ECE 3300
Electrical Circuits: Laboratory
Experiment 2 Pre-Reading
The Function Generator

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This Unit, and its associated experiment, introduces the student to the **Rigol DG1022A** Function Generator.

Learning Objectives

By the end of this unit, the student should have an understanding of the use of the function generator as a tool to generate various voltage waveforms. More specifically, the student should:

- Have a working knowledge of the various keys on the function generator's front panel.
- Interpret the display of the function generator.
- Identify the output signal connector on the front panel of the function generator.
- Be able to properly connect the function generator to a scope and/or a circuit.
- Be able to adjust the function generator's settings to generate a voltage signal with a pre-specified shape, amplitude, frequency, duty cycle and *dc* bias.
- Be able to set the function generator to supply a *dc* voltage.
- Know the effect of a 50Ω load and a high-impedance load on the supplied signal amplitude.
- Know the connection between the displayed peak-to-peak voltage and the actual load voltage.
- Be aware of the available range of signal amplitude and frequency.
- Be able to express and utilize the set of inequalities that govern a generated signal peak-to-peak, offset and maximum voltage.

The Rigol DG1022A Function Generator

The operation of the various controls of the **Rigol DG1022A** function generator is described. The front panel of this instrument is shown in Figure 1. In addition to generating four basic periodic *voltage* signals (sine, square, ramp and Pulse), this instrument can generate advanced modulated signals. Those advanced signals (labeled in blue on the front panel) like specific noise and Arb signal.

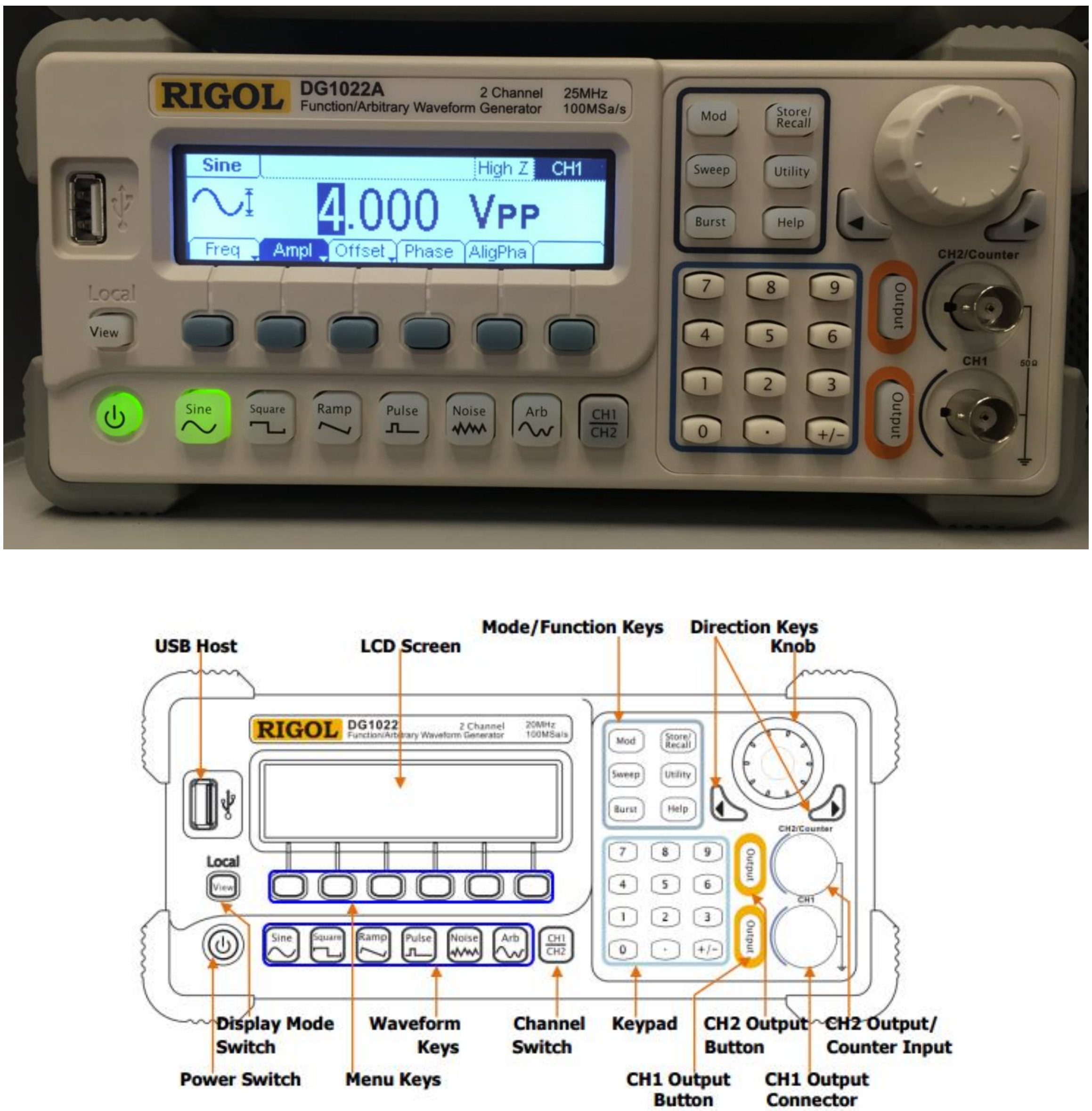
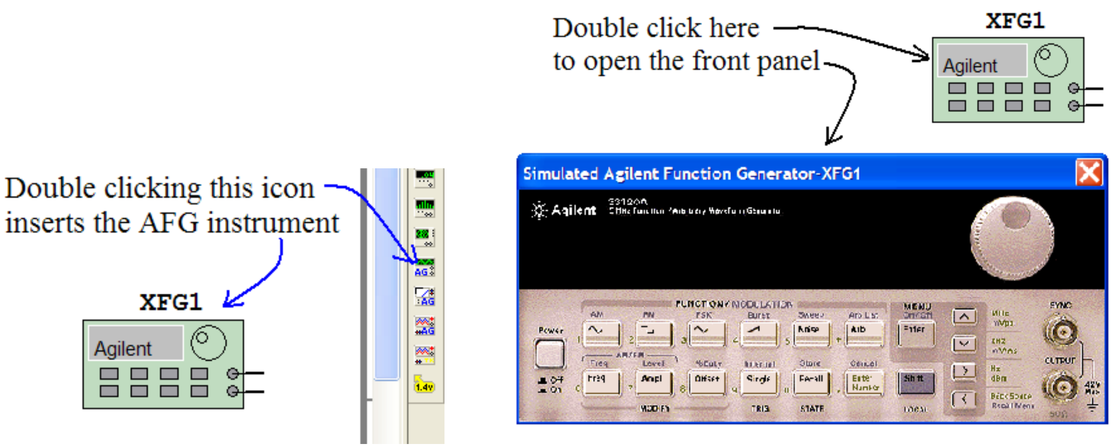


Figure 1 . Front panel of the Rigol DG1022A function generator (FG).

The reader is advised to experiment with the actual **Rigol DG1022A** function generator (FG) while reading the following material. Alternatively, the reader can run Mutisim on his/her computer and experiment with the *virtual* FG. This can be done by simply double clicking on the FG icon in the right hand side menu (refer to Figure 2-a). This will insert the FG instrument symbol (labeled XFG1) in the work area. Next, double clicking the inserted symbol will display the front panel of the virtual FG (refer to Figure 2-b). This Virtual FG is based on **Agilent 33120.**



(a) (b)

Figure 2 Running the virtual FG in Multisim.

The FG outputs its generated voltage signal at the BNC connector located in the lower right corner of the front panel, as shown in Figure 3.

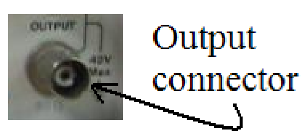


Figure 3 FG output BNC connector.

Safety Rules

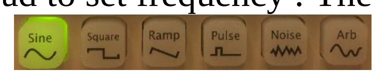
- **Operations of the function generators are quite simple; however, before turning on the function generator, the very first thing that you need to remember is, never short the function generator.**
- **The black hook (or clip) is negative, and it can only be connected to the clip of the probe; the red hook (or clip) is**

positive, and it can only be connected to the hook of the probe.

Output Signal Setting

1) Power the function generator up by pressing the **Power** key (). This operation resets the instrument to its default state.
2) The FG's default output is a sinusoidal voltage signal of the form $v(t) = A\sin(2\pi f\, t)$ Volts, with amplitude A = 500mV and frequency f = 1kHz. The FG default display is shown in Figure 4. It shows the peak-to-peak voltage $V_{pp} = 2A$ = 1V. It also displays the symbol of a sinusoidal wave ().

Figure 4 Default screen of the FG immediately after reset.

3) Pressing the **Freq** key () displays the frequency (in Khz here) of the generated signal (refer to Figure 5). Using numpad to set frequency . The output signal shape can be selected using the  keys.

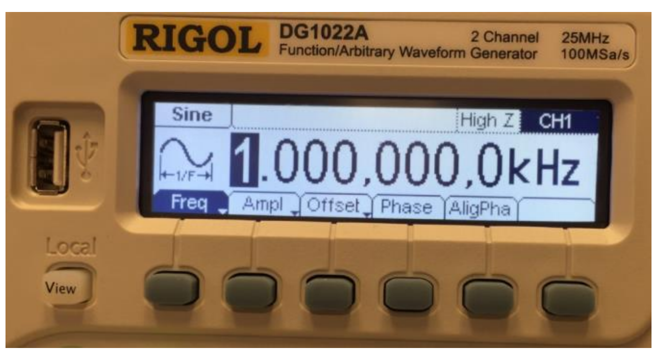


Figure 5 Frequency value of the output signal.

4) To adjust the peak-to-peak of the output signal, press 

. Similarly, to adjust the frequency of the output signal press 

. The front panel knob can be used to set the peak-to-peak voltage and frequency. Turning the knob changes the value of the digit. The The digit can be selected using the **Horizontal Arrow** keys ( and ).

5) Alternatively, a signal parameter value can be entered directly using the **Digit numpad** on the front panel. For example, to enter the voltage amplitude of 1.15V, press the following keys in the sequence shown: Ampl, Numpad,1,.,1,5. The Display will show 2.300 Vpp (recall that the peak-to-peak value = twice the amplitude). After entering the digits for voltage, press one of the mVpp, Vpp, mVrms, Vrms, to select the unit. Similarly for frequency, pressing one of sets the measurement unit to Hz, kHz or MHz, respectively.

Examples :

The following sequence of keys will cause the FG to output a square wave with f =10kHz and Vpp = 2.5V:

- Select square signal: Square.
- Set frequency: Freq, 1, 0, kHz.
- Set amplitude: Ampl, 2, . , 5, Vpp .

The following sequence of keys will cause the FG to output a sine wave of f = 4MHz and RMS voltage of 100 mVrms. The instrument will display VRMS next to the entered value.

- Select sine signal: Sine.
- Set frequency: Freq, 4, MHz.
- Set amplitude: Ampl, 1, 0 , 0, mVrms .

Note: while entering a number using the digit keys, the  key serves as "back space" and can be used to make corrections.

The FG has a waveform dependent frequency range, as shown in Table 1.

Function	Min Frequency	Max Frequency
Sine	1 µ Hz	25MHz
Square	1 µ Hz	5MHz
Ramp	1 µ Hz	500 kHz
Pulse	500 µ Hz	5Mhz

Table 1 Frequency range of the signals generated by the FG.

The Vpp range depends on the output termination mode of the FG, according to Table 2. Output termination is considered next. The ranges in Table 2 assume zero-average signals. If *dc* bias is added, then the maximum value of Vpp is reduced (see the section on DC Offset below).

Function	Output Termination(CH1)	Minimum Vpp	Maximum Vpp
Sine	50Ω	2 mVpp (<=20 MHz) 2 mVpp (> 20MHz)	10 Vpp (<=20 MHz) 5 Vpp (> 20MHz)
Square	50Ω	2 mVpp (<=20 MHz) 2 mVpp (> 20MHz)	10 Vpp (<=20 MHz) 5 Vpp (> 20MHz)
Ramp	50Ω	2 mVpp (<=20 MHz) 2 mVpp (> 20MHz)	10 Vpp (<=20 MHz) 5 Vpp (> 20MHz)
Pulse	50Ω	2 mVpp (<=20 MHz) 2 mVpp (> 20MHz)	10 Vpp (<=20 MHz) 5 Vpp (> 20MHz)

Table 2 Peak-to-peak voltage range

Output Termination

The FG has an internal resistance of 50Ω. The Vpp value that appears on the FG display is only valid if the output of the FG is loaded by a 50Ω resistor. *By design, and assuming no load is connected (open circuit), the FG outputs a signal that has twice the peak-to-peak voltage displayed*. The 50Ω resistance load forms a voltage divider with the FG 50Ω internal resistance. Since the two resistors are equal, the load gets half the FG voltage. In this case, the load voltage is equal to the FG displayed voltage.

On the other hand, if an oscilloscope is connected directly to the FG, the scope will display a waveform that has twice the peak-to-peak value of the signal. This is because the scope (assuming the 10x probe is used) acts as a load of about 10MΩ resistance. In this case, the voltage divider that is formed between the 50Ω internal FG resistance and the 10MΩ load gives a voltage at the scope's input that is equal to the *open circuit* (unloaded) FG voltage times 10MΩ/(10MΩ+50Ω); which is approximately equal to the open circuit FG voltage. Therefore, the scope will display a waveform that has twice the peak-to-peak voltage displayed on the FG.

In practice, the FG output is loaded by a circuit that does not necessarily have a 50Ω resistance. Therefore, the displayed FG voltage value is not the correct value supplied to the circuit. *Whenever the FG is used to provide a voltage signal to a given circuit, the user must use either the multimeter or the scope to set the desired voltage.*

The FG can be configured for a HIGH Z (*high impedance*) load (as opposed to the default 50Ω load). In this case, the displayed Vpp is equal to the open circuit FG voltage. In other words, a scope connected directly to the FG output will display a waveform whose peak-to-peak voltage matches the displayed Vpp on the FG. The following sequence of keys allows the user to access the High Z mode: Press Utility → CH1, you can select High Z model or normal modem refer to Fig 6

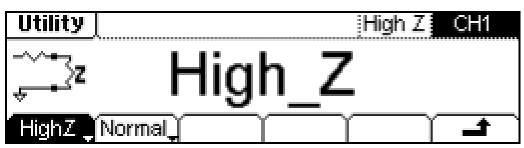


Figure 6 Setting interface of CH1

Generating a DC Signal

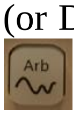
A *dc* (or DC) voltage signal can be generated by the FG. To select ***dc volts***, press  ,Then select load ,the select other in builtin menu ,Then select DC to make any value between -10 and +10 volts. For example, to output $v(t)$ = +3 V, First ,step into the DC model ,then use num pad to adjust offset to 3 Vdc. Figure 7 shows the display of the FG for a +3V *dc* output.

Figure 7 FG display for a DC signal.

The user should be aware that after generating a *dc* signal, if a *sine* (or other) signal is selected, the set *dc* value becomes an *offset voltage* applied to the sine signal.

DC Offset

The FG allows the user to add a *dc* bias (offset) to the output voltage. The offset is zero at power-on. The offset voltage can be set to a positive or a negative number. To set the **Offset**, press , then enter a value using the knob or the number keys. Figure 8 shows the FG display just after adding a 2V *dc* bias to a sine signal. Note how "Offset" lights up on the display to indicate a non-zero bias.

Figure 8 FG display for 2V dc bias added to a square signal.

The offset voltage and Vpp of the FG output signal is governed by the following two inequalities:

$$|V_{offset}| + \frac{V_{pp}}{2} \le V_{\max} \quad and \quad |V_{offset}| \le 2V_{pp}$$

Where, V_{max} = 5V for a 50Ω termination or 10V for a high impedance termination.

Duty Cycle

This feature applies only to square signals. Consider a pulse train signal with period *T*. The *duty cycle* is the ratio of the pulse width (*Width*, refer to Figure 9) to the period, expressed as a percentage:

$$\text{Duty cycle} = 100*(Width)/T = 100*(Width)*f$$

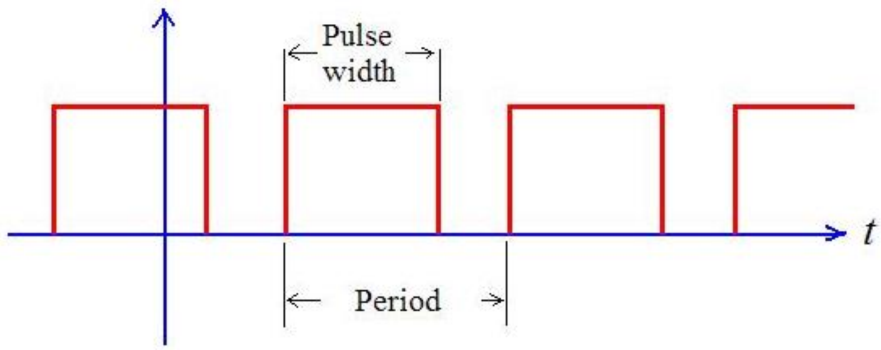


Figure 9 Pulse width of a squarer signal

The default duty cycle is 50%. It can be adjusted in increments of 1%. The duty cycle range is 20% to 80% for $f \leq$ 3MHz, and 40% to 60% for 3Mhz $<f$ <4MHz. 50% for 4Mhz $<f$ <5MHz.

To set the duty cycle, press DtyCyc, then use numpad to set required duty cycle