# ERASynth

An open source, Arduino-compatible RF signal generator with wi-fi connectivity

Finally, an affordable signal generator for everyone!

ERASynth is a high quality portable signal generator at a price point affordable by everyone including makers, students, universities, research labs, and start-ups.

1. **Makers/Hackers:** RF signal generators are expensive pieces of test equipment typically only accessible by pro engineers. ERASynth removes the cost barriers and makes quality RF signal synthesis accessible to everyone, especially budget-conscious makers.
2. **Students:** ERASynth is for everyone who wants to learn how signal generators work. Since it is open source with open schematics, students or anyone who is curious about the inner details of signal synthesis can learn from ERASynth. You can learn a lot by reverse engineering and hacking, without having to pay $50k in tuition in engineering program. After all, learning the design of test equipment turned Jim Williams into one of the best analog engineers in the world. ERASynth's advanced design will certainly teach you several RF tricks.
3. **Professionals:** Professional engineers will find ERASynth is a very good alternative to many of their existing signal generators. If you are professional engineer, you can compare it yourself: find the lowest cost equipment on your bench that can give you a 1 GHz signal with -120 dBc/Hz or better phase noise at 10 kHz offset. Its price tag will be several times more than ERASynth's. See the comparison charts below to learn more about how ERASynth compares to common signal generators.
4. **Professors/Researchers/Start-ups:** With all the cuts in research funds, who can afford to spend tens of thousands on signal generators? Whether you are a college professor studying Gigasample converters or a start-up developing state-of-the-art converter technology, you need to clock ADC/DAC somehow. Check out the specs, you will find ERASynth may very well be your next clock source. Besides the price, ERASynth's portability will definitely help when you are out in the field.
5. **Anyone else :** ERASynth is for anyone interested in RF testing. Below is a short list of application areas where users can take advantage of ERASynth:
   - General purpose RF testing. For example, to measure the gain of an amplifier, ERASynth can be used as the source.
   - Test signal source for SDR. People who are using any of the many SDR platforms can use ERASynth as the test signal source for testing and calibration of their SDR devices.
   - An agile LO source for up and down-converters.
   - Clock source for ADCs and DACs. When equipped with an optional OCXO, ERASynth's jitter performance exceeds the requirements of state-of-the-art giga-sample data-converters.
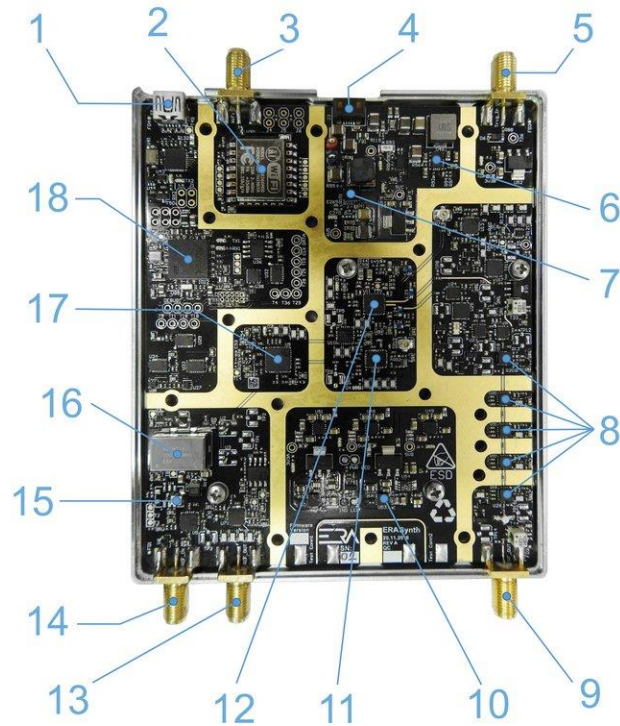
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1. Mini-USB for Serial Access	**10.** Ultralow Noise Ultrahigh PSRR RF LDO
2. Wi-Fi Module (ESP8266)	**11.** Ultralow Phase Noise PFD
3. Wi-Fi Antenna Connector	**12.** Wideband PLL with VCO
4. Micro-USB Input for Power	**13.** 10 MHz Reference Output
5. Trigger Input	**14.** 10 MHz Reference Input
6. Step-down Switcher	**15.** ±0.5ppm TCXO
7. Step-up Switcher	**16.** Ultralow Phase Noise VCXO
8. Attenuators for Level Control	**17.** Tunable Reference Generator
9. RF Output (50 Ω)	**18.** Arduino Due MCU

Features & Specifications

- **Architecture**: Multiloop Integer-N PLL driven by a tunable reference. No fractional-N or integer boundary spurs
- **Frequency Range**:
  - ERASynth: 10 MHz to 6 GHz
  - ERASynth+: 250 kHz to 15 GHz
- **Amplitude Range**: -60 to +15 dBm
- **Phase Noise**: typical phase noise @ 1 GHz output and 10 kHz offset
  - ERASynth: -120 dBc/Hz
  - ERASynth+: -125 dBc/Hz
- **Frequency Switching Time**: 100 µs
- **Reference**: Ultra-low noise 100 MHz VCXO locked to a
  - ±0.5 ppm TCXO for ERASynth
  - ±25 ppb OCXO for ERASynth+
- **MCU**: Arduino Due board with BGA package Atmel Microcontroller (ATSAM3X8EA-CU)
- **Interfaces**:
  - Wi-Fi interface for web-based GUI access
  - Serial-USB (mini USB) for serial access
  - Micro USB for power input
  - Trigger Input (SMA) for triggered sweep
  - REF In (SMA) for external reference input
  - REF Out (SMA) for 10 MHz reference output
  - RF Out
- **Dimensions**: 10 cm x 14.5 cm x 2 cm
- **Weight**: < 350 g (12.5 oz)
- **Power Input**: 5 to 12 V
- **Power Consumption**:
  - < 6 W for ERASynth
  - < 7 W for ERASynth+
- **Enclosure**: Precision-milled, nickel-plated aluminum case
- **Open Source**: Schematics, embedded Arduino code, Web GUI source code, and RS-232 command set

Signal Generator Architecture: Multiloop with a Tunable Reference vs Single Loop Fractional-N

Low cost, USB-controlled RF signal generators are available from a multitude of vendors. These signal generators usually include a single fractional PLL IC with integrated VCO. Examples of such PLL ICs are: ADF435x and ADF5355 series from ADI, LMX series from TI, MAX2870 from Maxim, and STuW series from STMicro. These signal generators are mostly a close replica of the eval board of the PLL/VCO IC and they are usually limited in terms of performance. ERASynth architecture provides several built-in features that overcome these limitations.
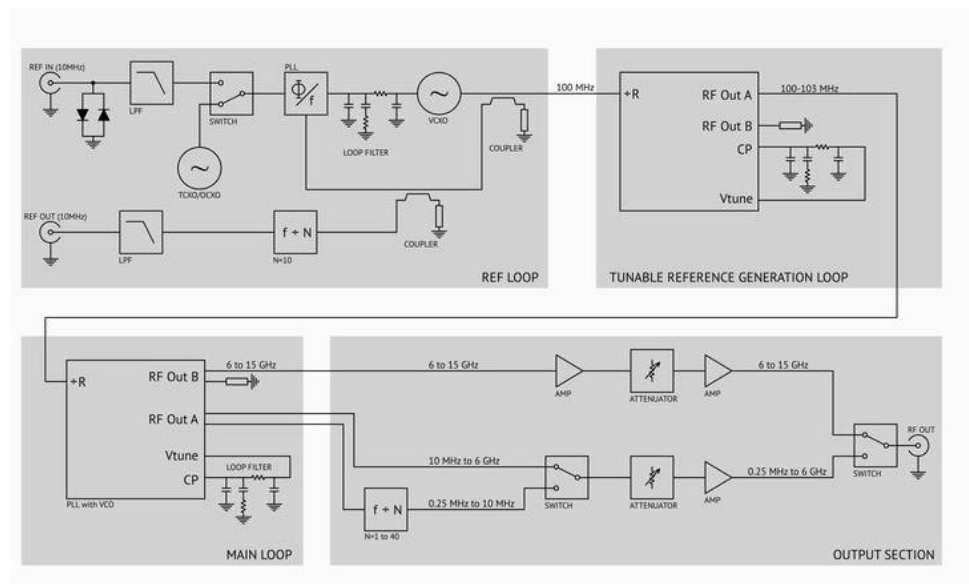

ERASynth block diargram
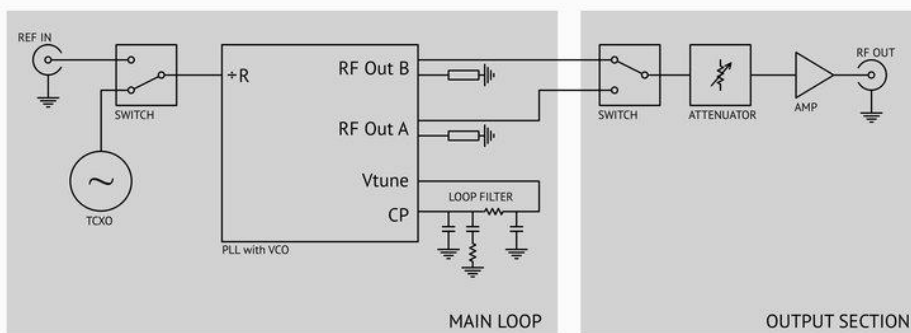
Competitor block diargram

ERASynth Eliminates Integer Boundary Spurs

While fractional-N PLLs are great for generating frequencies with fine frequency resolution, they suffer from a phenomenon called "integer boundary spurs" (IB spurs). IB spurs are visible at the output of a frac-N PLL IC when the output frequency is close to an integer multiple of the reference frequency. For example, generating an RF output of 6000.01 GHz from a 100 MHz reference will result in IB spurs as large as -30 dBc. This level of performance may be acceptable for some specific application, but generally it is unacceptable for signal generators. ERASynth's multi-loop architecture eliminates IB spurs by varying the reference in fine steps while keeping the main loop in integer-N mode. This architecture not only diminishes IB spurs but also helps reduce phase noise. PLL IC's phase noise floors are usually lower by 2-3 dB in integer-N mode compared to frac-N mode.
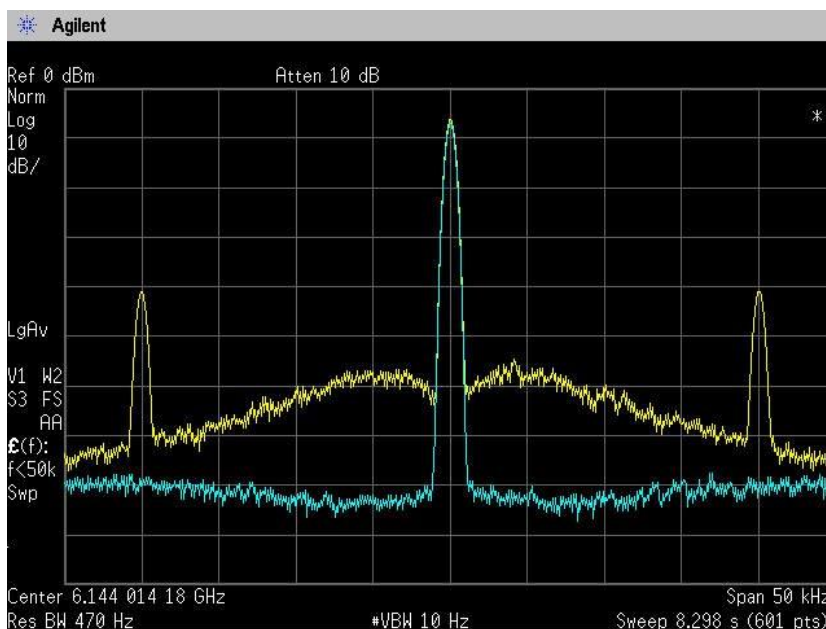
ERASynth rev2 (turquiose) vs ADF5355 Eval Board (yellow) @ 6.14401418 GHz. ERASynth rev2 uses ADF4356 as the main PLL.

ERASynth Improves Phase Noise

On top of the dual loop PLL that generates the RF output, ERASynth adds another PLL to minimize the reference phase noise. While many competitors use low-cost TCXOs in the range of a few tens of MHz, ERASynth uses a 100 MHz VCXO with a very low phase noise floor. This VCXO is stabilized with a ±0.5 ppm TCXO or ±25ppb OCXO depending on the model. The VCXO may also be locked to an external 10 MHz reference.
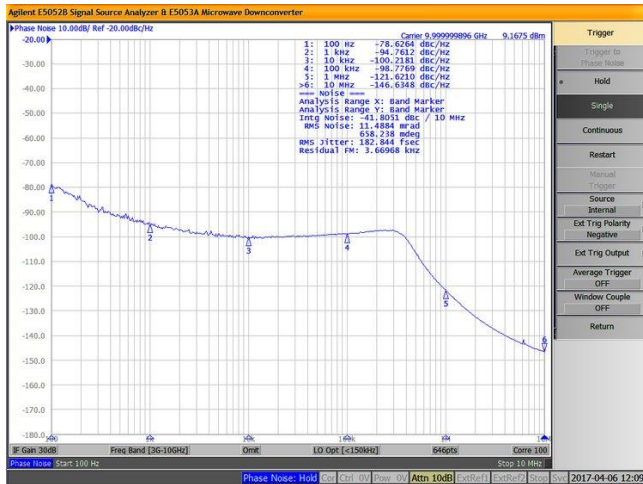
ERASynth rev2 phase noise at 10 GHz RF output.

ERASynth rev2 phase noise at 1 GHz RF output.
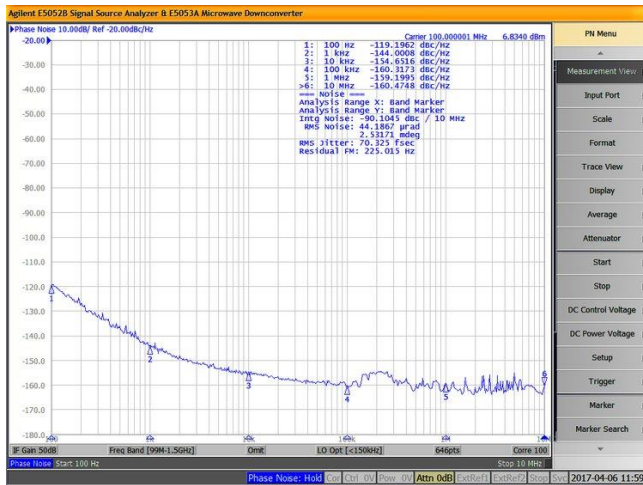
ERASynth rev2 reference phase noise.

Comparisons: ERASynth vs. Low-cost USB Signal Generators

_	ERA Instruments ERASynth	ERA Instruments ERASynth+	Vaunix LMS-602D	DS Instruments SG6000LD	Windfreak SynthHD
Architecture	Int-N Driven by Frac-N	Int-N Driven by Frac-N	?	Frac-N	Frac-N
Frequency Range	10 MHz to 6 GHz	250 kHz to 15 GHz	1.5 to 6 GHz	25 to 6000 MHz and 6 to 12 GHz	54 MHz to 13.6 GHz
Frequency Resolution	1 Hz	1 Hz	100 Hz	~3 kHz	0.1Hz
Max Frequency Error	6 Hz	0 Hz	?*	~3 kHz	0 Hz
Amplitude Range	-60 to +15 dBm	-60 to +15 dBm	-40 to +10 dBm	typical +11 dBm with 31.5dB attenuator	?*
Phase Noise at 1 GHz and 10 kHz offset	-120 dBc/Hz	-125 dBc/Hz	-97 dBc/Hz	-91 dBc/Hz (*)	-100 dBc/Hz
Frequency Switching Time	100 µs	100 µs	100 µs	?*	4 ms
Subharmonics	None	None	None	over 6 to 12 GHz	over 6.8 to 13.6 GHz
Reference	100 MHz VCXO locked to a ±0.5	100 MHz VCXO locked to a ±25	±2 ppm	±2.5 ppm 10 MHz TCXO	±2.5 ppm 10/27 MHz

_	ERA Instruments ERASynth	ERA Instruments ERASynth+	Vaunix LMS-602D	DS Instruments SG6000LD	Windfreak SynthHD
	ppm TCXO	ppb OCXO			TCXO
REF IN/REF OUT Connectors	Yes	Yes	Only REF IN. REF OUT is optional	Only REF IN	Only REF IN
Trigger Input	Yes	Yes	optional ($400 USD)	No	Yes
Enclosure	Milled aluminum	Milled aluminum	Milled aluminum	Extruded aluminum	Extruded aluminum
Power Input	5 to 12 V	5 to 12 V	5 V	5 V	6 V
Power Input Connector	micro USB	micro USB	mini USB	micro USB	power jack
Serial Connectivity	Yes	Yes	?*	Yes	Yes
Wi-Fi Connectivity	Yes	Yes	No	No	No
Open Source	Schematics, firmware and GUI	Schematics, firmware and GUI	Nothing	Nothing	LabVIEW GUI
GUI platform	Platform independent web-based GUI	Platform independent web-based GUI	Windows	Windows	Windows and Linux
Price (USD)					

*? = Unknown. Not included on product data-sheets.

Comparisons: ERASynth vs. Professional Bench-Top RF Signal Generators

-	ERA Instruments ERASynth	ERA Instruments ERASynth+	Rigol DSG830	Stanford Resarch SG386	Keysight N5171B EXA
Architecture	Int-N Driven by Frac-N	Int-N Driven by Frac-N	Int-N Driven by DDS?	Rational Approximation Frequency Synthesis	Proprietry Frac-N ASIC
Frequency Range	10 MHz to 6 GHz	250 kHz to 15 GHz	9 kHz to 3 GHz	DC to 6 GHz	9 kHz to 6 GHz
Frequency Resolution	1 Hz	1 Hz	0.01 Hz	1 µHz	0.001 Hz
Amplitude Range	-60 to +15 dBm	-60 to +15 dBm	-110 to +13 dBm	-110 to +16.5 dBm	-140 to +18 dBm
Level Control	Open Loop	Open Loop	Closed Loop ALC	Closed Loop ALC	Closed Loop ALC
Calibration over Temperature	Only at Room Temp	Only at Room Temp	0 to 50°C	0 to 45°C	0 to 50°C
Phase Noise at 1 GHz, 10 kHz offset	-120 dBc/Hz	-125 dBc/Hz	-104 dBc/Hz	-114 dBc/Hz	-122 dBc/Hz
Frequency Switching Time	100 µs	100 µs	<10000 µs	8000 µs	<5000 µs standard, <800 µs optional
Harmonics	-10 dBc	-10 dBc	<-30 dBc	<-35 dBc	<-35 dBc

-	ERA Instruments ERASynth	ERA Instruments ERASynth+	Rigol DSG830	Stanford Resarch SG386	Keysight N5171B EXA
	typical	typical			
Reference	100 MHz VCXO locked to a ±0.5 ppm TCXO	100 MHz VCXO locked to a ±25 ppb OCXO	±2 ppm TCXO or optional ±5 ppb OCXO	±2 ppb OCXO	±1 ppm TCXO or optional ±5 ppb OCXO
Modulation	None	None	AM/FM/FM and optional pulse	AM/FM/FM/pulse	optional AM/FM/FM/pulse

Manufacturing Plan

ERASynth is a complex hardware project that requires a good supply chain. We here at ERA instruments have the required expertise and connections to bring this product to market. We have established the following local partners:

Elektro AŞ: Elektro is ADI's and Murata's Turkey representative. They have already given us tremendous support during the prototype phase of ERASynth. We will try to procure most of the main ICs from them.

Ekom Ltd: Ekom is Digikey's Turkey representative and provides biweekly shipments from Digikey's headquarters to Istanbul. We can usually procure components available on Digikey in less than a week.

Nettek Ltd: Nettek has over 40 years of experience in CNC milling. Our prototype cases were designed and produced by them. We will utilize Nettek for mass production.

Hitech Corp: Hitech is a premium manufacturer of printed circuit coards. Hi-Tech is well-known for their express delivery and friendly support. We will utilize their PCB manufacturing expertise for our mass production.

Radarsan AŞ: Radarsan, loacated in Teknopark İstanbul, is owned and operated by a friend of ours. We will use Radarsan services for assembly of ERASynth PCBs.

We have already taped out second revision of the PCB. We tested it thoroughly. We will tape out the final revision of the board during the campaign run. It will fix a few existing bugs. We will also upgrade the main PLL to a newly released IC that has industry leading phase noise floor. Our phase noise target was -120 dBc/Hz at 1 GHz and 10 kHz offset in the second revision. With this new IC, we are targeting another 5 dB improvement over the second revision. So, the -125 dBc/Hz phase noise specification given in the comparison charts is preliminary and requires testing and validation.

Project Timeline

Date	Task
May 04	PCB rev3 SCH Design
May 24	PCB rev3 layout
May 31	Procurement of rev3 BOM
May 31	PCB rev3 production
June 07	PCB rev 3 assembly
June 16	Rev3 test & debug
June 23	Rev3 mechanical design

Date	Task
June 28	Final PCB production
August 03	Procurement of components for mass manufacturing
August 03	Mass production of mechanical enclosure
August 10	Production assembly
August 31	Ship to Crowd Supply
September 21	Ship to backers

Shipping & Fulfillment

ERASynths will be shipping from Crowd Supply's warehouse in Portland, Oregon USA. We can't pre-pay VAT, so if you are living in a country that collects VAT upon import, you will likely have to pay that and deal with customs clearance. International shipments will be fulfilled with Priority Mail, which is why the shipping fee is $35 USD for all international shipments (excluding Turkey). This fee does not include any applicable taxes, duties, etc. For more information about ordering, paying, and shipping please visit this [Crowd Supply Guide page](#).

Risks and Challenges

Hardware projects are vulnerable to several risks and challenges. ERASynth is a relatively complicated hardware project with over a hundred unique parts in its BOM. There are several risks involved:

Stock Status

RF components are not general purpose parts. They are not manufactured in massive amounts like general purpose chips. Hence, stocks may get depleted suddenly. If a part used by ERASynth becomes depleted and there are alternatives, we use the alternatives. If there are no foot-print compatible alternatives, then we don't have a lot to do other than waiting for it to become available again. Unfortunately, lead-times for RF components are usually long (up to 25 weeks). In the design of ERASynth, we tried to use the most readily available parts, but we can never be certain there will be no shortages.

Obsolescence

Nowadays, with all the mergers and acquisitions in the global IC market, components can become obsolete overnight. We have had experiences where a component that is available at the start of the PCB design becomes obsolete in a few weeks later as we finish the PCB design. We designed ERASynth to use the most up-to-date parts possible in order to minimize obsolescence risk.

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