FUNCTION GENERATOR GUIDE

Tektronix AFG300 Series

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1 – Introduction

This guide provides instructions for operating the Tektronix AFG310 and AFG320 Arbitrary Function Generators.

Features:

- Standard waveforms (sine, square, ramp, triangle, and pulse)
- Arbitrary waveforms
- Burst, sweep, and modulation (AM, FM, FSK)
- Single channel (AFG310) or dual channels (AFG320)
- GPIB interface

2 – Waveform Shapes

The AFG310 and AFG320 output these standard waveforms:

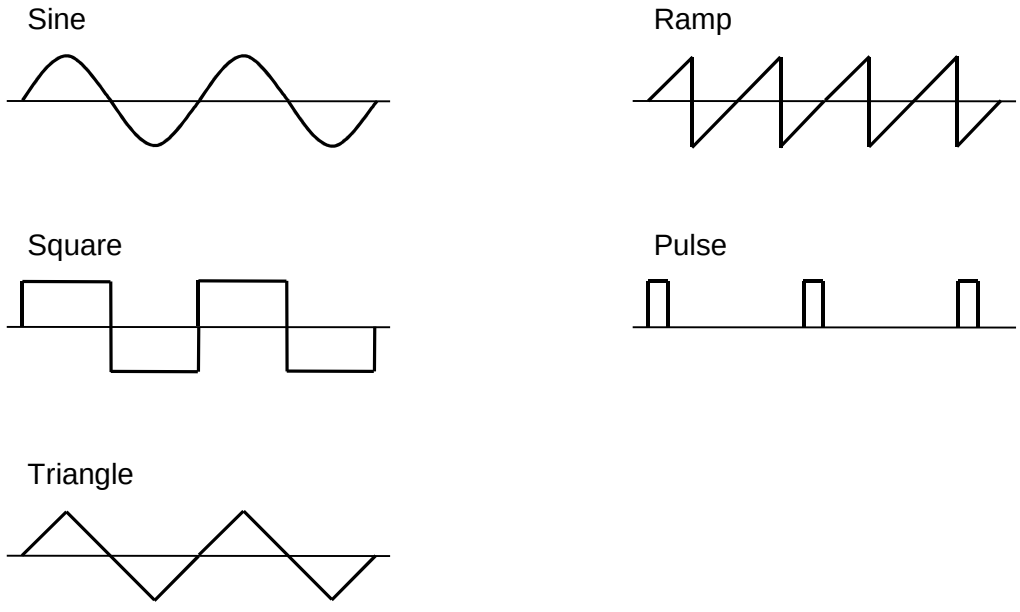


Figure 1: Idealized waveform shapes

In addition, the function generator supports user-defined waveforms of arbitrary shape.

3 – Waveform Characteristics

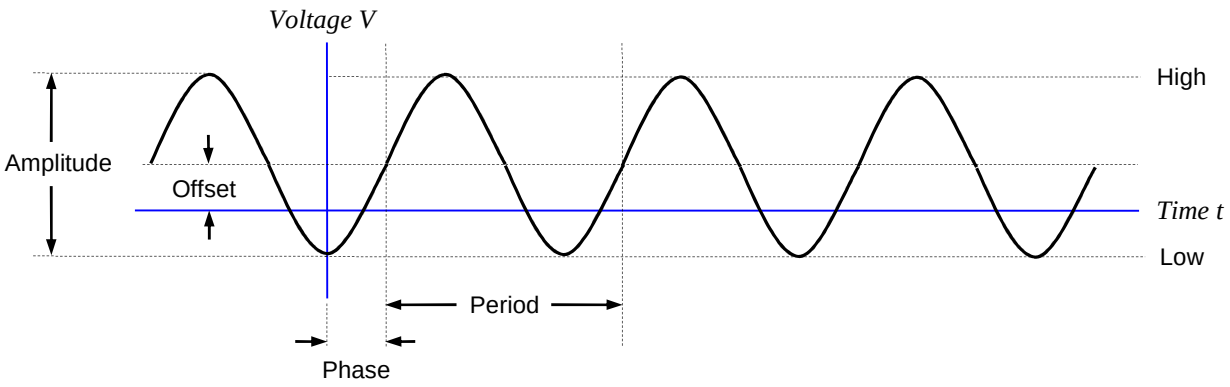


Figure 2: Characteristics of a periodic waveform (Tektronix terminology)

The amplitude of the waveform is the peak-to-peak variation[1] in voltage. The horizontal shift can be specified as a phase angle (degrees).

The waveform's vertical characteristics (i.e., voltage) can be specified as an amplitude and offset, or as high and low levels.

Some useful conversion equations are:

$$Frequency = \frac{1}{Period} \qquad Amplitude = High - Low \qquad High = Offset + \frac{Amplitude}{2}$$

$$Period = \frac{1}{Frequency} \qquad Offset = \frac{High + Low}{2} \qquad Low = Offset - \frac{Amplitude}{2}$$

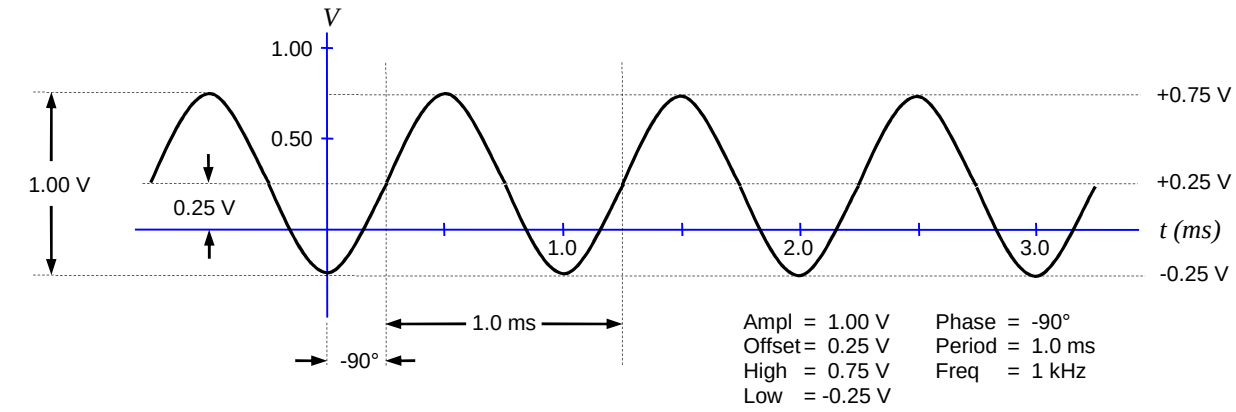


Figure 3: Example sinusoidal waveform with numeric values

[1] Math textbooks often define the amplitude as half the peak-to-peak variation. However, Tektronix assumes the amplitude is the full peak-to-peak value.

For a pulse train, the duty cycle (in %) is defined as: $Duty = \frac{Pulse\ Width}{Pulse\ Period} \cdot 100$

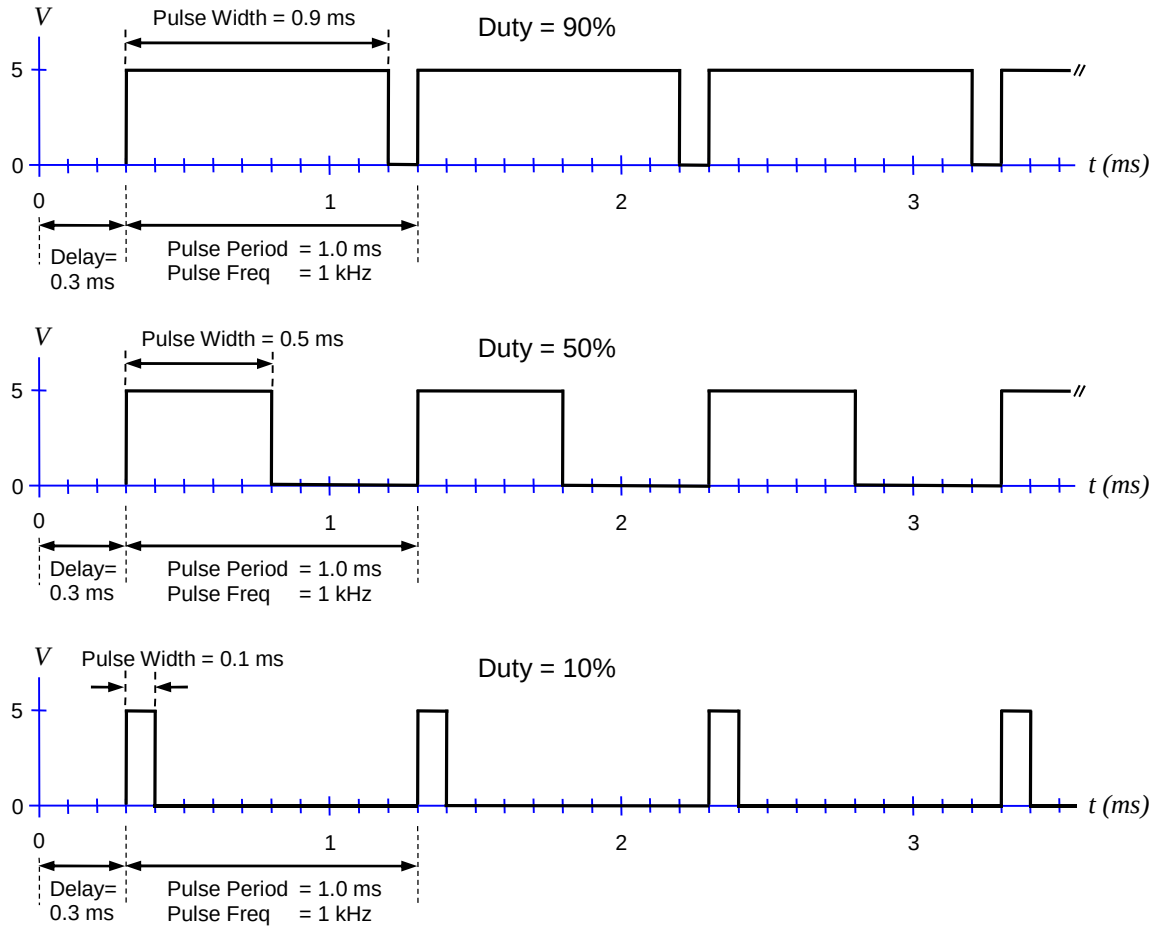
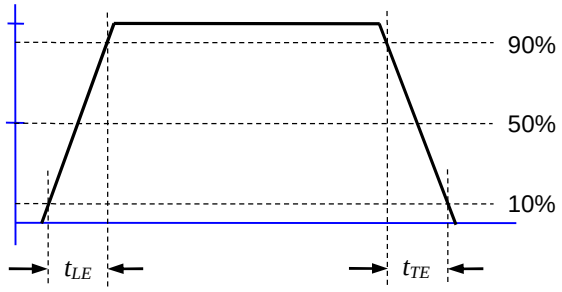


Figure 4: Examples of ideal pulse trains (Ampl = 5 V, Offset = 2.5 V, High = 5V, Low = 0 V)

Depending on the situation, a pulse's leading and trailing edge transition times may be relevant:



t_{LE} is the leading edge transition time.
t_{TE} is the trailing edge transition time.

The transition times are specified using the 10% and 90% amplitude points as references.

If t_{LE} and t_{TE} are a significant fraction of the total width, then the 50% amplitude point is a better reference for specifying the pulse width.

Figure 5: Edge transition widths for a realistic (non-ideal) pulse

4 – Instrument Front Panel

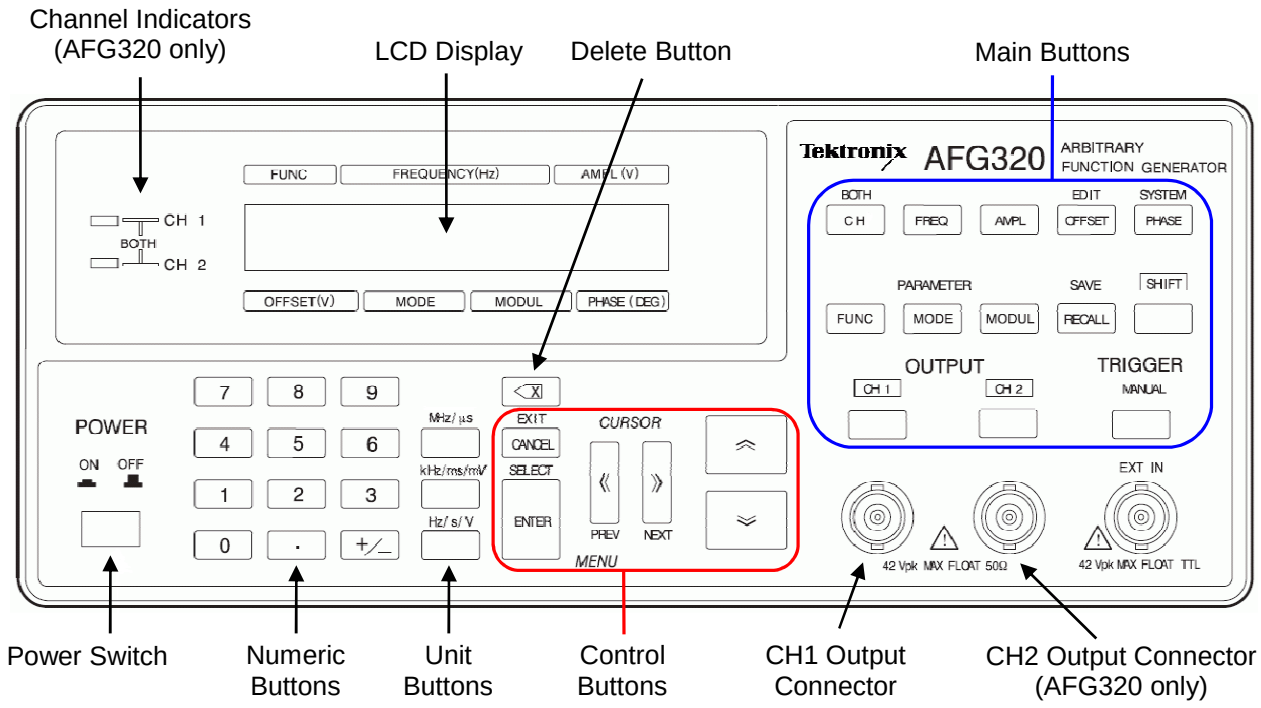


Figure 6: Tektronix AFG300 series front panel - Copyright © Tektronix, Inc.

Power Switch

This turns the function generator either on or off.

LCD Display

The LCD shows waveform parameters, selection and editing, and status messages on a two-line display.

Channel Indicators

This indicates which channel is currently selected for display and editing. (*Not installed on AFG310*)

CH1 Output Connector

This connector outputs the Channel 1 waveform signal.

CH2 Output Connector

This connector outputs the Channel 2 waveform signal. (*Not installed on AFG310*)

► Main Buttons

SHIFT	Some buttons have an alternate function that is printed in blue above the button. Pushing SHIFT before pressing the button will choose the alternate function.
CH/BOTH	The CH button toggles between either Channel 1 or Channel 2 as the currently selected channel for display and editing. (*Not installed on AFG310*)
FREQ	This selects the frequency parameter for editing.
AMPL	This selects the amplitude parameter for editing.
OFFSET/EDIT	This selects the offset parameter for editing. The alternate function activates the arbitrary waveform editing menu.
PHASE/SYSTEM	This selects the phase parameter for editing. The alternate function activates the system menu.
FUNC/PARAMETER	This activates the waveform selection menu (SINE, SQUA, TRIA, RAMP, PULS, DC, NOIS, USR1, USR2, USR3, USR4, EDIT). The alternate function selects the pulse duty parameter for editing.
MODE	This activates the run mode menu (CONT, TRIG, BRST)
MODUL	This activates the modulation menu (OFF, SWP, FM, FSK, AM)
RECALL/SAVE	This activates a menu for recalling waveform settings from internal memory. The alternate function activates a menu for saving waveform settings to memory.
CH1	This button turns the Channel 1 signal output either on or off. When the output is in the "on" state, the LED above the button is illuminated.
CH2	This button turns the Channel 2 signal output either on or off. When the output is in the "on" state, the LED above the button is illuminated. (*Not installed on AFG310*)
MANUAL	When pressed, a trigger signal is generated.

► Control Buttons

CANCEL:EXIT	Cancels a selected item or pending input value and restores the previous value.
ENTER:SELECT	1) Confirms the selected item, 2) Confirms numeric value using current unit
« »	PREV and NEXT buttons: 1) Changes items, 2) Moves the cursor during input
^ v	INC and DEC buttons: 1) Changes selections, 2) Increases or decreases a value

► Numeric Input

0 – 9 .	These digit and decimal point buttons are used for numeric input.
+/–	The +/– button toggles the sign of a number from positive to negative or from negative to positive.
MHz/µs **kHz/ms/mV** **Hz/s/V**	The unit buttons assign a unit to the numeric input. This also completes the input.
⌫	This deletes a single character (digit, decimal point, sign) to the left of the cursor.

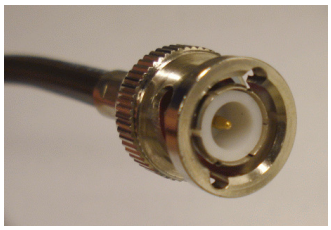
► Output Connectors

The output signals from the function generator are available at the BNC connectors on the front panel. If a channel is currently disabled, the output signal is turned off at the corresponding BNC connector.

Note:

The output impedance R_O of each channel is 50 Ω.

Female BNC (AFG320)



Male BNC (Cable)

Figure 7: BNC connections

5 – Screen Interface, Selection, and Numeric Input

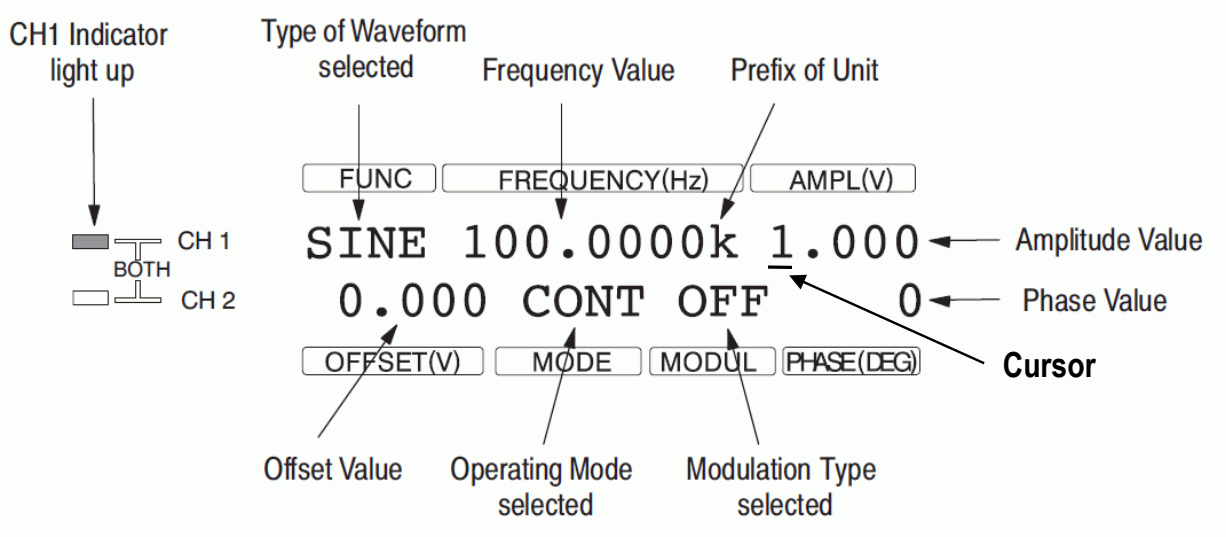


Figure 8: Default screen interface - Copyright © Tektronix, Inc.

A waveform has several numeric parameters that define its characteristics. If a parameter is selected via a Main button, then pushing any Number button will activate the numeric input mode. The standard digits from 0 through 9, the decimal point, and +/- are available.

When entering a number, an underscore cursor indicates the currently selected digit. The and buttons move the cursor. The and buttons can increment or decrement a digit. If needed, will erase digits, and the CANCEL button will cancel pending changes and restore the previous value.

In numeric input mode, pressing a Unit button causes the chosen unit to be attached to the number, which completes the input. The ENTER button can also be used for completing numeric input. In this case, the currently displayed unit is automatically attached to the number.

6 – Standard Setup Procedure

1. Disable the channel outputs.
2. For each channel you intend to use:
    a. Select the channel (if needed)
    b. Select the desired function (e.g., sine, square, etc.)
    c. Adjust the waveform parameters using the front panel buttons.
    d. Verify the parameter values to ensure the voltages and frequencies are within safety limits.
3. Enable the channel outputs.

7 – Examples

The Type codes are:

CB = Control Button, MB = Main Button, NB = Numeric Button, UB = Unit Button

In Examples #1 and #2, assume the currently selected channel is Channel 1 (both AFG310 & AFG320).

Example #1

Define a square waveform with the following properties:
Frequency = 1 MHz, High = 5 V, Low = 0 V

The AFG300 series only supports amplitude and offset parameters, so conversions are needed:

$$Amplitude = High - Low = 5 - 0 = 5 \text{ V}$$

$$Offset = \frac{High + Low}{2} = \frac{5 + 0}{2} = 2.5 \text{ V}$$

Buttons to push	Type
FUNC	MB
⏫ or ⏬ until SQUA appears on the LCD	CB
ENTER	CB
FREQ	MB
1	NB
MHz/µs	UB
AMPL	MB
5	NB
Hz/s/V	UB
OFFSET	MB
2.5	NB
Hz/s/V	UB

Example #2

Define a pulse waveform with the following properties:
Pulse period = 2 ms, Pulse width = 0.1 ms, High = 2.5 V, Low = -2.5 V

The AFG300 series only supports frequency and duty parameters, so conversions are needed:

$$Frequency = \frac{1}{Period} = \frac{1}{2\text{ ms}} = 0.5\text{ kHz}$$

$$Amplitude = High - Low = 2.5 - (-2.5) = 5\text{ V}$$

$$Offset = \frac{High + Low}{2} = \frac{2.5 + (-2.5)}{2} = 0\text{ V}$$

$$Duty = \frac{Pulse\ Width}{Pulse\ Period} \cdot 100 = \frac{0.1\text{ ms}}{2\text{ ms}} \cdot 100 = 5\%$$

Buttons to push	Type
FUNC	MB
⏫ or ⏬ until PULS appears on the LCD	CB
ENTER	CB
FREQ	MB
0.5	NB
kHz/ms/mV	UB
SHIFT FUNC	MB
5	NB
ENTER	CB
AMPL	MB
5	NB
Hz/s/V	UB
OFFSET	MB
0	NB
Hz/s/V	UB

Note: The AFG300 series does not allow the user to specify edge transition times for pulses.

Example #3 (for AFG320)

For Channel 1, define a sine waveform with the following properties:
Frequency = 10 Mhz, Amplitude = 2 V, Offset = 0.5 V, Phase = 0°.

For Channel 2, define a sine waveform with the following properties:
Period = 0.1 µs, High = 1.5 V, Low = -0.5 V, Phase = +45°.

$$Frequency = \frac{1}{Period} = \frac{1}{0.1\,\mu s} = 10\ \text{MHz}$$

$$Amplitude = High - Low = 1.5 - (-0.5) = 2\ \text{V}$$

$$Offset = \frac{High + Low}{2} = \frac{1.5 + (-0.5)}{2} = 0.5\ \text{V}$$

Setup for Channel 1	
Buttons to push	**Type**
CH/BOTH[1]	MB
FUNC	MB
⏫ or ⏬ until SINE appears on the LCD	CB
ENTER	CB
FREQ	MB
10	NB
MHz/µs	UB
AMPL	MB
2	NB
Hz/s/V	UB
OFFSET	MB
0.5	NB
Hz/s/V	UB

[1]If necessary, push the CH/BOTH button until Channel 1 is selected.

Setup for Channel 2	
Buttons to push	**Type**
CH/BOTH[1]	MB
FUNC	MB
⏫ or ⏬ until SINE appears on the LCD	CB
ENTER	CB
FREQ	MB
10	NB
MHz/µs	UB
AMPL	MB
2	NB
Hz/s/V	UB
OFFSET	MB
0.5	NB
Hz/s/V	UB
PHASE	MB
45	NB
ENTER	CB

[1]If necessary, push the CH/BOTH button until Channel 2 is selected.

As it turns out, these two signals are identical, except the Channel 2 waveform is shifted in phase with respect to the Channel 1 waveform.

8 – Output Voltage Amplitude

Suppose a load R_L is connected to an output channel on the function generator. The signal source has amplitude V_G. The generator's output impedance is R_O. Let V_O be the voltage present at the output terminals of the generator.

AFG3000 series:
R_O = 50 Ω

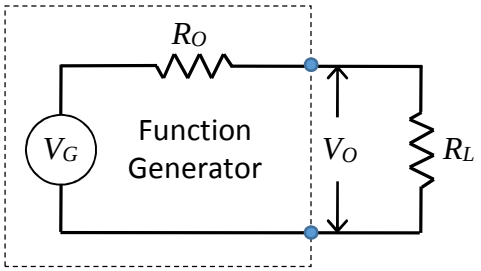


Figure 9: Load connected to output channel of the function generator

Let V_{SET} be the amplitude value that the user sets on the front panel of the function generator. By default, the instrument *assumes* an impedance match (i.e., R_L is equal to R_O), so it automatically produces a V_G that is *twice* the value of V_{SET}, i.e., $V_G = 2V_{SET}$.

The value of V_O can be calculated by realizing that R_O and R_L form a voltage divider:

General solution for any value of R_L, when $V_G = 2V_{SET}$:

$$V_O = \left(\frac{R_L}{R_L + R_O}\right) V_G = \left(\frac{R_L}{R_L + R_O}\right)(2V_{SET}) = F \cdot V_{SET}, \text{ where } F = \frac{2R_L}{R_L + R_O}$$

∴ The output voltage V_O is a scaled version of V_{SET}. The scale factor F is between 0 and 2, inclusive.

Special case #1: $R_L = R_O$ (impedance is actually matched, i.e., R_L = 50 Ω) → F = 1, so $V_O = V_{SET}$

Implication: The voltage present at the generator's output terminals is equal to the set voltage.

Special case #2: $R_L \approx \infty$ (open circuit, i.e., no load attached) → $F \approx 2$, so $V_O = 2V_{SET}$

Implication: The voltage present at the generator's output terminals is twice the set voltage.

Example:

You connect a function generator with output impedance R_O = 50 Ω to a test circuit which has a load resistance of R_L. You configure the generator to output a sinusoid of amplitude V_{SET} = 1 $V_{p\text{-}p}$ at frequency f_{SET}. The voltage V_L across the load is monitored with an oscilloscope using a 1× probe. The oscilloscope has an input resistance of R_{in} = 1M Ω in parallel with an input capacitance of C_{in} = 15 pF.

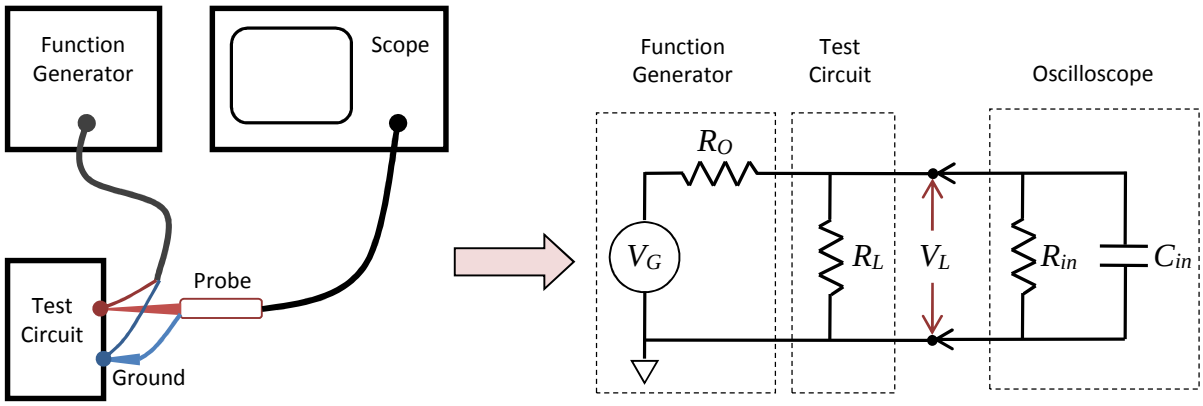


Figure 10: Example test circuit with oscilloscope

The function generator "sees" the load in parallel with the oscilloscope's input impedance:

$$Z_{EQ} = R_L \parallel R_{in} \parallel Z_{C_{in}} = \left(\frac{1}{R_L} + \frac{1}{R_{in}} + j\omega C_{in} \right)^{-1} = \frac{R_{in} R_L}{R_L + R_{in} + j\omega C_{in} R_{in} R_L} \quad \rightarrow \quad V_L = \left(\frac{2Z_{EQ}}{Z_{EQ} + R_O} \right) V_{SET}$$

Table 1: Calculated load voltage V_L versus load resistance R_L at specific signal frequencies f_{SET}
Given V_{SET} = 1 $V_{p\text{-}p}$, R_{in} = 1M Ω, C_{in} = 15 pF

R_L (Ω)	V_L (volts)		
	f_{SET} = 0 Hz (DC)	f_{SET} = 1 MHz	f_{SET} = 15 MHz
10	0.3333	0.3333	0.3333
50	1.0000	1.0000	0.9994
100	1.3333	1.3333	1.3318
500	1.8181	1.8181	1.8144
1000	1.9047	1.9047	1.9004
10K	1.9900	1.9899	1.9850
100K	1.9998	1.9998	1.9948

Appendix 1 – Specifications (AFG310 & AFG320)

Table 2: Manufacturer's instrument specifications

Channels	1 (AFG310) or 2 (AFG320)
Standard Waveforms	Sine, Square, Ramp, Triangle, Pulse, DC, Noise Sin(x)/x, Double Exponential Pulse, Damped Sine Wave, NRZ Random Signal
Sine Wave	0.01 Hz to 16 MHz
Square Wave	0.01 Hz to 16 MHz
Rise/Fall Time	≤ 20 ns
Overshoot	<< 2%
Ramp Wave	0.01 Hz to 100 kHz
Pulse Wave	0.01 Hz to 100 kHz
Pulse Duty	1% to 99% of period
Edge Transition Time	<< 100 ns
Jitter	2 ns at 100 kHz
Other Waveforms	0.01 Hz to 100 kHz
Noise Bandwidth (-3 dB)	8 MHz (White Gaussian)
DC (into 50 Ω)	-5 V to +5 V
Arbitrary Waveforms	0.01 Hz to 1.6 MHz
Sample Rate	16 MS/s
Vertical Resolution	12 bits
Jitter	2 ns at 100 kHz
Amplitude, 50 Ω load	50 mV_{p-p} to 10 V_{p-p}
Accuracy	±(1% of setting + 5 mV) (1 kHz sine wave, no offset)
Resolution	5 mV
Output Impedance	50 Ω

Appendix 2 – References

[1] *Tektronix AFG300 Series Data Sheet*, Tektronix, Inc.

[2] *Tektronix AFG310 and AFG320 Arbitrary Function Generator User Manual (071-0175-50)*, Tektronix, Inc.