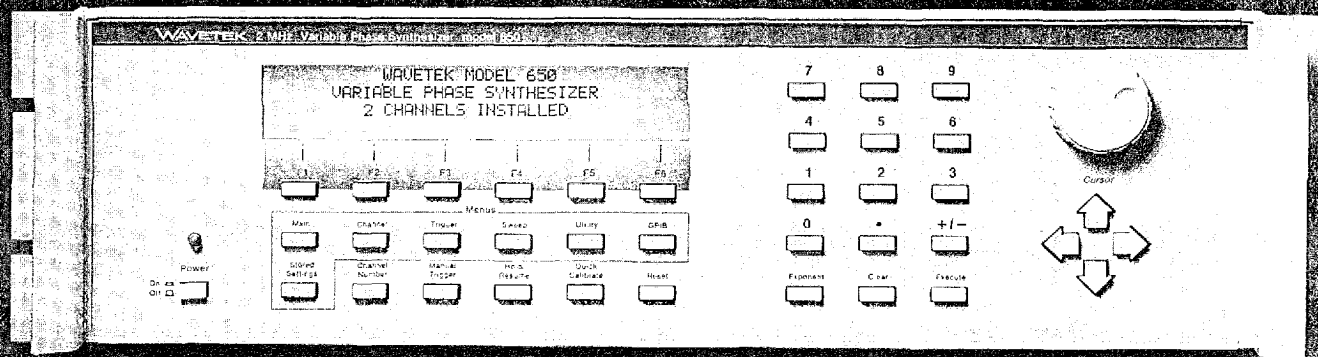




**SYNTHESIZED FUNCTION GENERATORS**  
**MODEL 650**



# 2 MHz Variable Phase Synthesizer

- 0.0001 Hz to 2 MHz Frequency Range
- High Accuracy Output up to 50 Vp-p into 0Ω
- 10 Digit Frequency Resolution, 5ppm Accuracy
- 0.005° Phase Accuracy at Low Frequencies
- 2 or 4 Channel Output with up to 40 Channels Cascadable
- Flexible Phase and Frequency Sweep Modes

Model 650 combines superb phase accuracy, synthesizer frequency accuracy, high output amplitude capability and excellent stability. The standard model has two channels which can be expanded to four. As many as ten Model 650s can be cascaded to obtain 40 channels of phase controlled signals. In addition to sine waves, each output can be independently programmed to square, triangle and variable duty-cycle square and ramp waveforms.

Model 650 is fully programmable via GPIB (IEEE-488). Many operating and sweep modes make it suitable for a multitude of applications related to analog and digital design work, phase meter calibration, phased arrays, avionics, industrial robotics and communications.

Quick-cal allows you to instantly calibrate (typically <5 sec.) the Model 650 in its operating environment; this provides

optimum instrument accuracy at the current instrument setup (for example, amplitude, offset, and phase at the current frequency).

**WAVEFORMS**

Programmable sine, square, triangle, ramp, DC and variable-duty-cycle square and ramp.

**Range**

Sine, Square: 0.1 mHz to 2 MHz.  
 Ramp, Triangle: 0.1 mHz to 200 kHz.  
 Resolution: 10 digits or 0.1 mHz.  
 Accuracy: ±5 ppm.  
 Stability: ±3 ppm.

**Waveform Quality**

Sine Wave	Frequency	Spurious	Harmonics
	≤10 kHz	≤-70 dBc	≤-60 dBc
	≤100 kHz	≤-60 dBc	≤-50 dBc
	≤2 MHz	≤-50 dBc	≤-40 dBc

**Square Wave**

Rise/Fall Time: ≤100 ns.  
 Aberrations: ≤5%.  
 Duty Cycle: 20 to 80% ±3% ±15 ns.

**Triangle/Ramp**

Linearity: ≥99% ≤10 kHz; ≥90% <-200 kHz.  
 Duty Cycle: 0 to 100% ±3% ±15 ns.

**PRIMARY MODES**

Continuous, triggered, gated and burst.  
**Burst Count:** 1 to 65,535.

**SECONDARY MODES**

**Phase Shift:** Phase of each channel can be programmed with respect to the main generator.

**Phase Resolution:** 10 millidegrees.

**Phase Accuracy:**

Frequency	Sine Wave Phase Accuracy For	
	Equal Ampl Angle	Unequal Ampl Angle
<1 kHz*	0.005°	0.020°
<10 kHz	0.030°	0.100°
<100 kHz	0.100°	0.500°
<1 MHz	0.500°	2.000°
<2 MHz	1.000°	5.000°

\*At phase settings equal to 360/n where n is an integer in the range 1 thru 8192.

**Phase Delay:** Phase offset of a channel may be programmed in delay time rather than in degrees. Model 650 will automatically compute phase in degrees (for any frequency) for a given delay.



**Delay Resolution:** 3 digits.

**Delay Range:** -2 to +2 ms.

**Phaselock:** In phaselock mode, Model 650 will lock onto an external reference in the frequency range of 40 Hz to 2 MHz. The main generator frequency will then be kept to the initial reference frequency. If the reference frequency changes in excess of ±10%, Model 650 will reset its main generator frequency to the new frequency.

**Phaselock Range:** 40 Hz to 2 MHz.

**Initial Lock Time:** ≤4 sec.

**Re-lock Time:** 100 periods +100 ms.

**Delta Frequency:** One channel at a time can run at a frequency that differs up to ±1000 Hz from the main frequency.

**Range:** -1000 to 1000 Hz.

**Resolution:** 3 digits but max 0.1 mHz.

**Accuracy:** 0.1%.

**TRIGGERING**

The 650 can be triggered via its internal trigger generator or an external trigger signal. In external trigger mode, trigger level and signal polarity are selectable.

**Internal Trigger Signal**

**External Availability:** Present at Marker Out connector in non-sweep modes.

**Range:** 2.5 mHz to ≥200 kHz.

**Resolution:** 3 digits.

**Accuracy:** 0.1%.

**External Trigger Signal**

**Frequency Range:** 0 to ≥200 kHz.

**Amplitude Range:** +10 to -10V.

**Level Setting Resolution:** 0.1V.

**Level Accuracy:** ±0.3V.

**MODULATION**

**Amplitude Modulation**

**Range:** 0 to 100%.

**AM Bandwidth:** 0 to 20 kHz.

**Modulation Gain (VCG):** 10.

**AM Input Impedance:** >10 kΩ.

**Protection:** ±50 Vdc (Momentary).

**Phase Modulation**

**Range:** Programmable 0 ±1080°.

**PM Bandwidth:** 25 kHz.

**Voltage Controlled Phase Modulation (VCPM):** -1V to +1V for full modulation between programmed start and stop phase with 8-bit resolution.

**PM Input Impedance:** ≥1 MΩ.

**Protection:** ±50 Vdc momentary.

**Frequency Modulation:** Programmable start and stop frequency in range 0.1 mHz to 2 MHz.

**FM Bandwidth:** 20 kHz.

**Voltage Controlled Frequency Modulation (VCFM):** -1V to +1V for full modulation between programmed start and stop frequency values with 8-bit resolution.

**Frequency Shift Keying:** Asynchronous (Async FSK) and Synchronous (Sync FSK).

**Max Rate of FSK:** 40 kHz (25 μs per step).

**Max No. of Different Frequencies in FSK Mode:** 100.

**Switching Time Between Frequencies:** ≤500 ns.

**Phase Shift Keying**

**Max Rate of PSK:** 65 kHz.

**Phase Shift Keying Capabilities:** Dual

**Table 1. Amplitude Range, Resolution and Accuracy**

Output Impedance	Range (Vp-p)	Resolution	Accuracy		
			≤100 kHz	≤1 MHz	≤2 MHz
0Ω	2.5-50	1 mV	±0.5% ±2 mV	±1.5% ±2 mV	±3% ±2 mV
50Ω	0.025-0.25	10 μV	(typ: ±0.2% ±1 mV)	(typ: ±0.3% ±1 mV)	(typ: ±1.5% ±1 mV)
	0.25-2.5	100 μV			
	2.5-25	1 mV			

**Table 2. Offset Range, Resolution and Accuracy**

Output Impedance	Range (Vp)	Resolution	Accuracy
0Ω	±25	1 mV	0.5% ±30 mV
50Ω	±12.5V	1 mV	0.5% ±20 mV
		0.1 mV	0.5% ±10 mV
	±0.125V	10 μV	0.5% ±5 mV (typ: 0.1% ±3 mV)

**Table 3. DC Range, Resolution and Accuracy**

Output Impedance	Range	Resolution	Accuracy
0Ω	±25V	1 mV	0.3% ±10 mV
50Ω	±12.5V	1 mV	0.3% ±5 mV
		0.1 mV	0.3% ±2 mV
	±0.125V	10 μV	0.3% ±1 mV

Phase Shift Keying (DPSK) and Quadrature Phase Shift Keying (QPSK) through sequenced phase sweep mode.

**Max No. of Different Phase Values in PSK Mode:** 100.

**Pulse Position Modulation**

**Max Rate of PPM:** 65 kHz.

**Max No. of Different PPM Values:** 99.

**CHANNEL OUTPUTS**

Each channel can individually be programmed for the following parameters.

**Function:** Sine, square, triangle, DC, ramp or programmable duty cycle square or ramp.

**Amplitude Range, Resolution and Accuracy:**

Refer to table 1 and figure 1. Range is restricted by DC offset as shown in figure 2.

**Offset Range, Resolution and Accuracy:**

Refer to table 2. Range is restricted by AC amplitude as shown in figure 2.

**DC**

**Maximum Range:** 12.5 mV to 25V.

**Range, Resolution and Accuracy:** Refer to table 3.

**Frequency Ratio:** Each channel can be set at a ratio of 1 to 99 times the main frequency.

**Output Impedance:** Output impedance can be programmed to be either 0Ω or 50Ω or the output can be turned off (output relay open). In the 50Ω mode a 50Ω termination is assumed. With 0Ω and FUNC OUT terminated with >100Ω load, the cable length must be <6 ft. in length.

**SWEEP**

**Frequency Sweep:** 12 modes.

**Range:** 0.1 mHz to 2 MHz.

**Resolution:** 10 digits but max 0.1 mHz.

**Accuracy:** 5ppm ±10 μHz.

**Sequenced Sweeps (Modes 9, 10, 11):**

No. of Programmable Steps (Index): 1 to 100.

**Frequency Switching Time:** ≤500 ns.

**Phase Sweep:** 11 modes.

**Range:** -10° to +10° degrees continuous.

**Resolution:** 10 millidegrees.

**Accuracy:** Refer to table.

**Sequenced Sweeps (Modes 19, 20, 21):**

No. of Programmable Steps (Index): 1 to 100.

**Phase Switching Time:** ≤500 ns.

**Combined Frequency and Phase Sweep:** 6 modes.

**Range, Resolution and Accuracy:** Same as for Frequency Sweep and Phase Sweep.

**Sequenced Sweeps (Modes 26, 27, 28):**

No. of Programmable Steps (Index): 1 to 100.

**Switching Time:** ≤500 ns.

**Sweep Functions:** Linear, Log, Random and Sine.

**Sweep Times and Resolution:** Greatly depend on the chosen sweep function (linear, log, sine or random), the swept parameter (frequency, phase or both) and whether or not compensation of parameters is required. The fastest sweep time of 10 ms allows for 100 sweeps per second. In compensated mode, the fastest sweep time of 200 ms allows for 5 sweeps per second. The longest sweep time is 10<sup>7</sup> seconds or approximately 116 days. Compensation is generally only necessary if sweeping in frequency ranges over 100 kHz.

**Sweep Time:**

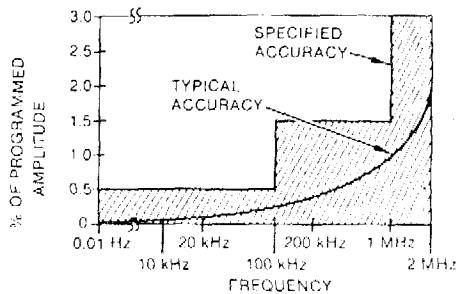
**Range:** 10 ms to 10<sup>7</sup> sec.

**Resolution:** 3 digits but max 1 ms.

**Accuracy:** 0.1%.

**Sweep Resolution:** Phase and frequency sweep resolution can be derived using the following fixed step rate table.

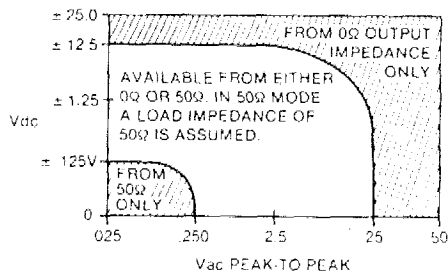
# MODEL 650



**NOTES:**

1. All accuracies  $\pm 2$  mV.
2.  $0\Omega$  output impedance into high impedance load or  $50\Omega$  output impedance into  $50\Omega$ , 0.001% accurate load.
3. Triangle and ramp to 200 kHz only.

**Figure 1. Amplitude Accuracy vs. Frequency**



**NOTES:**

1. Maximum output current in  $0\Omega$  modes  $\pm 0.5$ A.
2. Output voltage  $\leq 250$  mVp-p or  $\pm 125$  mVdc are available from  $50\Omega$  impedance only.

**Figure 2. Available and Permissible DC Offset and AC Amplitude Combinations.**

**Fixed Step Rates:** (For combinations of sweep function, swept parameter and compensation.) Refer to the following table.

Sweep Function	Compensation	
	On (Steps/sec)	Off (Steps/sec)
<i>Frequency Sweep</i>		
Linear	1443	13,333
Log	962	4,167
Sine	1053	6,667
Random	1156	15,400
<i>Phase Sweep</i>		
Linear	1176	20,000
Log	1010	5,263
Sine	1064	7,143
Random	1183	22,200
<i>Combined Frequency and Phase Sweep</i>		
Linear	1053	6,667

**Modulation Sampling Speed**

Module Mode	Compensation	
	On	Off
12: Ext FM	1.21 kHz	20.8 kHz
23: Ext PM	1.22 kHz	25.0 kHz
29: FM + PM	1.03 kHz	5.1 kHz

**MASTER/SLAVE CAPABILITIES**

Up to 10 Model 650's, each with up to 4 channels can be cascaded for a total of 40 phase-coherent, phase-controlled signals. Model 650 can be programmed to be either the master unit or a slave unit. Phase accuracy of slave units is equal to 2x the tolerance levels specified under Phase Accuracy.

**CALIBRATION**

Model 650 has internal calibration facilities that render classical calibration procedures obsolete. The calibration procedure is stepped through via a "plain English" menu built into Model 650. Complete calibration of a four channel Model 650 can be accomplished in a matter of minutes without the need for a manual or lengthy procedure.

Once the calibration is completed, an autocal procedure is initiated which performs a self-characterization of analog circuitry within 1 minute for a two channel unit (2 minutes for a 4 channel unit). The autocal procedure requires no external measurements or additional instruments. The results of the self-characterization are stored in battery protected memory.

**STORED SETTINGS**

Model 650 can store up to 25 complete instrument setups including every parameter for every channel you have selected. Moreover the 650 also stores the current setup automatically so you may turn the unit off and return the next day, week or month and with 4 keystrokes restore any of 25 setups exactly the way you stored them.

**GPIB INTERFACE**

Model 650 has a built-in alphabetical syntax list allowing you to start programming within minutes after unpacking the unit. The built-in "HELP" file can be printed out via a computer to give you your own syntax list. The 650 is extremely flexible in accepting GPIB commands.

Moreover, the 650 will detect programming errors. Syntax errors and parameter errors are detected, identified and categorized by the 650. The Input and SRQ buffers, each 256 characters long, can be displayed via the front panel or read by a computer. So all programming problems can be displayed, allowing easy program debugging. SRQ masks can be defined and, for example, even low battery voltage (for memory protection) will generate a service request. In short, the 650 reflects Wavetek's experience in providing easy to use, yet sophisticated programmable products.

**Address Range:** 0 to 30 switch selectable. If enabled via rear panel switch, address can also be changed from front panel.

**Subsets:** SH1, AH1, TE0, L4, RL1, PP0, DC1, C0, E2.

**I/O CONNECTIONS**

**Reference Out**

- Impedance:**  $50\Omega$  source.
- Level:** TTL,  $<0.4V$ ,  $>2.4V$  into  $50\Omega$ .
- Fanout:** 10 reference inputs.
- Frequency:** 10 MHz,  $\pm 5$  ppm.
- Protection:**  $\pm 5$  Vdc momentary.

**Reference In**

- Impedance:**  $>1k\Omega$ , AC coupled.
- Level:**  $>500$  mVp-p,  $<50$  Vdc.
- Frequency:** 10 MHz  $\pm 1\%$ .
- Protection:**  $\pm 50$  Vdc momentary.

**Trigger Input**

- Impedance:**  $>5$  k $\Omega$ .
- Level:**  $>500$  mVp-p,  $<10$  Vdc.
- Input:** 0 to  $>200$  kHz, 20 ns min.
- Protection:**  $\pm 50$  Vdc momentary.

**Hold Input**

- Impedance:**  $<1$  k $\Omega$ .
- Level:** TTL, active low.
- Protection:**  $\pm 20$  Vdc momentary.
- Function:** selectable sweep or waveform hold.

**FM/PM Input**

- Impedance:**  $>1$  M $\Omega$ .
- Level:**  $-1$  to  $+1V$  (for full range).

**Protection:**  $\pm 50$  Vdc.

**Sampling Speed**

Mode	Comp Off	Comp On
Ext FM	20 kHz	1 kHz
Ext PM	25 kHz	1 kHz
Ext FM/PM	5 kHz	1 kHz
Resolution	8 mV	
Accuracy	$\pm 5\%$	

**Marker Out**

- Impedance:**  $50\Omega$  source.
- Level:** TTL,  $<0.4V$ ,  $>2.4V$  into  $50\Omega$ .
- Output:** Low when freq/phase  $<$  marker.
- Protection:**  $\pm 20$  Vdc momentary.

**2.048 V Out**

- Impedance:** 1 k $\Omega$ .
- Level:** 2.048V  $\pm 5$  mV.
- Output:** Internal V ref cal test point.
- Protection:**  $\pm 50$  Vdc momentary.

**Phase Cal Input:** The Phase Cal input is intended to externally calibrate a master/slave pair or group, or to measure phase shift through external circuits. When these measurements are not being made a relay disconnects the BNC from internal circuits.

- Impedance:**  $>300\Omega$ .
- Level:** 40 Vp-p max.
- Input:** Slave channel for multi-unit cal.



## MODEL 650

**Protection:** Unprotected when calibrating, protected to  $\pm 100$  Vdc otherwise.

### Horizontal Out

**Impedance:** 1 k $\Omega$ .

**Level:** 0 to +10 Vdc.

**Output:** % of sweep.

**Accuracy:**  $\pm 2\%$ .

**Resolution:** 40 mV.

**Protection:**  $\pm 50$  Vdc momentary.

### Phase Out

**Impedance:**  $< 50\Omega$ .

**Level:** TTL.

**Output:** Sync pulse for master/slave configuration.

**Protection:** None.

### Phase Clear

**Impedance:**  $< 50$  ohm.

**Level:** TTL.

**Output:** Clear pulse for master/slave configuration.

**Protection:** None.

*Note: Phase Out and Phase Clear are only used to lock units together in a master/slave pair or group.*

### Channel Func Out

**Impedance:** 50 $\Omega$ , 0 $\Omega$  selectable. With 0 $\Omega$  and FUNC OUT terminated with  $> 100\Omega$  load, the cable length must be  $< 6$  ft. in length.

**Level:** -25 V to +25 V.

**Output:** Main function output.

**Protection:** Current limit at 500 mA. Withstands  $\pm 60$  Vdc indefinitely.

### Sync Out

**Impedance:** 50 $\Omega$  source.

**Level:** TTL,  $< 0.4$ ,  $> 2.4$  V into 50 $\Omega$ .

**Output:** Sync in phase with sine wave.

Phase accuracy not specified.

**Protection:**  $\pm 20$  Vdc momentary.

### AM Input

**Impedance:**  $> 10$  k $\Omega$ .

**Level:** 0 to +5 V.

**Input:** Modulation signal up to 20 kHz BW.

**Protection:**  $\pm 50$  Vdc momentary.

### GENERAL

#### Environmental

**Temperature Range:** 0° to +50°C. +25°  $\pm 8^\circ$ C for specified performance.

**Warm-up Time:** 20 minutes for specified performance.

**Relative Humidity:** 95% at +25°C and sea level (non-condensing).

**Altitude:** Sea level to 10,000 ft for operation. Sea level to 40,000 ft for storage.

**Dimensions:** 42.9 cm (16.9 in.) wide; 13.3 cm (5.25 in.) high; 54.6 cm (21.5 in.) deep.

**Weight:** 16.3 kg (36 lb).

**Power:** 90 to 126, 190 to 252 Vac, 48 to 66 Hz,  $\leq 250$  watts.

### MODEL 650MATE

MATE-CHIL capable. Meets MATE-CHIL Std. 2806763.

### OPTIONS

**001: Two Additional Channels.** Two additional channels and the associated RAM board mount in the chassis for a total of four channels.

### FACTORY/FOB

San Diego, CA

### ORDER INFORMATION

Model 650

Model 650MATE

Option 001

For full specifications or a demonstration, contact your Wavetek representative (pages 211 and 213).