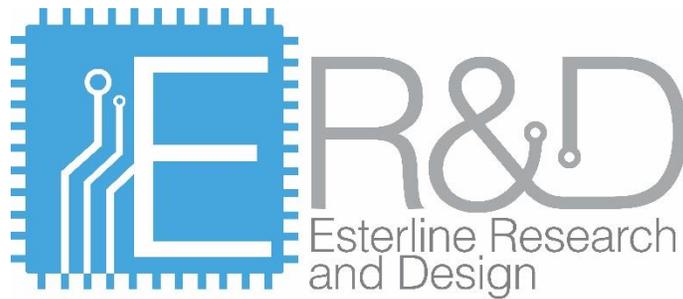


Operation Manual

ER&D Model CG5 Multi-Channel Clock Generator



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Doc #: CG5-OM

Revision -

Performance Certification

Esterline Research and Design (ERD) certifies that this product was 100% tested to validate compliance with its published specifications at the time of shipment.

Warranty

This product is warranted against defects in materials and workmanship for a period of one (1) year from the date of shipment.

Service

This product is neither designed nor documented for user repair; it must be returned to the factory for warranty or non-warranty service or repair. To avoid unnecessary delays, please contact the factory for authorization before returning this product for repair.

Information in this document is subject to change without notice.

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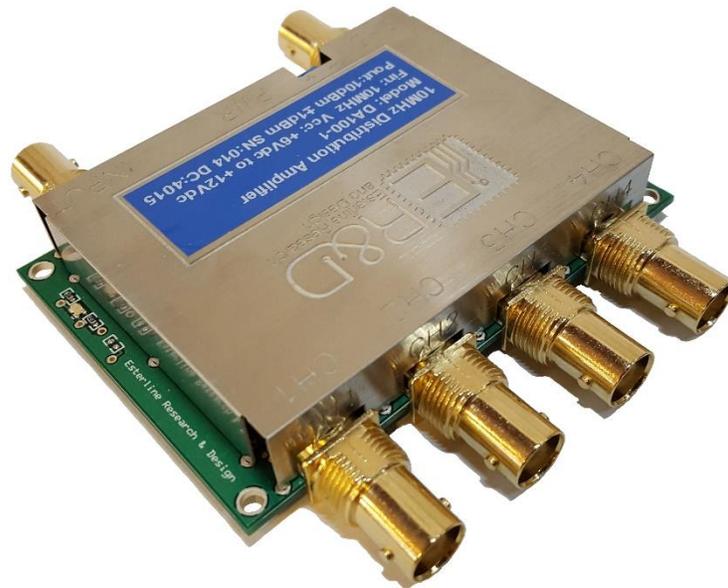
Product Overview:

The CG5 is a versatile, multi-channel signal source, which can provide five independent 3.3V, CMOS-compatible square wave output signals over the frequency range of 0.01 Hz to 128 MHz. Each output is uniquely settable for frequency, duty cycle and phase offset values. The onboard xtal has an output frequency of 6.25 MHz, which is multiplied by 16 to obtain a 100 MHz time base, allowing the CG5 to offer a 10 ns resolution for phase and duty cycle adjustments.

The CG5 derives its power from the USB port of the computer, which is then regulated to 3.3 V using a low-noise voltage regulator. While providing a stable, low-noise voltage source for the CG5, the voltage regulator also incorporates internal current limiting (150 mA) and thermal protection circuitry, permitting indefinite, damage-free operation into short-circuit conditions. A PTC resettable thermal fuse also provides an additional layer of protection for both computer and instrument from accidental short-circuiting. Since the CG5 consumes less than 50 mA of current, screw terminals are provided to allow the user to access the reserve 100 mA of current from the 3.3V regulated supply to power external applications.

The five signal outputs are designed to drive high-impedance circuits while providing 3.3 V CMOS-compatible logic levels. The instrument will also function in a 50-ohm environment but will not produce CMOS-compatible voltage levels. Operation in a 50-ohm environment will necessitate the use of a line receiver gate at the end of the transmission line to provide CMOS levels when these levels are required by the application. Please see 'USING THE CG5 IN A 50-OHM ENVIRONMENT' in the Applications Section of this document for more information.

The CG5 is designed to accept a 10 MHz reference signal from a frequency standard or other precision source. This 50-ohm input requires a +7.0 dBm minimum power level. This reference is used to software-correct the set frequency to compensate for error between the onboard oscillator and the external reference. Frequency corrections are calculated and implemented whenever a change to any CG5 parameter is made.



ELECTRICAL SPECIFICATIONS:

ABSOLUTE MAXIMUM RATINGS ¹

At room ambient conditions unless specified otherwise

		MIN	MAX	UNIT
VCC	Supply Voltage Range ²	-0.5	+6.5	V
IO	Continuous Output Current	-40	+40	mA
	Continuous Current Through VCC or GND	-200	+200	mA
Tstg	Storage Temperature Range	-40	125	°C

RECOMMENDED OPERATING CONDITIONS

At room ambient conditions unless specified otherwise

			MIN	MAX	UNIT
VCC	Supply Voltage Range ²		4.50	5.50	V
ICC	Input Current		N/A	50	mA
Output Adjust	Range	As Frequency	0.01	128 M	Hz
		As Period	7.8126 n	100	S
	Setability	As Frequency	0.01	N/A	Hz
		As Period	10 n	N/A	S
	Accuracy	At Duty=50% ³	-7.6	+7.6	ppm
At Duty<>50% ⁴		-1.22	+1.22	%	
Output Levels	V _{OL}	10K/10pF - DC Coupled	-0.05	0.05	V
		50 Ohm - DC Coupled	-0.05	0.05	V
	V _{OH}	10K/10pF - DC Coupled	3.2	3.5	V
		50 Ohm - DC Coupled	1.3	1.5	V
Duty Adjust ⁵	Range	As Percent	10 ns/PeriodX100	N/A	%
		As Time	10 n	Period	S
	Setability	As Percent	10 ns/PeriodX100	N/A	%
		As Time	10 n	N/A	S
Phase Adjust	Range	As Degrees	0.0	N/A	°
		As Time	10 n	N/A	S
	Setability	As Degrees	0.1	N/A	°
		As Time	10 n	N/A	S
TA	Operating free-air temperature		0	+50	°C

ELECTRICAL SPECIFICATIONS (Continued):

- ¹ Stresses beyond those listed under Absolute Maximum Ratings in the table above may cause permanent damage to the device. The ratings listed are for stress evaluation purposes, and functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions is not implied. Additionally, the exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- ² The CG5 is designed to derive its power from the computer's USB port, which can supply approximately 500 mA at 5.0 VDC. Therefore, when operated in this manner, the CG5 will never be subjected to voltage stresses which could induce failure.
- ³ The maximum error will occur at a set frequency of 1525.8673Hz. The error at other frequencies will be less.
- ⁴ This maximum error only occurs at non-50% duty cycles, resulting in a condition where some set frequencies cannot be generated.
- ⁵ Duty adjustment is only allowed at frequencies below 4.0 MHz. At frequencies of 4.0 MHz and above the duty cycle will be set to 50%.

GRAPHICAL USER INTERFACE (GUI):

The GUI shown below illustrates the CG5 versatility. In this example, the GUI is run in 'Demo Mode', where it is not necessary to have the CG5 connected to the computer. In this mode, the user can experiment with the instrument and become familiar with its capabilities. In the example below, CH2 is complementary to CH1, CH4 lags CH3 by 90°, and CH5 has a 5% duty cycle. More information on the GUI controls is provided in the following pages.

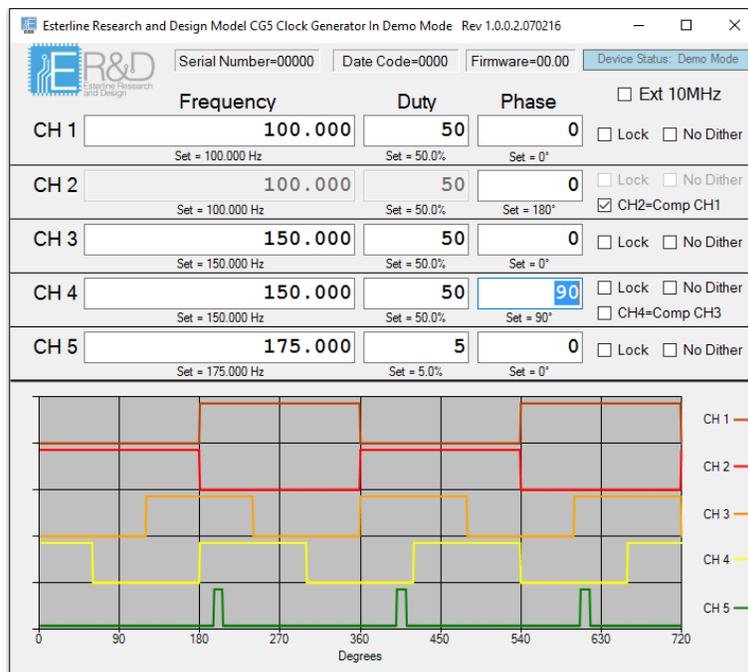


Figure 1: Example GUI Screenshot

GUI CONTROLS – Definitions and Descriptions:

Frequency:

By definition, frequency is cycles per second. Or, in its simplest terms, the rate at which the output level changes state from a high to low and low to high. A complete output cycle is low-high-low and frequency is given in Hertz (cycles per second). A one hertz frequency will be high for half of a second and low for half of a second.

The frequency setability is determined by the desired frequency and whether or not the desired signal is 50% duty cycle. The Frequency error is shown in Figure 2 below.

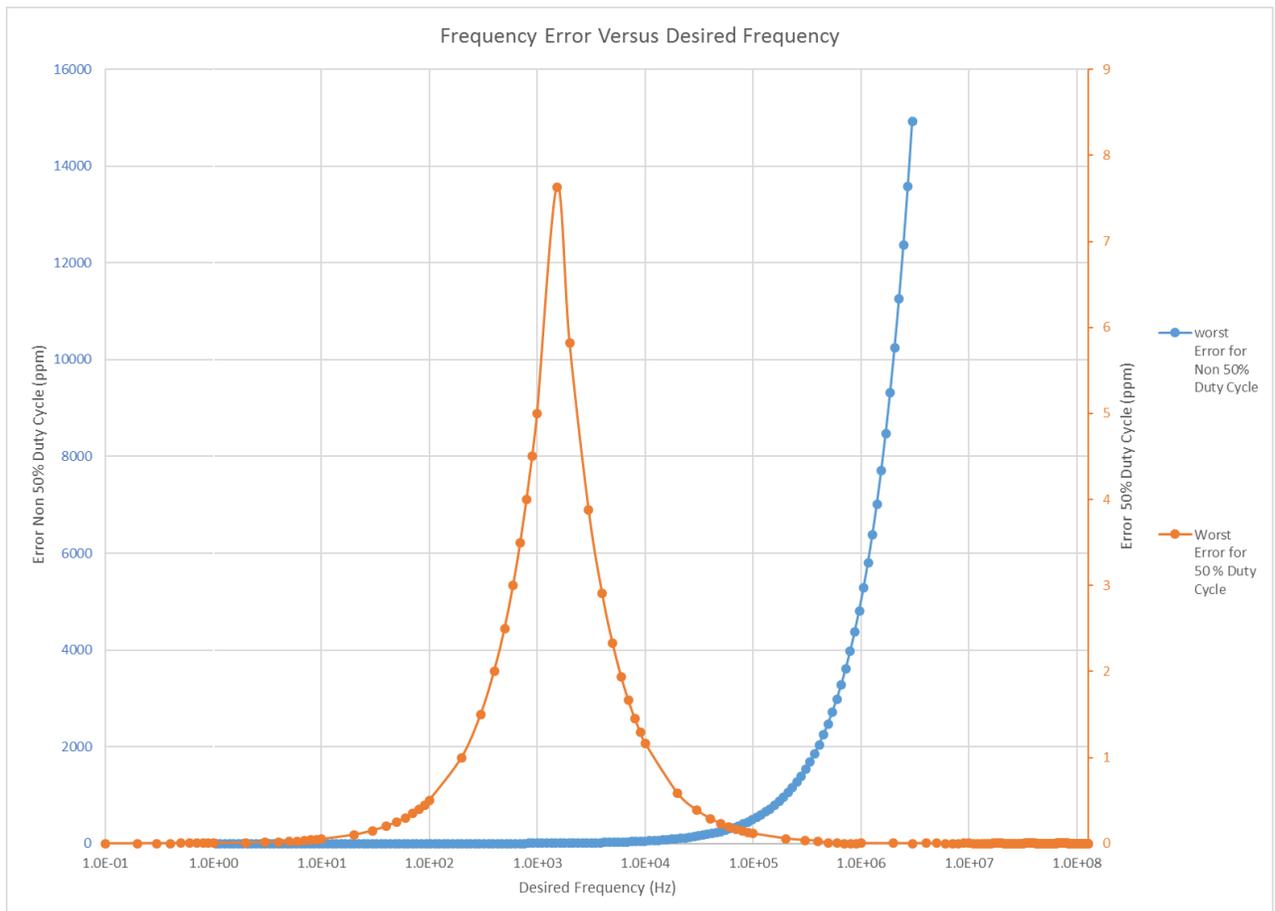


Figure 2: Frequency Error Versus Desired Frequency

Frequency can also be entered as period (seconds per cycle) if a time suffix is used (ns,us, ms, s).

M=Megahertz, K=Kilohertz, ns=Nanoseconds, us=Microseconds, ms=Milliseconds, s=seconds

Duty Cycle:

The duty cycle is the percentage of time that the signal is high compared to the signal period. If the signal is high 50% of the time, then the duty cycle is 50%. Small duty cycle values can be used to generate short pulses. For example, 10 Hz with a 1% duty cycle will generate a 1 millisecond pulse every 100 ms.

Because of how the signals are generated, the duty cycle can only be specified for frequencies below 3.0 MHz. Frequencies at 3.0 MHz and above can only be generated with a 50% duty cycle.

Duty cycle has a resolution of 10nsec, therefore higher frequencies have larger duty cycle steps and less available duty cycle settings. For example, at 2.5MHz the duty cycle can be generated with 2.5% steps (2.5%, 5%, 7.5% ... 92.5%, 95%, 97.5%).

Duty cycle can also be entered as time if a time suffix is used (ns, us, ms, s). The time specified is the amount of time the signal will be high.

A duty cycle of 0 means the output is always low, a duty cycle of 100 means the output is always high (make sure the frequency is 0.02 or greater).

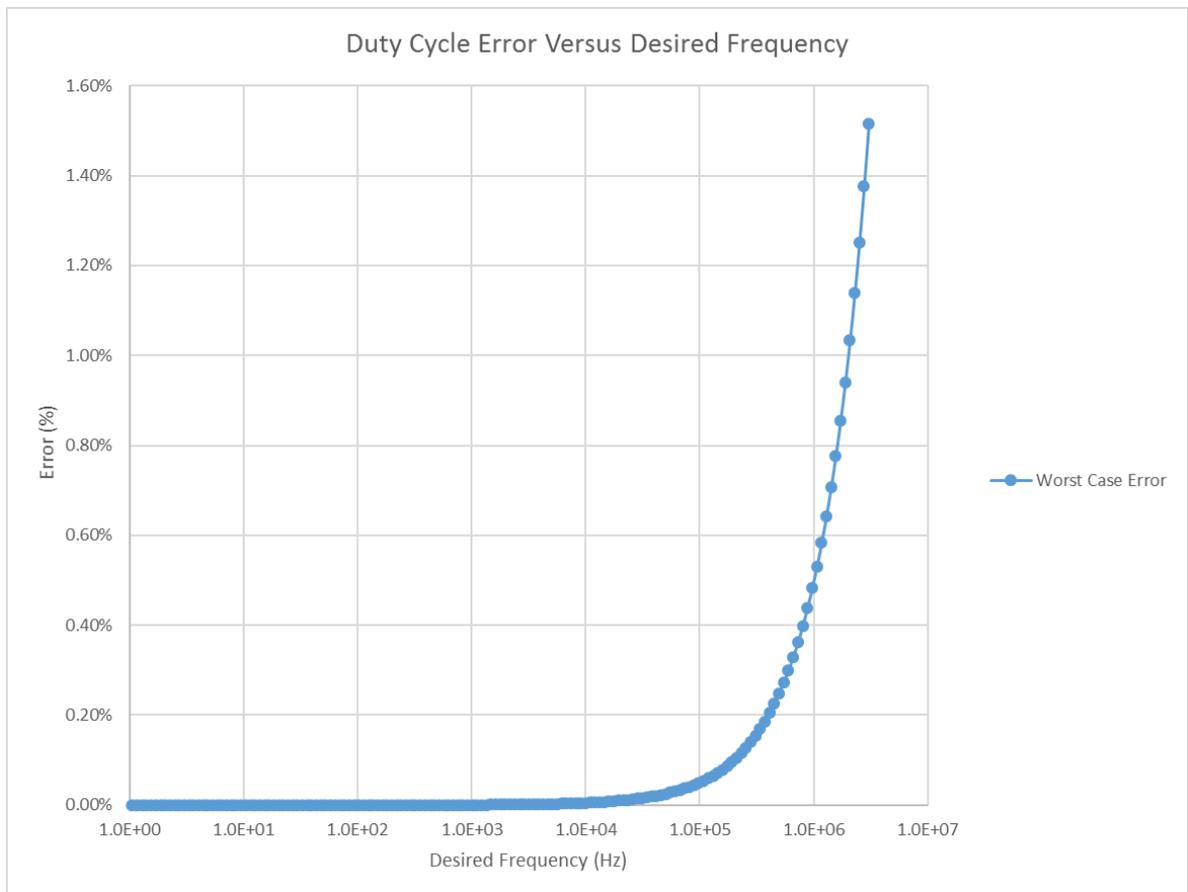


Figure 3: Duty Cycle Error Versus Desired Frequency

GUI CONTROLS – Definitions and Descriptions (Continued):

Dithering:

Dithering is a method used to generate a more accurate frequency over a long period of time at the expense of the frequency being unstable over a very short period of time. For example, a period of 1001 ns is not normally achievable because the 10 ns setting resolution of the CG5 will permit a setting of either 1000 ns or 1010 ns periods. The dithering function will generate 9 cycles with a period of 1000 ns, and 1 cycle with a period of 1010 ns, thus creating an average period of 1001 ns over 10 cycles. However, the output will have 10 ns of jitter. Disabling the dithering function by selecting the “No Dither” check box will cause the CG5 to create an output with a constant period of 1000 ns. As a result, the frequency will not be as accurate, but the cycle to cycle jitter will be very small. When using dithering, the maximum dither amount is 10 ns, so the period of any cycle will never be greater than 10 ns more or 10 ns less than the period of any other cycle.

Phase Offset:

The phase offset is a delay between a signal and a reference. For example, if two channels are used to generate 1000 Hz signals and one has phase of 0° and the other has a phase of 90° then the two signals will offset by $\frac{1}{4}$ of a wave (250 us). In other words, the one signal will transition from low to high then a quarter of the period (250 us) later the other signal will transition from low to high.

Phase offset will be rounded to the closest multiple of 10 ns.

When using complimentary outputs, the phase offset is always 180° and the 10 ns resolution restriction is not applicable.

Phase offset can also be entered as time if a time suffix is used (ns, us, ms, s). Phase offset has a resolution of 10 ns.

Complementary Outputs:

A complementary output is simply an inversion of another output signal. The CG5 can create complementary outputs using channels 2 and 4 such that channel 2 is the compliment of channel 1 and channel 4 is the compliment of channel 3. When complementary features are enabled, the frequency and duty cycle entry boxes of the complementary channels are disabled because these parameters are under the control of the reference channel.

Reference Input:

The CG5 has one frequency input channel, which can be connected to a 10MHz frequency standard. The signals generated from the CG5 are created from the on-board xtal reference frequency. When an external 10 MHz reference signal is detected, the CG5 uses it to adjust the module set frequency to correct the error between the on-board xtal frequency and the external reference frequency (at time of set only).

GUI CONTROLS – Definitions and Descriptions (Continued):

Locked Channels:

ALL channels are updated and restarted when new values are entered on any channel, unless a channel is locked. Restarting all channels is necessary to ensure phase coherence between them. During a restart, a channel output will stop for about 10 ms while the update is implemented.

Locking a channel prevents it from being restarted when another channel is updated; it will continue to produce its specified output during the process of restarting other unlocked channels. However, as previously stated, restarted channels will not be phase-coherent with locked channels. Therefore, the operator should be aware of how the CG5 works to avoid unexpected and/or undesired phase errors between channels when using the locking function.

The following example will result in a phase error between Channel 1 and Channel 2:

```
Set Channel 1 to 0°  
Lock Channel 1  
Set Channel 2 to 90°
```

Because Channel 1 was locked it was not updated when the Channel 2 command was executed, thus resulting in the phase error between Channel 1 and Channel 2. To ensure phase alignment the correct command sequence is as follows:

```
Set Channel 1 to 0°  
Set Channel 2 to 90°  
Lock Channel 1  
Lock Channel 2
```

APPLICATIONS AND EXAMPLES:

The following examples illustrate some uses for the CG5.

OSCILLATOR START-UP TIME MEASUREMENT:

Using the CG5 Clock Generator as a power supply switch will permit the measurement of oscillator start-up time. Because the CG5 output is 3.3V CMOS, it cannot accommodate all oscillator supply voltages. Therefore a voltage translator circuit will be required. This translator must also have sufficient current-handling capability so as to accommodate the wide variety of currents that will most likely be encountered testing oscillators of different output logic types and frequencies. A schematic for a Start Time Test Fixture is provided in the "Measurement Configuration" section on the following page. This circuit will support switching oscillator supply voltages up to 12 VDC at 0.1 Amps.

Because this fixture requires the use of an external power supply, care must be taken to ensure that the DUT (Device Under Test) is not subjected to an overvoltage condition during the measurement setup. This is best accomplished by using a dummy load resistor on the output or "BNC3" (with the unit removed). Referring to the manufacturer's specification sheet for the device to be tested, calculate the load resistor value from the maximum specified current and the nominal supply voltage as follows:

$$RL = \frac{V_{nom}}{I_{max}}$$

Connect the equipment as shown in the "MEASUREMENT CONFIGURATION" section on the following page. The resistor "RL" can be placed at connector "BNC3" on the test fixture or at the CH2 scope input. Set the external power supply to 0 V. Set CH1 on the CG5 to a constant '1 Level' by setting the frequency to 20 Hz and the duty cycle to 100%. Slowly increase the external power supply until the voltage measured on CH2 on the oscilloscope is within the tolerance specified for the oscillator to be tested. Inset the oscillator into the test socket and proceed with the measurement.

Adjust the oscilloscope horizontal time/division until the point where 100% of the oscillator peak to peak output voltage is evident on the oscilloscope.

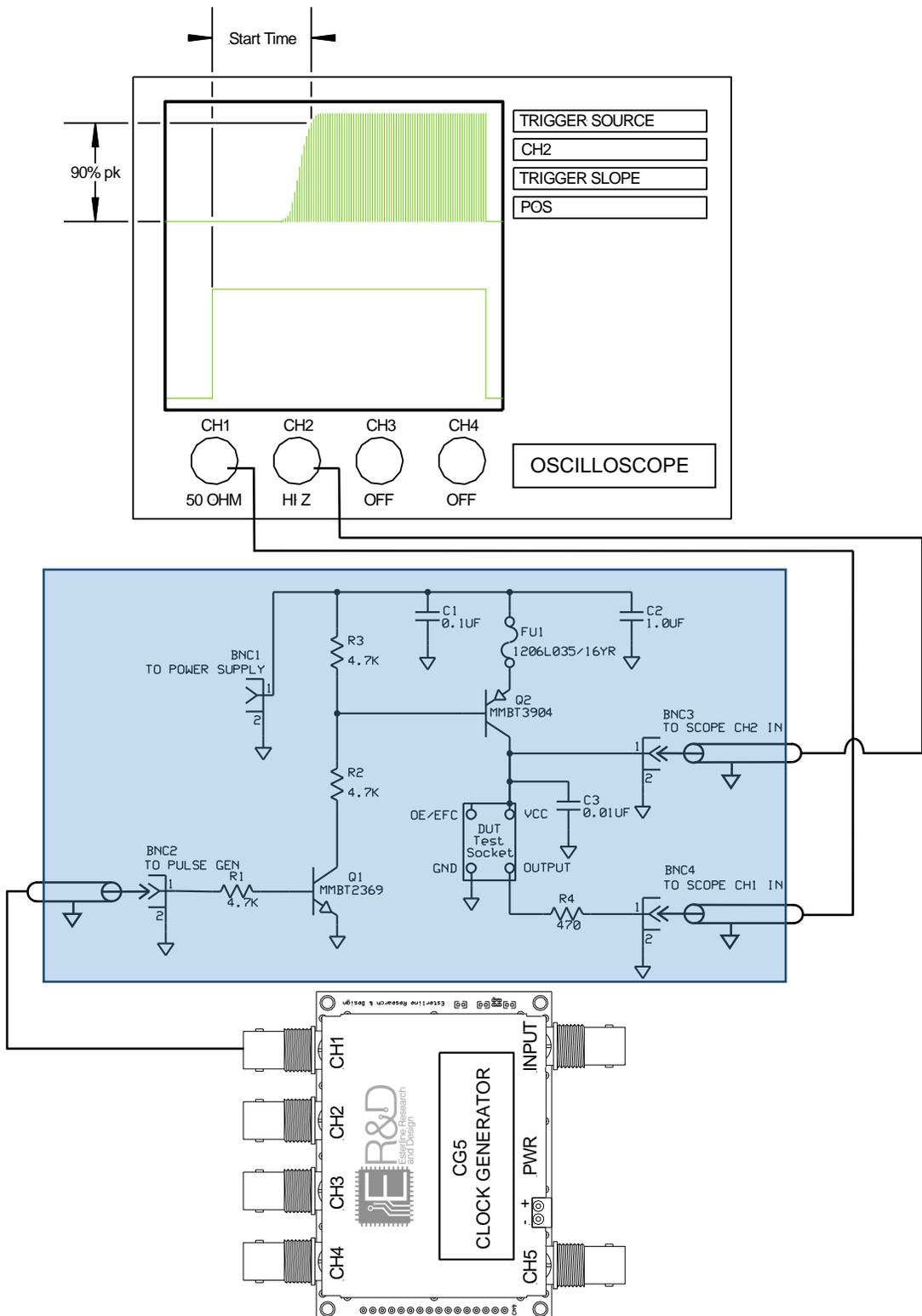
The oscillator start-up time is the measurement of time between points A and B as defined below:

'A' is the point where the DUT supply voltage reaches the minimum specified supply voltage.

'B' is the point where the oscillator output reaches 90 % of its final peak to peak value.

OSCILLATOR START-UP TIME MEASUREMENT (Continued):

MEASUREMENT CONFIGURATION



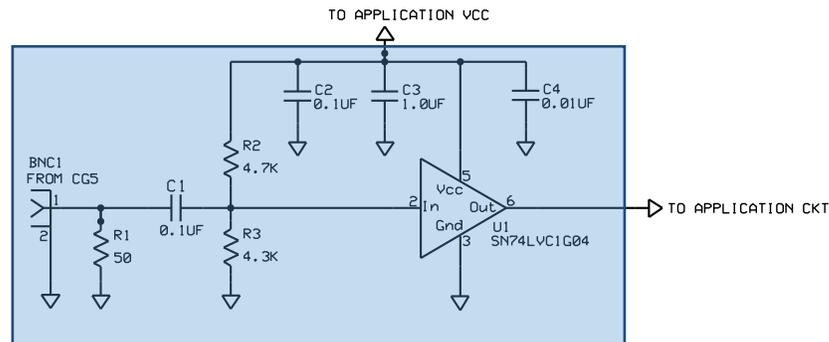
APPLICATIONS AND EXAMPLES (Continued):

USING THE CG5 IN A 50-OHM ENVIRONMENT

When terminated into 50-ohms, the CG5 will produce reduced amplitude signals due to the voltage divider formed by the source and load impedances of the instrument and its termination. As a result, the CG5 may produce unexpected results when connected to applications requiring 'normal' CMOS logic levels to function properly. For example, a CMOS device in a user application powered by a 5.0 V supply will often require a logic high level between 2.5 V to 3.5 V to toggle the device. When terminated into 50-ohms, the CG5 will only produce a logic high level of 1.65 V, which will not be sufficient to drive the application. Therefore, to use the CG5 in this application, a level translator will be required.

The circuit below can be used to convert low-amplitude square or sine wave signals to application-compatible square wave levels needed to drive user applications. This example is provided only as a sample solution and many other solutions are possible. The translator should be incorporated within or located as close to the user application as possible, with attention paid to minimizing component and grounding lead lengths. Also, the bypass capacitors should be located close to U1.

The circuit below will function from 0.5 MHz to 128 MHz and supply voltages from 1.8 V to 5.0 V. At frequencies below 0.5 MHz, it is not necessary to terminate the CG5 into 50-ohms. At these frequencies, an unterminated 50-ohm cable may drive the application directly for 3.3 V or 5.0 V user applications. However, 1.8 V applications will require some kind of attenuation to prevent forward biasing of the input protection diodes on the user application during the positive cycles of the 3.3 V, CG5 output waveform.



APPLICATIONS AND EXAMPLES (Continued):

Drive five LEDs in a chase sequence where each channel is on for 100msec:

Channel 1: Freq=500ms, duty=100ms, phase=0
Channel 2: Freq=500ms, duty=100ms, phase=100ms
Channel 3: Freq=500ms, duty=100ms, phase=200ms
Channel 4: Freq=500ms, duty=100ms, phase=300ms
Channel 5: Freq=500ms, duty=100ms, phase=400ms

Simulate a GPS 1PPS signal (One pulse, once a second, logic high for 1 ms).

Channel 1: Freq=1S, duty=1ms, phase=0

Drive a unipolar stepper motor in full steps at 1000 steps per second.

Channel 1: Freq=4ms, duty=1ms, phase=0
Channel 2: Freq=4ms, duty=1ms, phase=1ms
Channel 3: Freq=4ms, duty=1ms, phase=2ms
Channel 4: Freq=4ms, duty=1ms, phase=3ms

Drive a unipolar stepper motor in half steps at 2000 half steps per second.

Channel 1: Freq=4ms, duty=1.5ms, phase=0
Channel 2: Freq=4ms, duty=1.5ms, phase=1ms
Channel 3: Freq=4ms, duty=1.5ms, phase=2ms
Channel 4: Freq=4ms, duty=1.5ms, phase=3ms

Generate a three phase square waves at 60Hz.

Channel 1: Freq=60, duty=50, phase=0
Channel 2: Freq=60, duty=50, phase=120
Channel 3: Freq=60, duty=50, phase=240

Remote Programming:

The CG5 can be used with your own software (instead of the GUI) by sending it serial data at a rate of 1 MBaud. The complete command library is as follows:

Notes:

{cr} represents the “Carriage Return” or “Enter” character (ASCII Character 13 or 0x0d). This character must be placed at the end of any command string to instruct the device that it has received the entire command. This character is also transmitted at the end of any information supplied by the device as a response to a data request.

“!” aborts any command in progress.

If a terminal program is used for communicating with the CG5, errant commands cannot be corrected by using the backspace key. Instead, used the “!” character to abort the command, then reenter the corrected command.

Commands:

!I?
{cr} – Returns device information in three values as follows:

02,sssss,yyww,vvvv{cr}

Where “02” means this device is a CG5, “sssss” is the device’s unique serial number, “yyww” is the manufacture date code, and “vvv” is the firmware version (0201 = 02.01).

!M?
{cr} – Measure the frequency at the reference input. Returns four values.

0,0,0,0{cr} if no frequency input detected, otherwise

aaaaaaaa,bbbbbbbb,cccccccc,ddddddd{cr}

Where “aaaaaaaa/(bbbbbbbb/200,000,000)” is the long term frequency and “cccccccc/(ddddddd/200,000,000)” is the short term frequency. The long term frequency is more accurate, but requires the input to be stable for a longer period of time.

!Fn=mode,onTime[,offTime],delay]{cr} - Returns “OK{cr}”

Set frequency of channel “n” (1 to 5)

“delay” is always in 10nsec steps for all modes.

The PLL modes have less jitter and should be used whenever possible.

The outputs do not change until the “!S” command is sent.

Complementary outputs with software modes are done by delaying the complementary output and adjusting the duty if needed.

Remote Programming (Continued):

Mode 0 = Off (must also specify an onTime of 0)

Mode 1 = Software long on/off time (freq 0.02Hz to 3.7MHz)

onTime is in 10nsec steps (13 to 4294967295)

offTime is in 10nsec steps (14 to 4294967295)

For frequencies above 1525Hz @ 50% duty, use mode 32.

Mode 2 = Software short on time (freq 0.025Hz to 5MHz)

onTime is in 10nsec steps (1 to 2147483647)

offTime is in 10nsec steps (19 to 2147483647)

Mode 3 = Software short off time (freq 0.025Hz to 5MHz)

onTime is in 10nsec steps (19 to 2147483647)

offTime is in 10 nsec steps (1 to 2147483647)

Mode 16 = Hardware NCO/PLL (freq 500KHz to 1.5625MHz)

onTime = $\text{Int}(343.59738368 * \text{freq} + 0.5)$ (171798692 to 536870912)

offTime = 0 (not used duty is always 50%)

Mode 17 = Hardware NCO/PLL (freq 1MHz to 3.125MHz)

onTime = $\text{Int}(171.79869184 * \text{freq} + 0.5)$ (171798692 to 536870912)

offTime = 0 (not used duty is always 50%)

Mode 18 = Hardware NCO/PLL (freq 2MHz to 6.25MHz)

onTime = $\text{Int}(85.89934592 * \text{freq} + 0.5)$ (171798692 to 536870912)

offTime = 0 (not used duty is always 50%)

Mode 19 = Hardware NCO/PLL (freq 4MHz to 12.5MHz)

onTime = $\text{Int}(42.94967296 * \text{freq} + 0.5)$ (171798692 to 536870912)

offTime = 0 (not used duty is always 50%)

Mode 20 = Hardware NCO/PLL (freq 8MHz to 25MHz)

onTime = $\text{Int}(21.47483648 * \text{freq} + 0.5)$ (171798692 to 536870912)

offTime = 0 (not used duty is always 50%)

Mode 21 = Hardware NCO/PLL (freq 16MHz to 50MHz)

onTime = $\text{Int}(10.73741824 * \text{freq} + 0.5)$ (171798692 to 536870912)

offTime = 0 (not used duty is always 50%)

Mode 22 = Hardware NCO/PLL (freq 32MHz to 100MHz)

onTime = $\text{Int}(5.36870912 * \text{freq} + 0.5)$ (171798692 to 536870912)

offTime = 0 (not used duty is always 50%)

Remote Programming (Continued):

Mode 23 = Hardware NCO/PLL (freq 64MHz to 128MHz)

onTime = $\text{Int}(2.68435456 * \text{freq} + 0.5)$ (171798692 to 343597384)

offTime = 0 (not used duty is always 50%)

Mode 27 = Same as mode 19, but with complementary output

Only use for channels 1 or 3. Complementary channel cannot be phase shifted.

Mode 28 = Same as mode 20, but with complementary output

Only use for channels 1 or 3. Complementary channel cannot be phase shifted.

Mode 29 = Same as mode 21, but with complementary output

Only use for channels 1 or 3. Complementary channel cannot be phase shifted.

Mode 30 = Same as mode 22, but with complementary output

Only use for channels 1 or 3. Complementary channel cannot be phase shifted.

Mode 31 = Same as mode 23, but with complementary output

Only use for channels 1 or 3. Complementary channel cannot be phase shifted.

Mode 32 = Hardware NCO (1525Hz to <500KHz)

onTime = $\text{Int}(42.94967296 * \text{freq} + 0.5)$ (1 to 2147483647)

offTime = 0 (not used duty is always 50%)

For frequencies below 1525Hz use mode 1

For frequencies 4MHz and above use mode 19

Mode 40 = Same as mode 32, but with complementary output

Only use for channels 1 or 3. Complementary channel cannot be phase shifted.

!S{cr} – Start updated channels. Returns “OK{cr}”. This command implements any changes entered through the GUI or through an external call (see the Remote Programming Section).

!L=value{cr} – Set the CG5 LED color. Returns “OK{cr}”

0 = Off, 1=Red, 2=Green, 3=Yellow, 4=Blue, 5=Magenta, 6=Cyan, 7=White

Technical Notes:

The CG5 uses the Parallax Propeller P8X32A microcontroller. The Propeller contains eight 32-bit processors (called cogs). Each CG5's output is controlled by a separate cog. When an output parameter is changed, the cog is stopped and restarted with the new parametric information implemented. This process of stopping and restarting causes a 10 ms loss of signal on the output.

Outputs can be generated in two different ways: software or hardware. When using software, all timing is based on a 10 ns (100MHz) clock and the output state can only change in 10nsec steps. Additional time is also required to process the requested waveform parameters in software. This results in minimum step sizes depending on the mode chosen.

Software Mode 1:

High time: Minimum = 130nsec (13 steps), Maximum = 42.9 Seconds (4294967295 steps)

Low time: Minimum = 140nsec (14 steps), Maximum = 42.9 Seconds (4294967295 steps)

Software Mode 2: (optimized for short high time)

High time: Minimum = 10nsec (1 steps), Maximum = 21.4 Seconds (2147483647 steps)

Low time: Minimum = 190nsec (19 steps), Maximum = 21.4 Seconds (2147483647 steps)

Software Mode 3: (optimized for short low time)

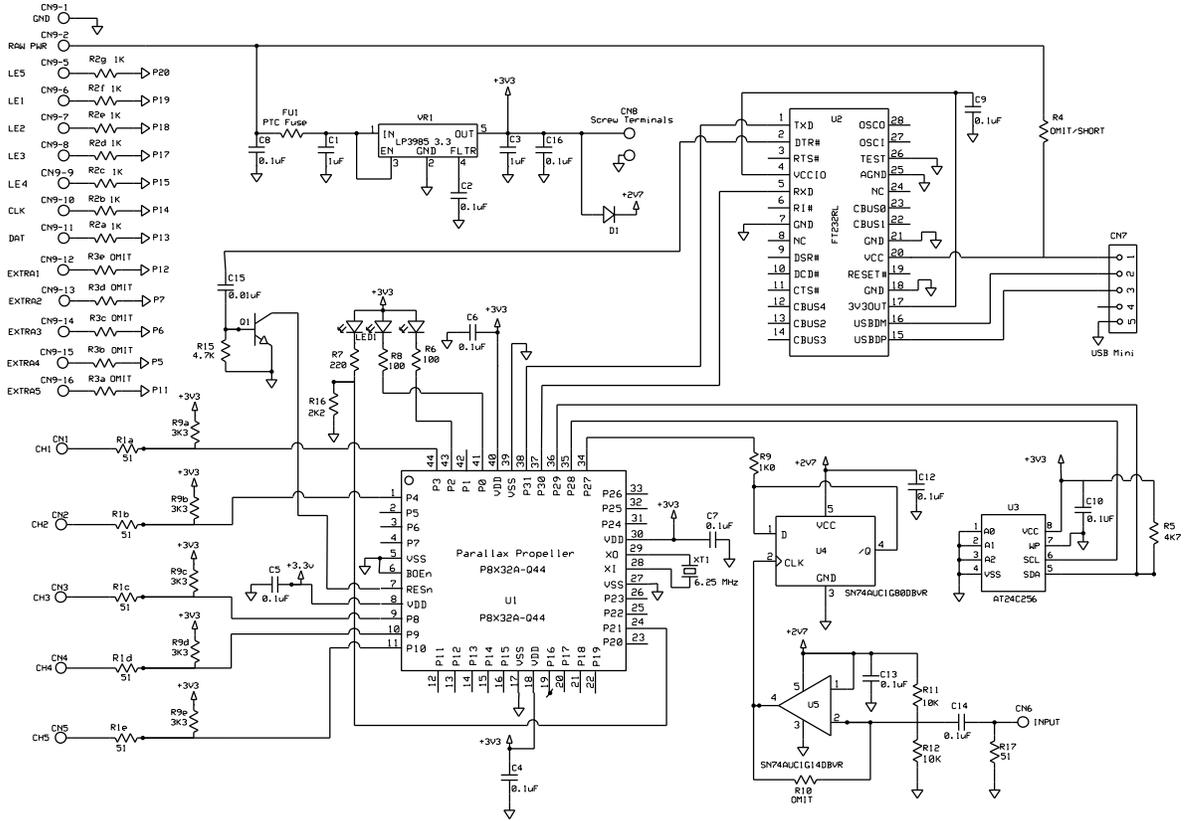
High time: Minimum = 190nsec (19 steps), Maximum = 21.4 Seconds (2147483647 steps)

Low time: Minimum = 10nsec (1 steps), Maximum = 21.4 Seconds (2147483647 steps)

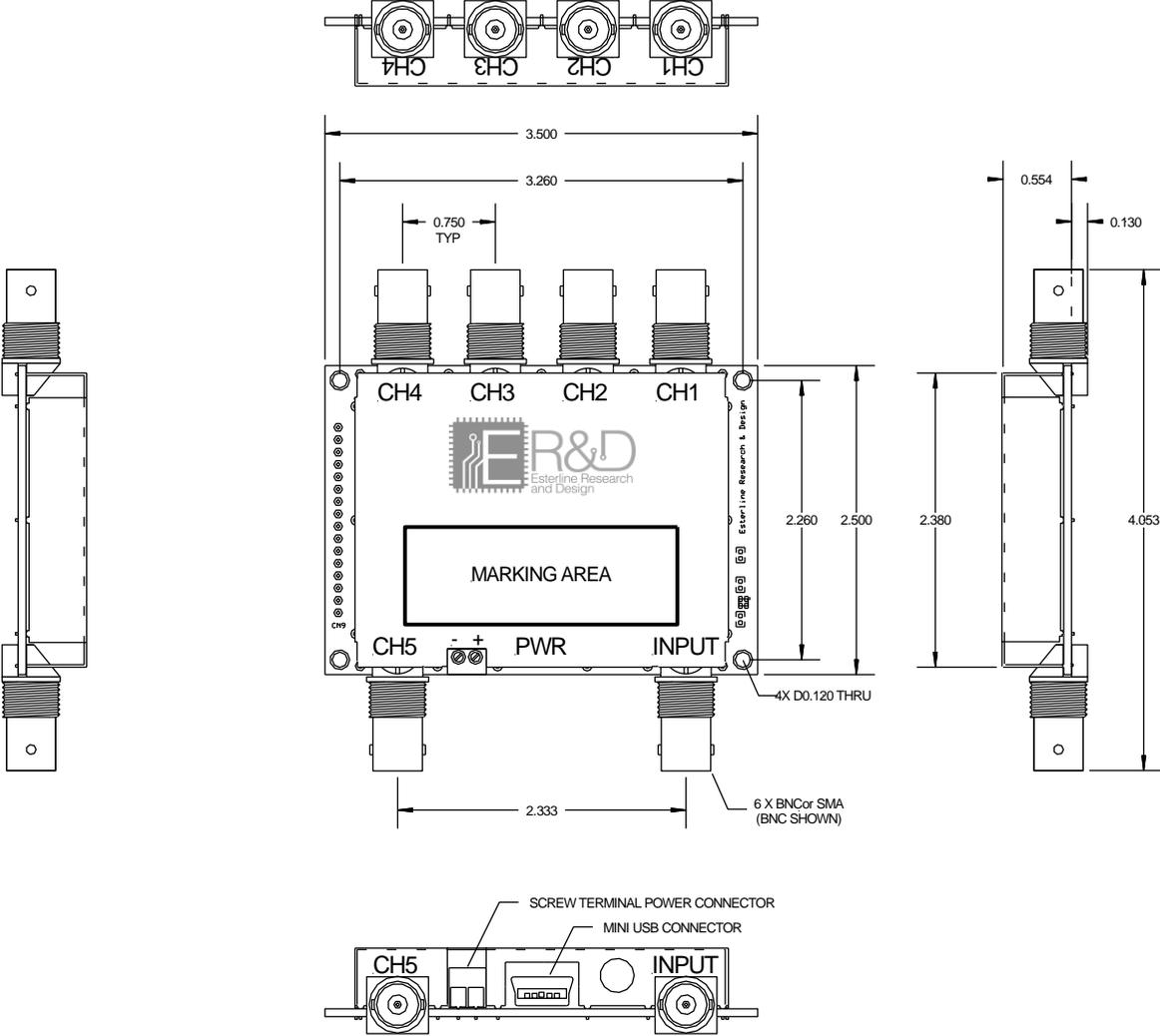
Hardware output generation is produced by using the hardware counters, which can also be configured to provide complementary outputs on another pin (or channel number). The hardware counters can only generate 50% duty cycle outputs and have a PLL that will multiply the frequency by 16, so the values given are used to generate a frequency relative to the 100MHz system clock. That generated frequency is fed into the X16 PLL. The output of the PLL is fed to a programmable divider that can divide by 1,2,4,8,16,32,64, or 128, which is then routed to the output connector. The input to the PLL must be between 4MHz and 12.5MHz for stable operation. This makes the output of the PLL range from 64MHz to 200MHz before the divider. The slowest frequency the hardware counters can create is therefore **64MHz / 128 = 500KHz**, the fastest is **200MHz / 1 = 200MHz**.

CG5 SCHEMATIC

The following information is provided for reference only and is not intended to provide documentation to facilitate maintenance or repair.



Mechanical Specifications:



All dimensions are in inches with a tolerance of ± 0.020 "