

# 12000A

## MICROWAVE SYNTHESIZER



### ORDERING INFORMATION

#### MODEL NUMBERS AND FREQUENCY RANGES:

CW Generator Step Sweep, No Modulation	Signal Generator Step Sweep, Modulation	Swept Signal Generator Step and Ramp Sweep, Modulation	Frequency Range
12420A	12520A	12720A	10 MHz to 20 GHz
12422A	12522A	12722A	2 GHz to 20 GHz
12408A	12508A	12708A	10 MHz to 8 GHz
12428A	12528A	12728A	2 GHz to 8 GHz

#### AVAILABLE OPTIONS AND ACCESSORIES:

- Option 01: Rack ears with slides
- Option 02: Rack mount without track slides
- Option 20: Provides +20 dBm output power, .01 to 20 GHz
- Option 22: Moves the RF Output Connector from the instrument's front panel to its rear panel
- Option 23: Type N output connector
- Option 24: Provides built-in function generators for generating AM, FM, and pulse
- Option 26: Provides a built-in 110 dB attenuator (in 10 dB steps)
- Option 36: Provides 1 kHz resolution throughout the frequency range
- Option 29: 60 dB SCAN modulation
- A011: Ruggedized Carrying Case

#### CW OPERATION

- Range: 0.01 to 8 GHz, 2 to 8 GHz, .01 to 20 GHz, and 2 to 20 GHz
- Resolution: 0.1 Hz (Standard), 1 kHz (Option 36)
- Accuracy and Stability: Identical to time base oscillator
  - Time Base (Internal): 10 MHz
  - Aging Rate:  $<5 \times 10^{-10}$ /day after 72 hours of continuous oven operation
  - Temperature Stability:  $\pm 2 \times 10^{-10}/^{\circ}\text{C}$  (0 to  $+55^{\circ}\text{C}$ )
  - Time Base (External): 5 or 10 MHz ( $\pm 1 \times 10^{-6}$  or better) 0.5 to 5 Vpp into 100  $\Omega$  (Nominal)
  - Switching Time List Mode:  $<500 \mu\text{s}$  to within 1 kHz of set frequency
  - Switching Time CW Mode:  $<35 \text{ ms}$  to within 1 kHz of set frequency (includes IEEE overhead)
  - Residual FM During Switching: (refer to Frequency Modulation Table, Wide Mode Residual FM column)

#### RF OUTPUT (CW)

Maximum Levelled Output (0 to  $35^{\circ}\text{C}$ ):

Frequency (GHz)	Output Power (dBm)	Option 20 (dBm)	Option 26 (dBm)
0.01 to 2.0	+15	+20	+14
> 2 to < 8.0	+15	+20	+15
8.0 to 15.0	+15	+20	+13
> 15.0 to 20.0	+15	+20	+12

- Incremental Level Range:  $-20$  (typ) to  $+25$  dBm
- Resolution: 0.01 dB, entry and display
- Minimum Calibrated Output Level:  $-10$  dBm;  $-120$  dBm (with Option 26)
- RF Off: Attenuates the output to  $<-140$  dBm at the output connector
- Flatness ( $25^{\circ} \pm 10^{\circ}\text{C}$ ) (Internally levelled, CW, or frequency step or ramp mode):  $\pm 0.5$  dB ( $-10$  dBm to maximum specified power); add  $\pm 0.1$  dB/10 dB (with Option 26);  $\pm 2.5$  dB (with Option 20)
- Accuracy: add 0.2 dB to flatness
- Temperature Coefficient:  $-0.25 \text{ dB}/^{\circ}\text{C}$
- Maximum Slope of Level Variation:  $<.5 \text{ dB}/\text{MHz}$
- Output Switching Time:  $<500 \mu\text{s}$ ; 20 ms with attenuator change (Option 26)
- Output Impedance: 50  $\Omega$ , nominal
- Output SWR:  $<2.0:1$
- Level Drift:  $<0.05 \text{ dB}/\text{hour}$ ; max 0.1 dB/24 hours.

**SPECTRAL PURITY**

Harmonics:

Frequency (GHz)	Standard (at +6 dBm)	With Option 20 (at +20 dBm)
	dBc	dBc
0.01 to 0.10	-30	-5
> 0.10 to 2	-50	-20
> 2 to 20	-55	-20

Subharmonics: None, .01–2 GHz; &lt;-55 dBc &gt;2 GHz

Nonharmonics(&gt;300 Hz offset): &lt;-60 dBc (0.01 to 16 GHz); &lt;-55 dBc (&gt;16 to 20 GHz)

SSB Phase Noise (dBc/Hz, CW Mode):

Frequency (GHz)	Offset from Carrier				
	100 Hz	1 kHz	10 kHz	100 kHz	1 MHz
0.25	-101	-101	-109	-122	-129
0.5	-95	-95	-103	-122	-124
2.0	-87	-92	-94	-120	-125
4.0	-81	-86	-88	-110	-130
6.0	-81	-83	-83	-110	-130
8.0	-75	-80	-83	-105	-130
10.0	-75	-80	-80	-105	-125
18.0	-68	-73	-73	-97	-120
20.0	-68	-73	-73	-97	-120

Residual FM (Hz, rms; CW Mode):

Frequency Range (GHz)	Post Detection Bandwidth	
	300 Hz to 3 kHz	50 Hz to 15 kHz
< 2	Decreases by 1/2 per oct	Decreases by 1/2 per oct
2 to <4	< 6	< 45
4 to <8	< 12	< 70
8 to <16	< 24	< 160
16 to 20	< 32	< 280

AM Noise (5MHz offset): &lt;-130 dBm/Hz (0.01 to 2 GHz); &lt;-145 dBm/Hz (&gt;2 GHz)

**RAMP FREQUENCY SWEEP (12700A Series)**

Linear continuous sweep, self-generated within the instrument, may be operated simultaneously with step power sweep.

Range: Minimum frequency of instrument (FA) to maximum frequency of instrument (FB), up or down in frequency

Minimum Sweep Width: 100 Hz (1 MHz, Option 36)

Sweep Time (any sweep mode): 1 ms to 200 s

Sweep Time Resolution: 10  $\mu$ s

Minimum Sweep Rate: 100 kHz/sec.

Maximum Sweep Speed: 8 ms/octave

Band Crossing Dead Time: <400  $\mu$ s. Filter crossing: 200 ns (sweep not stopped)

Sweep Width Resolution: 0.1 Hz (1 kHz, Option 36)

Start, Stop, Halted Frequency Accuracy: Phase locked to time base

Sweep Linearity (Relative to a linear RAMP OUT voltage, sweep time  $\geq$ 100 ms, < 100 sec, any sweep mode): < 0.03% of sweep width

Sweep Modes:

START/STOP (FA  $\leq$  [F1  $\neq$  F2]  $\leq$  FB): Sweeps up or down from a preset start frequency (F1) to a preset stop frequency (F2)START/ $\Delta$  (FA  $\leq$  [F1  $\pm$   $\Delta$ F]  $\leq$  FB): Sweeps up or down from a preset start frequency (F1) through a preset sweep width ( $\Delta$ F)CTR/ $\Delta$  (FA  $\leq$  [CF  $\pm$  ( $\Delta$ F/2)]  $\leq$  FB): Sweeps up or down through a preset sweep width ( $\Delta$ F) centered symmetrically about a preset center frequency (CF) $\Delta$  MKR (FA  $\leq$  [Mx  $\neq$  My]  $\leq$  FB): Sweeps up or down from any preset marker (Mx) to any other preset marker (My)

Sweep Functions:

AUTO: Continuous recycle of preset sweep

SINGLE: A single cycle of preset sweep initiated by manual operation of the front panel push-button or reception of the corresponding GPIB command

EXT: A single cycle of preset sweep initiated by each trigger from an external source

Frequency Markers (Step and Ramp frequency sweep):

Twelve intensity, video, and/or amplitude markers, individually selected from either the front panel or via the GPIB

Resolution: Sweep width/4,000

Accuracy: Same as sweep linearity except the marker may vary  $\pm$ 25 mV relative to the linear 0 to +10 V RAMP OUT

Amplitude markers: A -10 to 10 dB change in RF output during analog frequency sweep

Video markers: TTL level output or  $\pm$ 5 V

Intensity markers: Provides a timed dwell of frequency sweep

**STEP FREQUENCY SWEEP**

Range: Min. frequency of instrument (FA) to max. frequency of instrument (FB)

Step Size: Any increment within the instrument's frequency resolution

Dwell Time: May be set in 1 ms increments from approx. 1 ms to 200  $\mu$ sSetup time/step: 200  $\mu$ s

Memory: Up to 30,000 frequency points and/or 100 list tables, depending on available dynamic memory

Accuracy and Stability: Same as in CW when locked at each step during dwell time

Modes:

START/STOP (FA  $\leq$  [F1  $\neq$  F2]  $\leq$  FB): Sweeps up or down from a preset start frequency (F1) to a preset stop frequency (F2)START/ $\Delta$  (FA  $\leq$  [F1  $\pm$   $\Delta$ F]  $\leq$  FB): Sweeps up or down from a preset start frequency (F1) through a preset sweep width ( $\Delta$ F)CTR/ $\Delta$  (FA  $\leq$  [CF  $\pm$  ( $\Delta$ F/2)]  $\leq$  FB): Sweeps up or down through a preset sweep width ( $\Delta$ F) centered symmetrically about a preset center frequency (CF)START/STEPS (FA  $\leq$  [F1  $\pm$  (Step Size X Number of Steps)]  $\leq$  FB):

Sweeps up or down from a preset start frequency (F1) through a preset number of frequency steps

Functions:

AUTO: Continuous recycle of preset sweep

SINGLE: A single cycle of preset sweep or (with stop activated) a single preset step, initiated by manual operation of the front panel push-button or reception of the corresponding GPIB command

EXT: A single cycle of preset sweep, initiated by each trigger from an external source

EXT STEP: A single step of a preset sweep initiated by each trigger from an external source

**RAMP POWER SWEEP**

Continuous sweep, self-generated within the instrument. May be operated simultaneously with step frequency sweep.

Range: -10 dBm (LA) to max. power (LB) up or down (-120 dBm to max. power with opt. 26)

Sweep Time (Any Sweep Mode): 2 ms to 200 s in five ranges

Minimum sweep time is determined by the sweep width and the maximum sweep speed

Minimum Sweep Width: .01 dB

Maximum Sweep Speed: 1 dB/ms

Range	Resolution
2.0 to 20.0 ms	10.0 $\mu$ s
20.0 to 200.0 ms	100.0 $\mu$ s
200 ms to 2.0 s	1.0 ms
2.0 to 20.0 s	10.0 ms
20.0 to 200.0 s	100.0 ms

Sweep Level Resolution (any sweep mode): 0.01 dB

Start Level Accuracy (any sweep mode): Same as CW

Sweep Level Linearity (any sweep mode):  $\pm$ 0.25 dB

**Sweep Modes:**

- START/STOP ( $LA \leq [L1 \neq L2] \leq LB$ ): Sweeps up or down from a preset start level (L1) to a preset stop level (L2)
- START/ $\Delta$  ( $LA \leq [L1 \pm \Delta L] \leq LB$ ): Sweeps up or down from a preset start level (L1) through a preset sweep width ( $\Delta L$ )
- CTR/ $\Delta$  ( $LA \leq [CL \pm (\Delta L/2)] \leq LB$ ): Sweeps up or down through a preset sweep width ( $\Delta L$ ) centered symmetrically about a preset center level (CL)

**Sweep Functions:**

- AUTO: Continuous recycle of preset sweep
- SINGLE: A single cycle of preset sweep initiated by manual operation of the front panel push-button or reception of the corresponding GPIB command
- EXT: A single cycle of preset sweep initiated by each trigger from an external source

**STEP POWER SWEEP**

Range: Minimum level of instrument (LA) to maximum level of instrument (LB)  
 Step Size: Any increment within the instrument's level resolution  
 Dwell Time: May be set in 1 ms increments from approximately 1 ms to 200 s  
 Setup time/step: 100  $\mu$ s typical  
 Accuracy and Stability: Same as in CW when locked at each step during dwell time

**Sweep Modes:**

- START/STOP ( $LA \leq [L1 \neq L2] \leq LB$ ): Sweeps up or down from a preset start level (L1) to a preset stop level (L2)
- START/ $\Delta$  ( $LA \leq [L1 \pm \Delta L] \leq LB$ ): Sweeps up or down from a preset start level (L1) through a preset sweep width ( $\Delta L$ )
- CTR/ $\Delta$  ( $LA \leq [CL \pm (\Delta L/2)] \leq LB$ ): Sweeps up or down from a preset sweep width ( $\Delta L$ ) centered symmetrically about a preset center level (CL)
- START/STEPS: ( $LA \leq [L1 \pm (\text{Step Size} \times \text{Number of Steps})] \leq LB$ ): Sweeps up or down from a preset start level (L1) through a preset number of level steps

**Sweep Functions:**

- AUTO: Continuous recycle of preset sweep
- SINGLE: A single cycle of preset sweep or (with stop activated) a single preset step, initiated by manual operation of the front panel push-button or the corresponding GPIB command
- EXT: A single cycle of preset sweep or (with stop activated) a single preset step, initiated by each trigger from an external source
- EXT STEP: A single step of preset sweep initiated by each trigger from an external source

**MODULATION PARAMETERS AND OPERATIONAL MODES (12500A and 12700A Series)**

All models provide as standard; AM, FM and Pulse driven by an external waveform. Option 24 provides two function generators for internally generating amplitude and frequency modulation envelope waveforms. A pulse generator is also provided.

**PULSE/SQUARE WAVE MODULATION (PM)**

Specifications apply with Scan/AM and FM off.

**PM Envelope Parameters**

On/Off Ratio: >80 dB (60 dB with Option 20)  
 Rise/Fall Times:

Rise Time	Frequency Range
< 10 ns	> 500 MHz
< 50 ns	> 64 to 500 MHz
< 350 ns	25 to 64 MHz
< 500 ns	< 25 MHz

Overshoot, Undershoot and Ringing: <10%, >500 MHz  
 Settling Time (to within 1 dB): <75 ns (for pulses >75 ns)  
 Leveled Pulsed Output Power Accuracy (Referenced to CW output power) at 25° +/- 10°C:  $\pm 0.5$  dB,  $\geq 100$  ns pulse width: ( $\pm 1$  dB (typ), <100 ns pulse width) (Requires a typical setup time of 100 $\mu$ s after initial setting)

Minimum Width	Frequency Range
20 ns	> 500 MHz
100 ns	64 to 500 MHz
1 $\mu$ s	< 64 MHz

Externally Generated PM Envelope: One PM envelope produced by each pulse  
 Repetition Rate: 5 Hz to 5 MHz, leveled output  
 Pulse Width: Defined by external pulse width  
 Pulse Offset Delay (Output envelope leading edge referenced to input pulse leading edge): 50 ns, typical  
 Input Pulse Required: Positive or negative-going TTL voltage level trigger pulse,  $\geq 75$  ns wide (leveled output);  $\geq 20$  ns wide (unleveled output); pulse must be able to drive a 50 ohm load

**INTERNALLY GENERATED PM ENVELOPE (Option 24)**

Repetition Rate:

Range	Resolution
1 Hz to 1 kHz	1 Hz
> 1 to 10 kHz	10 Hz
> 10 to 100 kHz	100 Hz
> 100 kHz to 1 MHz	1 kHz
> 1 to 3 MHz	10 kHz

Accuracy (% of range max value):  $\pm 1\%$   $f_m < 100$  kHz,  $\pm 4\%$   $f_m$  100 kHz to <1 MHz,  $\pm 10\%$   $f_m > 1$  MHz  
 Jitter: Same as instrument time base  
 Pulse Start Variable Delay (Referenced to sync output)  
 Range: 0 to 1.67 s  
 Resolution: 10 ns  
 Accuracy:  $\pm 1\%$  of setting or  $\pm 20$  ns, whichever is greater  
 Jitter:  $\pm 0.01\%$  of setting or  $\pm 100$  ps, whichever is greater

**Pulse Width:**

Range: 100 ns to 1.67 s  
 Resolution: 10 ns  
 Accuracy:  $\pm 1\%$  of setting or  $\pm 20$  ns, whichever is greater  
 Jitter:  $\pm 0.01\%$  of setting or  $\pm 100$  ps, whichever is greater

**Externally Triggered PM Envelope: One PM envelope produced by each trigger**

Repetition Rate: 5 Hz to 5 MHz  
 Pulse Delay: Set by internal delay control  
 Pulse Width: Set by internal width control  
 Input Trigger Required: Positive or negative-going TTL level trigger pulse, >20 ns wide (unleveled); >75 ns (leveled)

**Pulse Modes (Triggered, gated, delayed, singlet, doublet, triplet, or quadlet):**

Interval  
 Range: 100 ns to 1.67 s  
 Resolution: 10 ns  
 Accuracy:  $\pm 1\%$  of setting or 20 ns, whichever is greater  
 Note: The intervals between triplets and quadlets are the same. The start delay for pulse one is independent.

**AMPLITUDE MODULATION**

Specifications apply with FM off.

**AM Envelope Parameters**

Modulation Depth: 0 to 90%, at 0 dBm output power  
 Modulation Resolution: 1%  
 Modulation Bandwidth: DC to 150 kHz,  $\pm 3$  dB, at 0 dBm output  
 Modulation Accuracy:  $\pm 10\%$  of depth setting

**Externally Supplied AM Envelope**

Waveform: Any waveform compatible with bandwidth considerations  
 Input Sensitivity (AM depth control set to 100%): 1 Vp-p, for 50% depth  $\pm 10\%$  depth, at 1 kHz modulation rate  
 Input Impedance: 600  $\Omega$ , nominal

**Internally Generated AM Envelope (Option 24)**

Waveform: Sine, square, triangle, ramp (+ or -), Gaussian Noise  
 Rate: .01 Hz to 1 MHz, all waveforms  
 Resolution: .01 Hz  
 Accuracy: Same as time base.  
 THD: 1% typical

**SCAN MODULATION (Option 29)**

Specifications apply with FM and PM off.

Frequency of operation: 0.01 to 20 GHz

**Envelope Parameters**

Range: 0 to 60 dB at output level  $\geq 10$  dBm  
 Resolution: 0.1 dB  
 Sensitivity: -10 dB/V in 1 dB increments  
 Step Response: <1  $\mu$ s for 50 dB change (< 10  $\mu$ s below 1 GHz)

Frequency Response: DC to 150 kHz sine wave, 3 dB  
 Accuracy:  $\pm 0.25$  dB plus  $\pm 5\%$  of depth in dB (for .01 to 2 GHz, specification applies up to 30 dB depth)  
 Linearity:  $\pm 0.6$  dB (0 – 20 dB),  $\pm 1$  dB (20 – 60 dB)  
 Power: Reduce power by 2 dB  
 Input Impedance: 600  $\Omega$ , nominal

**Internally Generated SCAN Envelope** (Option 24)  
 Same as internally generated AM envelope

## FREQUENCY MODULATION (FM)

Specifications apply with SCAN/AM and PM off.

### FM Envelope Parameters

#### Wide Mode

Max Deviation: (See following table)  
 Minimum Deviation: 10 kHz, at 4 – 8 GHz (other ranges proportional)  
 Modulation Resolution: 1 kHz, (deviation <1 MHz); 10 kHz (deviation >1 MHz) (at 4 – 8 GHz, other ranges proportional)  
 Rate: 100 Hz to 1 MHz  $\pm 2$  dB;  $\pm 3$  dB to 8 MHz  
 Residual FM: (See following table)  
 Distortion: <5% ( $\pm 1$  MHz deviation)

#### Narrow Mode

Max Deviation: (See following table)  
 Modulation Resolution: 10 Hz, (deviation <10 kHz); 1 kHz, (deviation >10 kHz) (at 4 – 8 GHz, other ranges proportional)  
 Rate: DC to 1 MHz  $\pm 2$  dB;  $\pm 3$  dB to 8 MHz  
 Residual FM: Same as CW  
 Distortion: <5% ( $\pm 1$  MHz deviation); <1% at 10 kHz (4 – 8 GHz)

#### Both Modes

Modulation Accuracy:  $\pm 5\%$  at maximum deviation; 190 kHz modulation rate  
 Incidental AM:  $< \pm 0.2\%$ /MHz of deviation

### Internally Generated FM/ØM Envelope

 (Option 24)

Same as internally generated AM envelope

### Externally Supplied FM/ØM Envelope

Waveform: Any waveform compatible with bandwidth considerations  
 Rate: DC to 8 MHz  
 Input sensitivity, settable: 1 Vp for maximum peak deviation (FM deviation control set to maximum)  
 Input Impedance: 50  $\Omega$ , nominal

## PHASE MODULATION

Maximum Rate: 100 kHz  
 Maximum Resolution: 0.01 Radians  
 Accuracy:  $\pm 5\%$  (relative to FM) at max deviation, 100 kHz modulation rate  
 Maximum Modulation Index:

Frequency (GHz)	Max Wide Deviation (Peak)	Max Narrow Deviation (Peak)	Wide Mode Residual FM	Max Wide Mode Index Radians	Max Narrow Mode Index Radians
.010 to .016	40 kHz	2 kHz	200 Hz	.4	.02
.016 to .032	80 kHz	4 kHz	200 Hz	.8	.04
.032 to .064	160 kHz	8 kHz	200 Hz	1.6	.08
.064 to .125	320 kHz	16 kHz	200 Hz	3.2	.16
.125 to .25	640 kHz	32 kHz	200 Hz	6.4	.32
.25 to .5	1.25 MHz	64 kHz	200 Hz	12.5	.64
.5 to 1	2.5 MHz	125 kHz	375 Hz	25	1.25
1 to 2	5 MHz	250 kHz	750 Hz	50	2.5
2 to 4	10 MHz	.5 MHz	1.5 kHz	100	5
4 to 8	20 MHz	1 MHz	3 kHz	200	10
8 to 16	40 MHz	2 MHz	6 kHz	400	20
16 to 20	80 MHz	4 MHz	12 kHz	800	40

## INPUTS/OUTPUTS

All connectors are type BNC unless otherwise stated.

### Front Panel

RF OUT: Generator's RF output signal on type SMA (f) connector  
 AM IN: Input signal for external amplitude modulation  
 FM IN: Input signal for external frequency modulation  
 PM IN: Input signal for external pulse modulation

### Rear Panel

REF IN: External time base input signal, 5 or 10 MHz ( $\pm 1 \times 10^{-6}$  or better), 0.5 to 5 V, p-p, overrides internal time base  
 Input Impedance: 100  $\Omega$ , nominal  
 REF OUT: Buffered time base output,  $\geq 2$ V, p-p squarewave, into 50  $\Omega$ , derived from internal or external time base  
 STOP SWEEP IN/OUT: TTL level signal, low input to stop frequency sweep or output to indicate that sweep has been stopped  
 LOCK/LEVEL OUT: TTL high, indicating that frequency is phase-locked and output power is leveled  
 PM VIDEO OUT: TTL level (approximately 1 V into 50  $\Omega$ ) pulse modulation envelope waveform (opt 24)  
 PM SYNC OUT: TTL level (approximately 1 V into 50  $\Omega$ ) 50 ns wide trigger pulse out coincident with leading edge of pulse modulation envelope waveform (opt 24)  
 AM OUT: 2 V, p-p, into 1 m $\Omega$ , amplitude modulation waveform output (opt 24)  
 FM OUT: 2 V, p-p, into 1 m $\Omega$ , frequency modulation waveform output (opt 24)  
 BLANK/MKR OUT:  $\pm 5$  V during band changes, filter changes and retrace; 0 V during sweep; and  $\pm 5$  V during markers; signal polarity software selectable  
 V/GHz OUT: Signal directly proportional to the output frequency (0.5 v/GHz for  $\leq 20$  GHz models)  
 SWEEP TRIGGER IN: TTL level,  $\geq 50$  ns wide trigger input to initiate sweep or step  
 RAMP OUT: 0 to +10 V ramp out, proportional to frequency between set sweep limits  
 SWP TRIG OUT: Trigger output coincident with frequency step ending event  
 AM IN: Input signal for external amplitude modulation  
 FM IN: Input signal for external frequency modulation  
 PM IN: Input signal for external pulse modulation

## GENERAL SPECIFICATIONS

Remote Interface: IEEE STD 488.2 – All parameters except AC power on/off; RS232 Serial Interface DB9 Connector  
 Operating Temperature: 0 to 55°C  
 Environmental: Complies with MILPRF-28800F, Class 3  
 Approvals: CE marked  
 Power: 90-253 VAC, 47-64 Hz (400 Hz optional), 150 Watts nominal  
 Fuse Rating: 2A, 5B  
 Weight: 13.6 kg (30 lb)  
 Dimensions: 133 mm H x 425 mm W x 533 mm D (5.25 in H x 16.75 in W x 21 in D)

Data subject to change without notice.

Typical Characteristics are indicated by *italic* type

06/02

# Giga-tronics