Introducing the new SG384 4GHz RF Signal Generator — finally, a high performance, affordable RF source.

The SG384 uses a unique, innovative architecture (Rational Approximation Frequency Synthesis) to deliver ultra-high frequency resolution (1µHz), excellent phase noise, and versatile modulation capabilities (AM, FM, PM, pulse modulation and sweeps) at a fraction of the cost of competing designs.

The standard model SG384 produces sine waves from DC to 4.05GHz. There is an optional frequency doubler (Opt. 02) that extends the frequency range to 8.10GHz. Low-jitter differential clock outputs (Opt. 01) are available, and an external I/Q modulation input (Opt. 03) is also offered. For demanding applications, the SG384 can be ordered with a rubidium timebase (Opt. 04).

On the Front Panel

The SG384 has two front-panel outputs with overlapping frequency ranges. A BNC provides outputs from DC to 62.5 MHz with adjustable offsets and amplitudes from 1 mV to 1 Vrms into a 50 Ω load. An N-type output supplies frequencies from 950 kHz to 4.05 GHz with power from +13 dBm to −110 dBm (1 Vrms to 0.707 µVrms) into a 50 Ω load.
Modulation

The SG384 offers a wide variety of modulation capabilities. Modes include amplitude modulation (AM), frequency modulation (FM), phase modulation (ΦM), and pulse modulation. There is an internal modulation source as well as an external modulation input. The internal modulation source produces sine, ramp, saw, square, and noise waveforms. An external modulation signal may be applied to the rear-panel modulation input. The internal modulation generator is available on the rear-panel modulation output.

Unlike traditional analog signal generators, the SG384 can sweep continuously from DC to 62.5 MHz. And for frequencies above 62.5 MHz, each sweep range covers more than an octave.

OCXO or Rubidium Timebase

The SG384 comes with a oven-controlled crystal oscillator (OCXO) timebase. The timebase uses a third-overtone stress-compensated 10 MHz resonator in a thermostatically controlled oven. The timebase provides very low phase noise and very low aging. An optional rubidium oscillator (Opt. 04) may be ordered to substantially reduce frequency aging and improve temperature stability.

The internal 10 MHz timebase (either the standard OCXO or the optional rubidium reference) is available on a rear-panel output. An external 10 MHz timebase reference may be supplied to the rear-panel timebase input.

Square Wave Clock Outputs

Optional differential clock outputs (Opt. 01) are available on the rear panel which make the SG384 a precision clock source. Option 01 provides differential clock outputs at rates from DC to 4.05 GHz with 1 µHz resolution. The clocks have transition times of about 35 ps. Both the offset and amplitude of the clock outputs can be adjusted for compliance with standard logic levels. Shown here at 2 ns/division; 100 MHz front panel sine wave output (top trace) and differential clock outputs (bottom traces). The displayed transition times are limited by the 1.5 GHz bandwidth of the oscilloscope.

Amplitude Modulation (100 %)

The frequency range of the SG384 extends from DC to 4 GHz. All of the analog modulation modes also extend to DC allowing the SG384 to perform function generator tasks. Shown here is a 20 kHz carrier being amplitude modulated by a 1 kHz sine.

Top trace: Modulation output
Bottom trace: Front-panel BNC output
SG384 RF Signal Generator

The SG384 can be ordered with a frequency doubler (Opt. 02) that generates signals from 4.05 GHz to 8.10 GHz. The amplitude of the rear-panel RF output can be adjusted from −15 dBm to +7 dBm. This option also allows the I/Q modulator to be driven by an internal noise generator with adjustable bandwidth. Rear-panel outputs allow the noise source to be viewed or used for other purposes.

Output Frequency Doubler

The SG384 can be ordered with a frequency doubler (Opt. 02) that generates signals from 4.05 GHz to 8.10 GHz. The amplitude of the rear-panel RF output can be adjusted from −15 dBm to +7 dBm. This option also allows the I/Q modulator to be driven by an internal noise generator with adjustable bandwidth. Rear-panel outputs allow the noise source to be viewed or used for other purposes.

Easy Communication

Remote operation of the SG384 is supported with GPIB, RS-232 and Ethernet interfaces. All instrument functions can be controlled and read over any of the interfaces. Up to nine instrument configurations can be saved in non-volatile memory.

I/Q Inputs

Optional I/Q inputs (Opt. 03) allow I & Q baseband signals to modulate carriers from 400 MHz to 4.05 GHz. This option also allows the I/Q modulator to be driven by an internal noise generator with adjustable bandwidth. Rear-panel outputs allow the noise source to be viewed or used for other purposes.

Option 03 allows I/Q modulation of carriers from 400 MHz to 4.05 GHz. Two signal sources may be used for I/Q modulation: external I & Q inputs or an internal noise generator. The external I & Q BNC inputs are on the rear panel. The internal noise generator has adjustable noise bandwidth. Shown here is a 1 GHz carrier being modulated by the internal noise generator with 1 kHz noise bandwidth.

I/Q Modulation of 1 GHz Carrier by Internal Noise Generator

The polar plot shows the trajectory of a signal in the I/Q plane. An unmodulated carrier at the analyzer’s reference frequency (1 GHz in this case) appears as a single dot in the I/Q plane. When the carrier frequency is offset, the single dot moves in a circle about the center of the I/Q plane. The pattern shown occurs when the carrier amplitude is modulated with 100 % depth at a rate of five times the carrier offset frequency (creating five lobes). The symmetry of the lobes indicates that there is no residual phase distortion (AM to ΦM conversion) in the amplitude modulator. The narrow line of the trajectory is indicative of low phase and amplitude noise.

Polar Plot of 1.000001 GHz Referenced to 1 GHz with 100 % AM at 5 kHz

Outputs below 62.5 MHz are generated by direct-digital synthesis with a sample frequency of 1 GHz. In this example, a 50 MHz carrier is frequency modulated at a rate of 10 kHz and a deviation of 24.0477 kHz, for a modulation index $\beta = 2.40477$. The carrier amplitude is proportional to the Bessel function $J_0(\beta)$, which has its first zero at 2.40477.

Spectrum of Frequency Modulated 50 MHz Carrier
A New Frequency Synthesis Technique

The SG384 is based on a new frequency synthesis technique called Rational Approximation Frequency Synthesis (RAFS). RAFS uses small integer divisors in a conventional phase-locked loop (PLL) to synthesize a frequency that would be close to the desired frequency (typically within ±100 ppm) using the nominal PLL reference frequency. The PLL reference frequency, which is sourced by a voltage controlled crystal oscillator that is phase locked to a dithered direct digital synthesizer, is adjusted so that the PLL generates the exact frequency. Doing so provides a high phase comparison frequency (typically 25 MHz) yielding low phase noise while moving the PLL reference spurs far from the carrier where they can be easily removed. The end result is an agile RF source with low phase noise, essentially infinite frequency resolution, without the spurs of fractional-N synthesis or the cost of a YIG oscillator.

FSK in the Time Domain

Frequency shift keying (FSK) can be used to transmit data. In this example, the internal modulator is set to FM between 1 MHz and 3 MHz with a 100 kHz square wave.

Top trace: Rear-panel modulation output
Middle trace: Front-panel BNC output
Bottom trace: Front-panel N-type output

Unmodulated Spectrum of a 1 GHz Output

The SG384 output exhibits low phase noise and low spurious content. In this direct measurement taken with 100 Hz RBW, the noise floor of the spectrum analyzer dominates over most of the 200 kHz span.

Ordering Information

SG384 RF Signal Generator
Option 01 Rear-panel clock outputs (SMA)
Option 02 8 GHz doubler & DC bias
Option 03 External I/Q modulation
Option 04 Rubidium timebase
RM2U-S Single rack mount kit
RM2U-D Dual rack mount kit
**Frequency Setting**

- **Frequency ranges**
  - DC to 62.5 MHz (BNC output)
  - 950 kHz to 4.05 GHz (N-type output)
  - 4.05 GHz to 8.1 GHz (opt. 02)
- **Frequency resolution**
  - 1 µHz at any frequency
- **Switching speed**
  - <8 ms (to within 1 ppm)
- **Frequency error**
  - \(<10^{-18}\times\text{timebase error})\times f_C\)
- **Frequency stability**
  - \(1 \times 10^{-11}\) (1 s Allan variance)

**Front-Panel BNC Output**

- **Frequency range**
  - DC to 62.5 MHz
- **Amplitude**
  - 1.00 Vrms to 0.001 Vrms
- **Offset**
  - ±1.5 VDC
- **Offset resolution**
  - 5 mV
- **Max. excursion**
  - 1.41 V
- **Amplitude resolution**
  - <1%
- **Amplitude accuracy**
  - ±5%
- **Harmonics**
  - <–40 dBc
- **Spurious**
  - <–75 dBc
- **Output coupling**
  - DC, 50Ω ±2%
- **User load**
  - 50Ω
- **Reverse protection**
  - ±5 VDC

**Front-Panel N-Type Output**

- **Frequency range**
  - 950 kHz to 4.05 GHz
- **Power output**
  - +13 dBm to –110 dBm
- **Voltage output**
  - 1 Vrms to 0.7 µVrms
- **Power resolution**
  - 0.01 dBm
- **Power accuracy**
  - ±1 dB
- **Output coupling**
  - AC, 50Ω
- **User load**
  - 50Ω
- **VSWR**
  - <1.6
- **Reverse protection**
  - 30 VDC, ±25 dBm RF

**Spectral Purity of the RF Output Referenced to 1 GHz**

- **Sub harmonics**
  - None
- **Harmonics**
  - <–25 dBc (<+7 dBm, N-type output)
- **Spurious**
  - <–10 kHz offset: <–65 dBc
  - >10 kHz offset: <–75 dBc
- **Phase noise**
  - 10 Hz offset: –80 dBc/Hz (typ.)
  - 1 kHz offset: –102 dBc/Hz (typ.)
  - 20 kHz offset: –116 dBc/Hz (typ.)
  - 1 MHz offset: –130 dBc/Hz (typ.)
- **Residual FM (typ.)**
  - 1 Hz rms (300 Hz to 3 kHz BW)
- **Residual AM (typ.)**
  - 0.006 % rms (300 Hz to 3 kHz BW)

*Spurs, phase noise and residual FM scale by 6 dB/octave to other carrier frequencies*

**Phase Setting on Front-Panel Outputs**

- **Max. phase step**
  - ±360°
- **Phase resolution**
  - 0.01° (DC to 100 MHz)
  - 0.1° (100 MHz to 1 GHz)
  - 1.0° (1 GHz to 8.1 GHz)

**Standard OCXO Timebase**

- **Oscillator type**
  - Oven controlled, 3rd OT, SC-cut crystal
- **Stability (0 to 45°C)**
  - <±0.002 ppm
- **Aging**
  - <±0.05 ppm/year

**Rubidium Timebase (Opt. 04)**

- **Oscillator type**
  - Oven controlled, 3rd OT, SC-cut crystal
- **Physics package**
  - Rubidium vapor frequency discriminator
- **Stability (0 to 45°C)**
  - <±0.0001 ppm
- **Aging**
  - <±0.001 ppm/year

**Timebase Input**

- **Frequency**
  - 10 MHz, ±2 ppm
- **Amplitude**
  - 0.5 to 4 Vpp (–2 dBm to +16 dBm)
- **Input impedance**
  - 50Ω, AC coupled

**Timebase Output**

- **Frequency**
  - 10 MHz, sine
- **Source**
  - 50Ω, DC transformer coupled
- **Amplitude**
  - 1.75 Vpp ±10% (8.8 dBm ±1 dBm)

**Internal Modulation Source**

- **Waveforms**
  - Sine, ramp, saw, square, pulse, noise
- **Sine THD**
  - –80 dBc (typ. at 20 kHz)
- **Ramp linearity**
  - <–0.05% (1 kHz)
- **Rate**
  - 1 µHz to 500 kHz (f_C < 62.5 MHz)
  - 1 µHz to 50 kHz (f_C > 62.5 MHz)
- **Rate resolution**
  - 1 µHz
- **Rate error**
  - 1.231 + timebase error
- **Noise function**
  - White Gaussian noise (rms = dev/5)
- **Noise bandwidth**
  - 1 µHz < ENBW < 50 kHz
- **Pulse generator period**
  - 1 µs to 10 s
- **Pulse generator width**
  - 100 ns to 9999.9999 ms
- **Pulse timing resolution**
  - 5 ns
- **Pulse noise function**
  - PRBS 2^5 – 2^19. Bit period (200 + 5N) ns

**Modulation Waveform Output**

- **Output impedance**
  - 50Ω (for reverse termination)
- **User load**
  - Unterminated 50Ω coax
- **AM, FM, ΦM**
  - ±1 V for ± full deviation
- **Pulse/Blank**
  - “Low” = 0 V, “High” = 3.3 VDC

**External Modulation Input**

- **Modes**
  - AM, FM, ΦM, Pulse, Blank
- **Unmodulated level**
  - 0 V input for unmodulated carrier
- **AM, FM, ΦM**
  - ±1 V input for ± full deviation
- **Modulation bandwidth**
  - >100 kHz
- **Modulation distortion**
  - <–60 dB
- **Input impedance**
  - 100 kΩ
- **Input offset**
  - <500 µV
- **Pulse/Blank threshold**
  - +1 VDC
### Amplitude Modulation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>0 to 100% (decreases above +7 dBm)</td>
</tr>
<tr>
<td>Resolution</td>
<td>0.1%</td>
</tr>
<tr>
<td>Modulation source</td>
<td>Internal or external</td>
</tr>
<tr>
<td>Modulation distortion - BNC output</td>
<td>&lt;0.1% ( f_c &lt; 62.5 \text{ MHz}, f_m = 1 \text{ kHz} )</td>
</tr>
<tr>
<td>Modulation distortion - N-type output</td>
<td>&lt;3% ( f_c &lt; 62.5 \text{ MHz}, f_m = 1 \text{ kHz} )</td>
</tr>
<tr>
<td>Modulation bandwidth</td>
<td>&gt;100 kHz</td>
</tr>
</tbody>
</table>

### Frequency Modulation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency deviation</td>
<td>10 Hz to 1 MHz</td>
</tr>
<tr>
<td>Deviation resolution</td>
<td>Larger of 1 Hz or 0.1% of deviation</td>
</tr>
<tr>
<td>Deviation accuracy</td>
<td>(&lt;0.1% ( f_c &lt; 62.5 \text{ MHz} )) ,&lt;3% ( f_c &gt; 62.5 \text{ MHz} )</td>
</tr>
<tr>
<td>Modulation source</td>
<td>Internal or external</td>
</tr>
<tr>
<td>Modulation distortion - Ext. FM carrier offset</td>
<td>(&lt;1:1,000 \text{ of deviation} )</td>
</tr>
<tr>
<td>Modulation bandwidth</td>
<td>&gt;100 kHz</td>
</tr>
</tbody>
</table>

### Frequency Sweeps (Phase Continuous)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency span</td>
<td>10 Hz to entire sweep range</td>
</tr>
<tr>
<td>Sweep ranges</td>
<td>DC to 62.5 MHz, 59.375 MHz to 128.125 MHz, 118.75 MHz to 256.25 MHz, 237.5 MHz to 512.5 MHz, 475 MHz to 1025 MHz, 950 MHz to 2050 MHz, 1900 MHz to 4100 MHz, 3800 MHz to 8200 MHz (Opt. 02 only)</td>
</tr>
<tr>
<td>Deviation resolution</td>
<td>Larger of 1 Hz or 0.1% of deviation</td>
</tr>
<tr>
<td>Sweep source</td>
<td>Internal or external</td>
</tr>
<tr>
<td>Sweep distortion</td>
<td>(&lt;0.1 \text{ Hz} \times \text{ (deviation/1,000)} )</td>
</tr>
<tr>
<td>Sweep offset</td>
<td>(&lt;1:1,000 \text{ of deviation} )</td>
</tr>
<tr>
<td>Sweep function</td>
<td>Triangle or ramp sweeps up to 120 Hz</td>
</tr>
</tbody>
</table>

### Phase Modulation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deviation</td>
<td>0 to 360°</td>
</tr>
<tr>
<td>Deviation resolution</td>
<td>0.01° to 100 MHz, 0.1° to 1 GHz</td>
</tr>
<tr>
<td>Deviation accuracy</td>
<td>(&lt;0.1% ( f_c &lt; 62.5 \text{ MHz} )) ,&lt;3% ( f_c &gt; 62.5 \text{ MHz} )</td>
</tr>
<tr>
<td>Modulation source</td>
<td>Internal or external</td>
</tr>
<tr>
<td>Modulation distortion - Modulation bandwidth</td>
<td>&gt;100 kHz</td>
</tr>
</tbody>
</table>

### Pulse/Blank Modulation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse mode</td>
<td>Logic “High” turns RF “on”</td>
</tr>
<tr>
<td>Blank mode</td>
<td>Logic “High” turns RF “off”</td>
</tr>
<tr>
<td>On/Off ratio</td>
<td>40 dB (1 GHz to 4 GHz)</td>
</tr>
<tr>
<td></td>
<td>60 dB (100 MHz to 1 GHz)</td>
</tr>
<tr>
<td></td>
<td>75 dB (DC to 100 MHz)</td>
</tr>
<tr>
<td>Pulse feed-through</td>
<td>10% of carrier for 20 ns at turn on (typ.)</td>
</tr>
<tr>
<td>Turn on/off delay</td>
<td>60 ns</td>
</tr>
<tr>
<td>RF rise/fall time</td>
<td>20 ns</td>
</tr>
<tr>
<td>Modulation source</td>
<td>Internal or external pulse</td>
</tr>
</tbody>
</table>

### External I/Q Modulation (Opt. 03)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier frequency range</td>
<td>400 MHz to 4.05 GHz</td>
</tr>
<tr>
<td>Modulated output</td>
<td>Front-panel N-type only</td>
</tr>
<tr>
<td>I/Q inputs</td>
<td>50Ω, ±0.5 V</td>
</tr>
<tr>
<td>I or Q input offset</td>
<td>&lt;500 µV</td>
</tr>
<tr>
<td>I/Q full scale</td>
<td>((I^2+Q^2)^{1/2} = 0.5 \text{ V} )</td>
</tr>
<tr>
<td>Carrier suppression</td>
<td>&gt;40 dB</td>
</tr>
<tr>
<td>Modulation bandwidth</td>
<td>200 MHz (–3 dB)</td>
</tr>
</tbody>
</table>

### Square Wave Clock Outputs (Opt. 01)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Differential clocks</td>
<td>Rear-panel SMAs drive 50 Ω loads</td>
</tr>
<tr>
<td>Frequency range</td>
<td>DC to 4.05 GHz</td>
</tr>
<tr>
<td>Transition time (typ.)</td>
<td>&lt;35 ps (20% to 80%)</td>
</tr>
<tr>
<td>Jitter</td>
<td>( f_c &gt; 62.5 \text{ MHz} ) ,&lt;300 fs rms (1 kHz to 5 MHz BW) ,&lt;10^{-4} \text{U.I. rms (1 kHz to 5 MHz BW)}</td>
</tr>
<tr>
<td>Amplitude</td>
<td>0.4 Vpp to 1 Vpp</td>
</tr>
<tr>
<td>Offset</td>
<td>±2 VDC</td>
</tr>
<tr>
<td>Ampl/offset resolution</td>
<td>5 mV</td>
</tr>
<tr>
<td>Ampl/offset accuracy</td>
<td>±5%</td>
</tr>
<tr>
<td>Output coupling</td>
<td>DC, 50 Ω ±2 %</td>
</tr>
<tr>
<td>Compliance</td>
<td>ECL, PECL, RSECL, CML, LVDS, NIM</td>
</tr>
</tbody>
</table>

### Frequency Doubler Output (Opt. 02)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td>Rear-panel SMA</td>
</tr>
<tr>
<td>Frequency range</td>
<td>4.05 GHz to 8.10 GHz</td>
</tr>
<tr>
<td>RF amplitude</td>
<td>–15 dBm to +7 dBm</td>
</tr>
<tr>
<td>Sub harmonic ( f_c/2 )</td>
<td>&lt;25 dBc</td>
</tr>
<tr>
<td>Mixing products ( 3f_c/2 )</td>
<td>&lt;25 dBc</td>
</tr>
<tr>
<td>Spurious (8 GHz)</td>
<td>&lt;55 dBc (&gt;1 kHz offset)</td>
</tr>
<tr>
<td>Phase noise (8 GHz)</td>
<td>&lt;98 dBc/Hz at 20 kHz offset (typ.)</td>
</tr>
<tr>
<td>Amplitude resolution</td>
<td>0.01 dBm</td>
</tr>
<tr>
<td>Amplitude accuracy</td>
<td>±1 dB</td>
</tr>
<tr>
<td>Modulation modes</td>
<td>FM, ΦM, sweeps</td>
</tr>
<tr>
<td>Output coupling</td>
<td>AC, 50 Ω</td>
</tr>
<tr>
<td>Reverse protection</td>
<td>30 VDC, +25 dBm RF</td>
</tr>
</tbody>
</table>

### DC Bias Source (comes with Opt. 02)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td>Rear-panel SMA</td>
</tr>
<tr>
<td>Voltage range</td>
<td>±10 V</td>
</tr>
<tr>
<td>Offset voltage</td>
<td>&lt;20 mV</td>
</tr>
<tr>
<td>DC accuracy</td>
<td>±0.2 %</td>
</tr>
<tr>
<td>DC resolution</td>
<td>5 mV</td>
</tr>
<tr>
<td>Output resistance</td>
<td>50 Ω</td>
</tr>
<tr>
<td>Current limit</td>
<td>20 mA</td>
</tr>
</tbody>
</table>

### Computer Interfaces

- **Ethernet (LAN)** 10/100 Base-T.TCP/IP & DHCP default
- **GPIB** IEEE488.2
- **RS-232** 4800 to 115,200 baud, RTS/CTS flow

### General

- **Line power** <90 W, 90 to 264 VAC, 47 to 63 Hz w/ PFC
- **Dimensions, weight** 8.5” × 3.5” × 13” (WHD), 10 lbs.
- **Warranty** One year parts and labor