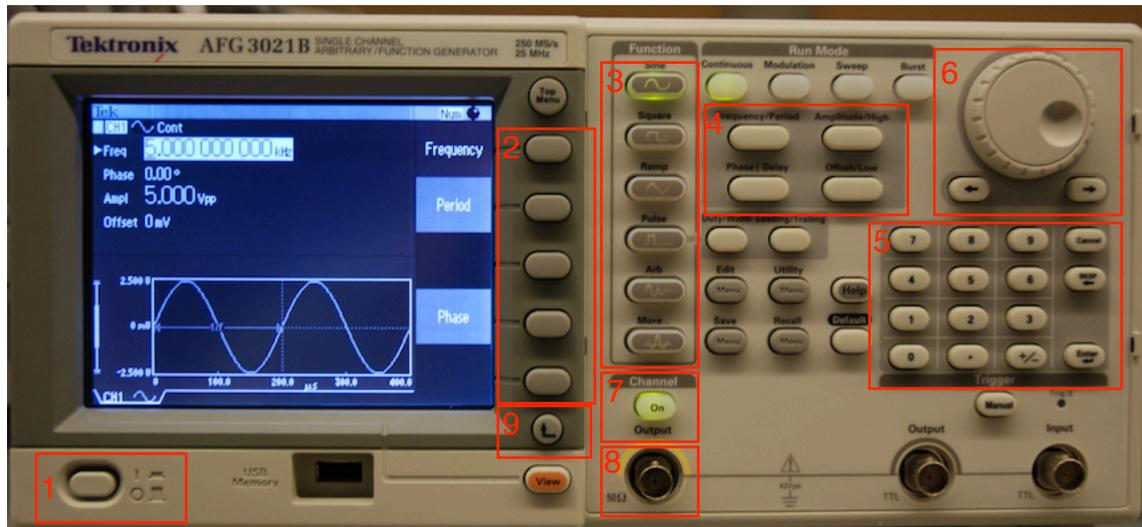


## EE 201 Lab

### Tektronix 3021B function generator

The function generator produces a time-varying voltage signal at its output terminal. The Tektronix 3021B is capable of producing several standard waveforms (sinusoidal, square, triangle), as well as special-purpose, user-defined waveforms. The operation is relatively simple, and everything is controlled from buttons on the front panel. See the figure below.



**Figure 1.** Front panel of 3012 function generator.

### Controls

Study the front panel of the function generator. The display screen on the left shows all of the information relating to the generated waveform. In addition, note the location of the following:

1. Power on/off
2. Soft keys – used for selecting / entering waveform parameters
3. Waveform functions — used to select the different types of waveforms
4. Parameter keys – used in conjunction with softkeys to change waveform parameters
5. Numeric keypad — for entering parameters
6. Rotary control knob — alternative method for changing parameters. Arrows underneath allow you to choose the particular digit that is changed when turning the knob
7. Output button — turns on the output waveform (Don't forget to use it!)
8. BNC connection for output terminal — Connects the output to your circuit. (Note: The other connectors are not used very much. We will never use them in EE 201.)
9. System settings — use this to change the load impedance and other system functions

### Periodic signals

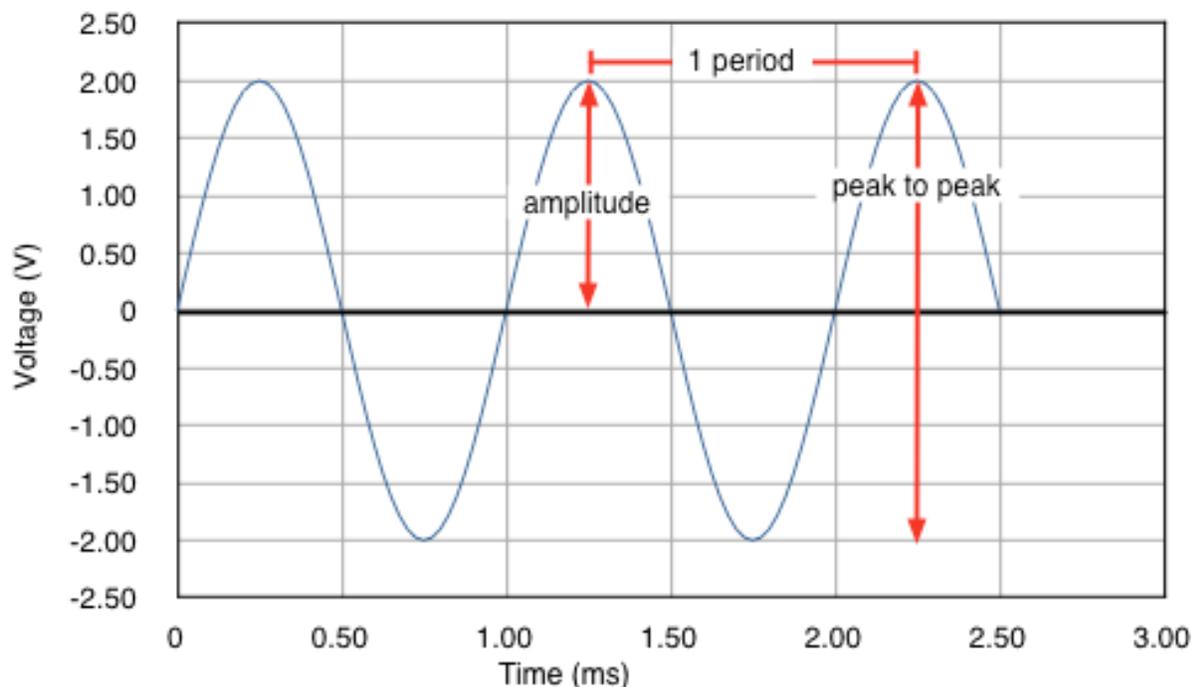
In setting up periodic waveforms on the signal generator, we need to specify a few parameters for each. The three waveforms that we will use most often in lab are sinusoidal, square, and ramp (or triangle).

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One of the most important attributes of a periodic waveform is the *period* — the time required for the signal to repeat. In electronics, typical periods may range from a few milliseconds to less than a nanosecond. The repetition of the periodic signal can also be described in terms of the *frequency* — the number of periods that occur each second. The frequency is the inverse of the period,  $f = T^{-1}$ . The units of frequency are  $s^{-1}$  or hertz (Hz). Typical frequencies range from a few tens of Hz, as might be the case for the low end of the audio range to several billion Hz (GHz), as might be used in communication systems. Either period or frequency can be used to specify the repetition of the waveform. In the power industry, there is one frequency that is more important than any other — 60 Hz, which corresponds to a period of 16.67 ms.

The second important attribute is the *amplitude* — the maximum voltage (or current) of the waveform. Note that amplitude can be specified either in terms of the *peak* — from 0 to the maximum or by *peak-to-peak* — from the minimum to the maximum. Obviously, the peak-to-peak amplitude will be twice the peak amplitude. Sinusoids can also be expressed in terms of RMS (root-mean-square) voltage.

Figures 2 – 4 below show sketches of the three types of waveforms. The function generator can produce any of these waveforms. The sinusoid requires that the amplitude and frequency (or period) be specified. The square wave and ramp wave have more parameters that can be used to fine-tune the shape of the waveforms.



**Figure 2.** Sinusoidal waveform.

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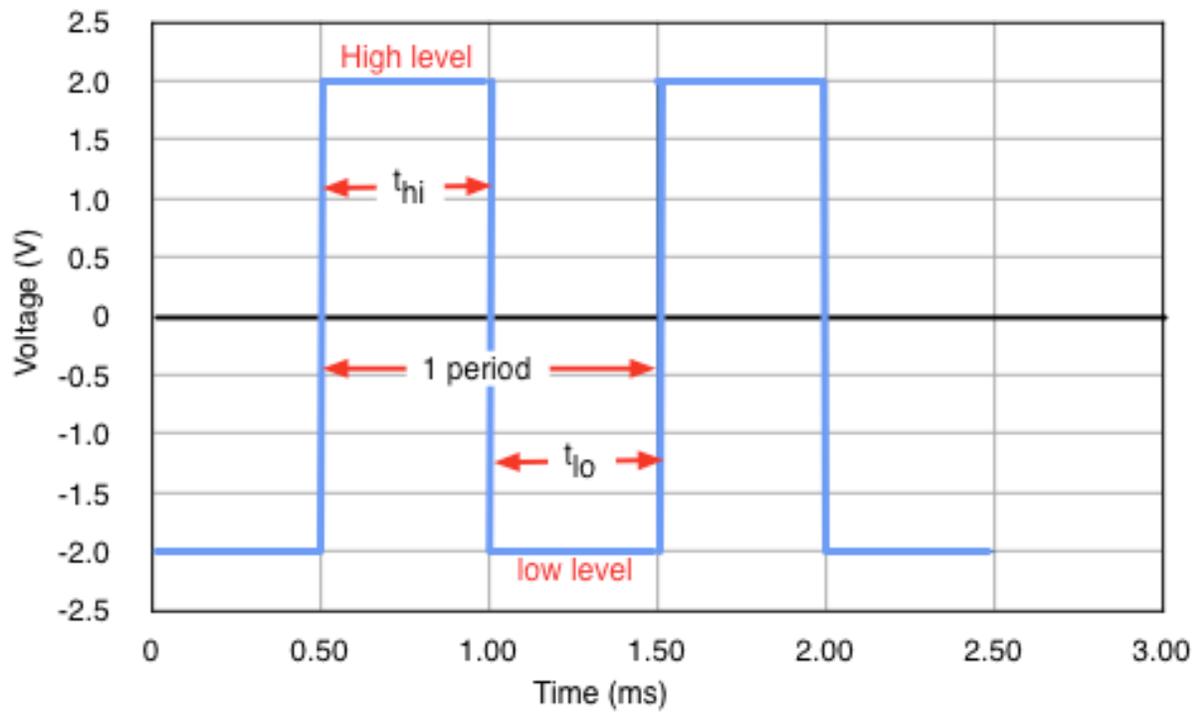


Figure 3. Square waveform.

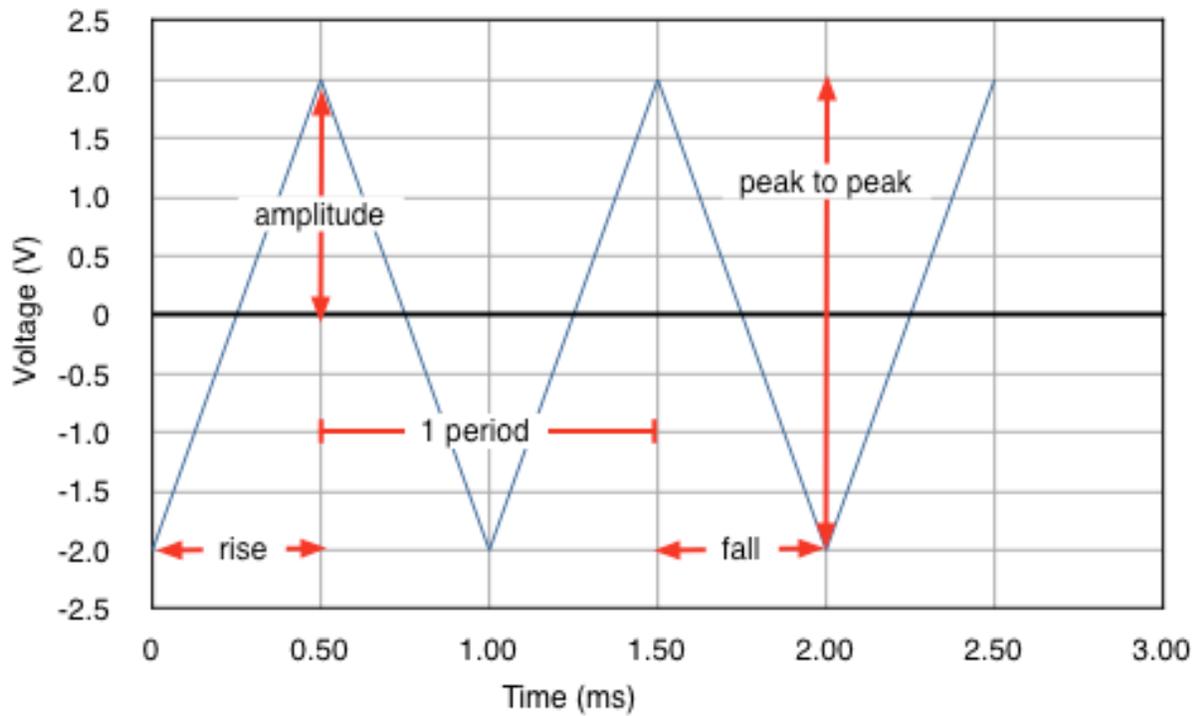


Figure 4. Ramp (triangle) waveform.

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## Basic Operation

1. Press the power switch of the generator. After a short boot-up sequence, the generator will be in its default state — a sine wave with 1-V peak-to-peak amplitude and frequency of 1 MHz ( $10^6$  Hz). There is no voltage being applied to the output at this point.
2. To change the parameters of the waveform, use the parameters buttons (section 4 in Fig. 1) to select the parameter that you intend to alter. Frequency and amplitude are the two things you will change most frequently. The display next to the soft-keys will change to reflect the parameter choice. Use the soft-key to choose which parameter you would like to specify. For example, if you pushed the Frequency/Period parameter button, you can then choose either Frequency or Period using the soft-keys.
3. Parameter values can be changed by two methods. The first is to simply punch in the value using the numeric keypad. Use the number keys to change the period to  $250\ \mu\text{s}$ . First, choose “period” using the soft-key, then enter 250 with keypad, and then select the units —  $\mu\text{s}$  — using the soft-keys. The change takes effect when the units key is pushed. Note that changing the *period* to  $250\ \mu\text{s}$  is the same thing as changing the *frequency* to 4 kHz. The parameter values and waveform shown on the graph will change accordingly. The second method for changing parameters is to use the rotary dial (item 6 in Fig. 1). The arrow keys beneath the dial can be used to select to select the particular digit that the dial will adjust.

If you are using sinusoidal signal, you can express the amplitude either in peak-to-peak volts or RMS volts. The default unit is peak-to-peak. To change to RMS units, press the *Amplitude* button to go to the amplitude screen, press the *More* softkey to switch screens, press the *units* softkey, and then select the  $V_{\text{RMS}}$  softkey. To switch back to peak-to-peak, use the same process but select  $V_{\text{pp}}$  at the last step.

It is easy to convert between peak-to-peak and RMS — the relation is  $V_{\text{PP}} = 2.828 \cdot V_{\text{RMS}}$ . When writing about sinusoidal voltages or currents, it is important to be clear about which units you are using. It would be a serious misunderstanding if you are describing peak-to-peak values but have not been clear about units and your reader mistakenly assumes RMS values.

4. To change the waveform type, use the waveform buttons, located in a vertical column to the right of the display (item 3 in Fig. 1). In addition to three basic periodic waveforms, there are others geared towards specific applications in electronics and communication systems. Change the waveform type to a square wave. Note the parameters for the square wave. Finally change the waveform to ramp and note the different parameters that can be set for that.
5. The output button (item 7 in Fig. 1) turns on the voltage waveform to the output terminal. Until this button is pressed, the output voltage will be zero. To connect the output to your circuit, you will need to use a BNC-to-banana plug adaptor. You can use a short length of coaxial cable with BNC connectors at both ends between the function generator and the adaptor, or you can connect the adaptor directly to the generator output port. Be careful to

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avoid accidentally connecting to the other ports on the front panel.

6. The system function button at the bottom of the front panel (item 9) provides access to some of the instrument settings. For the most part, you won't need to access these, except for one bit of quirkiness that you need to set *every time that you start up the function generator*.

In its default setup, the generator assumes that you will be connecting a load that has a 50- $\Omega$  input resistance. To match to this, the generator provides 50- $\Omega$  output resistance, creating a voltage divider with a ratio of 1/2. Accordingly, the source adjusts its output so that voltage you are requesting will appear on the output side of the voltage. For example, if you want 1-V peak-to-peak, the source provides 2-V peak-to-peak. (This sort of thing is common for microwave-frequency test equipment.)

However we rarely use 50- $\Omega$  resistances in our basic circuits and electronics labs — the input resistances for most of our circuits are much bigger — and so the voltage divider is wrong. This, in turn, means that the generator will not provide the correct voltage. To avoid these voltage discrepancies, we need to put the unit into the “High Z” mode. To make this change, press the System button, and then press the “Output Menu” softkey. Press the “Load Impedance” softkey and then select the “High Z” softkey.

If you don't make this change, the output of the source will be twice what it is indicating.

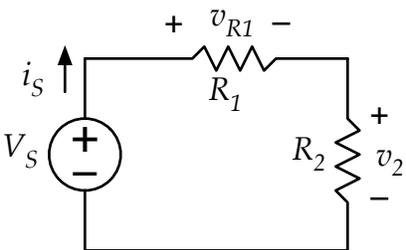
This covers most of what we will need to do with the function generator in our labs. Of course, there are many more operational details that you can control if you want. If you are interested in knowing all the gory details of 3012B operation, you can consult the manual. A copy is on the class web site: [http://tuttle.merc.iastate.edu/ee201/lab/tek3021B\\_manual.pdf](http://tuttle.merc.iastate.edu/ee201/lab/tek3021B_manual.pdf).

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### Simple exercise

Set up a voltage divider circuit as shown in Fig. 5 below. For the source, use the function generator.

- The exact values of  $R_1$  and  $R_2$  are not important, as long as they are not too small. A reasonable set of values might be  $R_1 = 1 \text{ k}\Omega$  and  $R_2 = 2.2 \text{ k}\Omega$ .
- Set the output to “High Z” mode.
- Select the waveform type to be a sinusoid.
- Switch the units to RMS.
- Set the amplitude of the sinusoid to  $5 \text{ V}_{\text{RMS}}$ . (Calculate the corresponding peak-to-peak voltage.)
- Set the frequency of the sinusoid to 1 kHz (or 1000 Hz – you can enter the value either way).
- Turn on the output.
- Set the multimeter to measure AC volts. Measure the source voltage and the voltages across  $R_1$  and  $R_2$ . (Remember that voltmeter reports AC voltage only in RMS. If you want to know what the reading means in terms of peak-to-peak, you will have to make the conversion yourself.) Does the voltage divider work as expected?
- Try changing the amplitude to  $2 \text{ V}_{\text{RMS}}$  and measure the three voltages again. Note the difference in the readings.
- Change the amplitude back to  $5 \text{ V}_{\text{RMS}}$  and then change the frequency to 5 kHz. Note the difference in the voltage readings.



**Figure 5.** Simple voltage circuit for testing the basic operation of the function generator.