. Valid range is -999999999999 to +999999999999.

Purpose: Set the current frequency offset to the amount given in the command line option. The offset amount is interpreted as a right justified, fractional frequency change in parts in 10^{19}. The maximum offset change is therefore limited to nearly 10^{-7}.

Note: Although offset changes greater than 10^{-10} may be used, doing so may result in a loss of signal lock.

5.11. Status Report

Command: **status or st**

Usage: **st**

Options: <none>

Purpose: Returns a formatted AOG status report that identifies: the AOG Unit Name, VCO phase voltage, VCO oven voltage, internal multiplier #1 instrumentation voltage, multiplier #2 instrumentation voltage, system power status (AC or DC), VCO lock status (LOCK or UNLOCK), chassis oven voltage, the main power bus voltage, the DCx input voltage, current frequency offset number, phase offset number, interval number and AOG time of day. During an active phase offset, the status report will warn of the active offset and report the time remaining in the offset.

5.12. Synchronize 1PPS

Command: **sync**

Usage: **sync**

Options: <none>

Purpose: Synchronize the 1PPS output to the 1PPS reference input. This command enables a 1.75 second window within which time the output 1PPS will be synced to the 1PPS reference. At the time that the output synchronizes, the time of day clock will also synchronize to the reference 1PPS - rounding up or down to the nearest second.

Maintenance

Other than routine monitoring of system data, there is no specific maintenance required for the AOG. Some important operating recommendations and suggested procedures for analysis and repair of faults are given in this section.

6.0. System Data Monitoring

Since applications of the AOG typically involve very long term uninterrupted operation, one of the most important recommendations for reliable operation is that a log or other record of the instrumentation be kept and updated on a periodic basis. Sections 4 and 5 discuss the front panel and serial based methods of obtaining all instrumented data.

6.0.1. VCO Oven

The VCO Oven voltage represents the internal thermal control heater voltage for the VCO crystal oscillator (VCXO). When turned on initially (cold start), the heater voltage saturates to between 3 and 4 volts and will remain there until the oven temperature is within the linear control range. Once balanced, the heater voltage should remain around 0.5 volts. Unusual variations in the VCO heater voltage may be associated with impending failure. If a problem with the VCXO is suspected, this data channel should be monitored for erratic behavior.

6.0.2. Multiplier 1 and 2

The Multiplier 1 and Multiplier 2 voltages are derived by a rectification of the 5 MHz reference multiplier input and the VCO output multiplier input, respectively. Normally these channels read between 0.5 and 1.2 volts. A voltage lower than 0.3 volts on either channel may indicate a problem with the multiplier input signal (or a bad connection in the case of Multiplier 1.) If the reference is within specifications and the problem is with Multiplier 2, Sigma Tau should be contacted.

6.0.3. Thermal Control Station

The Chassis Oven indicates the heater voltage on the Thermal Control Station (TCS). The TCS maintains precise control over the temperature of the internal high-frequency components of the AOG. The heaters saturate at about 7.3 volts and balance between 2 and 3 volts for normal ambient temperatures. An extremely low or zero voltage may indicate overheating due to the heat given off by another apparatus nearby.

6.0.4. Input Power

The indicated voltage of the V Bus should read 19.5 volts or above when the AOG is operating on main AC power. The external DC input, DCx, may be between 22 and 28 volts. System Power channel indicates whether AC or DC power is being used.

6.1. VCO Adjustment

The nominal VCO phase voltage is 2.25 volts and the nominal frequency control sensitivity of the VCO 1 x 10^{-8}/volt. Under normal conditions, the VCO

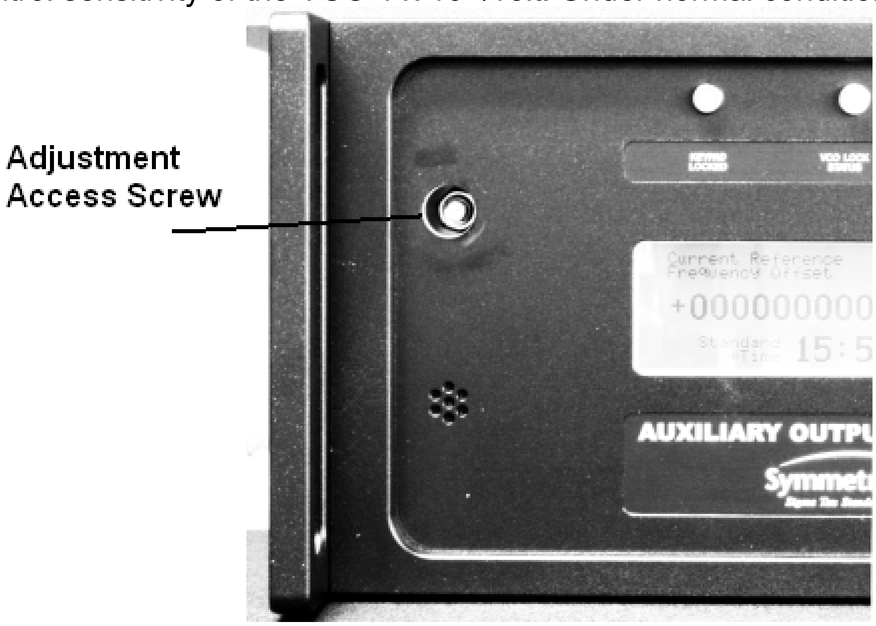


Figure 6.0. VCXO Coarse Adjustment Port Access.

will remain locked over a wide range of voltages, typically between 0.1 and 4.5 volts, provided that the noise of the reference input in conjunction with the VCO loop bandwidth do not cause too rapid modulation of the VCO voltage. Under unfavorable conditions, the loop may not immediately acquire lock when the reference is first connected, nor recapture lock if it is lost.

The VCO alarm is set conservatively so that the VCO Lock indicator turns red when the phase voltage falls below 1.25 volts or rises above 3.75 volts. The phase voltage should be kept well within this range to allow for largest possible range of programmed frequency offsets. For this reason, the voltage is set initially to 2.25 volts (±0.25 volts) and should be kept within about 1.5 to 3.5 volts. This gives a frequency variation range of approximately $5x10^{-8}$ with a safety margin of about $\pm 5x10^{-9}$. If the VCO drifts or the reference input changes frequency causing the VCO voltage to exceed this range, the VCO coarse control should be adjusted.

If the AOG loses lock, and lock cannot be re-acquired using the techniques described in Section 3.3, the following procedure may be helpful.

1. Make sure the frequency offset displayed on the front panel is zero as shown in Figure 3.1 before starting this procedure. Make sure the voltage reported on the system data screen for Multiplier 1 exceeds 0.5 volts.

2. To access the VCO coarse control, the access plug should be removed as in Figure 6.0. The VCO crystal oscillator frequency is adjusted by turning a slot-headed screw within the AOG housing. Using an insulated screwdriver and monitoring the phase voltage on the system data display, the voltage can be brought within the desired range. The adjustment must be made carefully to avoid damaging the oscillator - DO NOT USE EXCESSIVE FORCE WHEN TUNING THE COARSE CONTROL ADJUSTMENT SCREW (THIS IS A TEN TURN POT, AND MAY REQUIRE SEVERAL TURNS TO ACHIEVE LOCK).

3. Connect a dual channel oscilloscope to the AOG input signal on one channel and trigger on this channel. Monitor one of the AOG output signals on the other channel. You can easily see when the unit is locked (the relative motion of the displayed waveforms will be zero). CAUTION: It is possible for the light to be green and the phase voltage to read 2.25 volts and the unit NOT to be locked, if there is a very large offset and resulting high beat frequency between the input signal and the internal oscillator frequency. Be sure the relative motion of the displayed waveforms IS zero.

4. When you are sure the unit is locked, the coarse frequency pot should be adjusted until the phase voltage reads ~ 2.25 volts and the VCO Lock Status indicator light on the front panel is green.

5. Please confirm lock using the method described above, or some other method that confirms input and output frequency agree with zero frequency offset programmed on the AOG front panel. Once a satisfactory adjustment has been made, replace the access plug.