

WIRELESS CONNECTIVITY & RF FRONT-END

Wireless Connectivity & RF Front-End

Coordinate the radio reference clock, low-power timebase and RF front-end path for reliable short-range wireless links, connected devices and embedded radio modules.

Radio Reference + Sleep Timing + RF Selectivity + Coexistence + Integration Boundary

Bluetooth LE

Wi-Fi

Thread / Matter

Zigbee

Sub-1 GHz

UWB

Application Scope

Wireless SoCs, discrete transceivers, IoT radio modules, smart-home nodes, gateways, remote controls, telemetry devices and embedded products requiring reference clocks, always-on timing or RF filtering.

Selection Philosophy

Selection begins with the replaceable circuit node. The HFXO loop, external clock input, 32.768 kHz domain and RF signal path remain separate design positions even when they coexist within one wireless product.

HF Reference

Crystal loop or supported external clock for the radio / MCU synthesizer.

Low-Power Timebase

32.768 kHz RTC, sleep timing, wake scheduling and retention.

RF Front End

Regional preselection, coexistence filtering, matching and antenna path.

Module Boundary

Externally accessible functions versus clocks and RF parts already integrated.

01

Application Scope & Engineering Domains

Wireless products combine reference-clock, low-power and RF-path functions, each with a different component role and validation method.

One radio platform, multiple engineering domains. The wireless-SoC oscillator loop, optional external clock input, always-on timebase and RF front end must be defined independently. The RF carrier band does not identify the crystal or oscillator frequency.

Typical Equipment

Connected End Devices

Smart-home nodes
Wearables
Sensors & meters
Remote controls
Battery-powered IoT devices

Wireless Platforms

Wireless SoCs
Discrete transceivers
Certified radio modules
Connectivity gateways
Host MCU + radio designs

Radio Technologies

Bluetooth LE
Wi-Fi
Thread / Matter / Zigbee
Sub-1 GHz ISM / SRD
UWB ranging & location

Five Engineering Domains

High-Frequency Reference

Platform-specific HFXO crystal loop or compatible external clock input.

Low-Frequency Timebase

External 32.768 kHz crystal / clock or an internal low-frequency source.

Sub-1 GHz RF Path

315, 433.92, 868 and 915 MHz regional filtering and channel plans.

2.4 / 5 GHz RF Path

Matching, FEM, coexistence, antenna routing and conditional filtering.

Integration Boundary

Bare IC, module and host-board functions that remain externally replaceable.

Oscillator Interface

XTAL pins · clipped-sine / CMOS CLKIN · enable · startup · bias.

Accuracy Budget

Tolerance · stability · aging · load error · PCB parasitics · calibration.

RF Loss & Rejection

Passband · insertion loss · impedance · blockers · power · matching.

Power & Environment

Sleep current · wake latency · temperature · package · qualification.

Clock-definition note: 2.4 GHz, 5 GHz and UWB channel frequencies describe the RF carrier path. The external crystal or oscillator normally operates at a much lower reference frequency defined by the selected SoC, transceiver or host device.

02

Select by System Node First

Identify the replaceable circuit position before comparing frequency, device class, electrical performance or package.

System Node	Clock / RF Role	Representative Reference	Typical Device	Selection Focus
Wireless SoC / Transceiver HFXO	Radio synthesizer and MCU root reference	24 / 26 / 32 / 38.4 / 40 / 48 MHz platform-dependent	AT-cut crystal	CL · ESR · C0 · drive · startup · total ppm · temperature
Supported External Clock Input	Driven radio / MCU reference	Frequency defined by the receiver	XO / TCXO	waveform · amplitude / bias · VDD · load · enable · phase noise
RTC / Sleep Domain	Always-on timebase and wake scheduling	32.768 kHz	Tuning-fork crystal / low-current XO	XTAL vs CLKIN · CL · ESR · drive · startup · current · ppm
Sub-1 GHz RF Path	Regional preselection / coexistence filtering	315 / 433.92 / 868 / 915 MHz	SAW filter	center · bandwidth · insertion loss · rejection · impedance · power
2.4 GHz RF Path	BLE / 802.15.4 / Wi-Fi coexistence path	2.4 GHz band	Matching / FEM / conditional SAW	radio topology · S-parameters · power · loss budget · blockers
5 GHz Wi-Fi Path	Separate dual-band RF port / duplexer path	5 GHz band	Application-specific RF solution	band coverage · duplexer topology · antenna plan · rejection mask
Bare UWB Transceiver	Reference clock plus UWB RF path	38.4 MHz class 6.5 / 8.0 GHz RF channels	Crystal + RF network	current device guide · channel · layout · antenna · certification
Integrated Radio Module	Host-side clock and interface boundary	Module-dependent	Host clock only when exposed	module BOM boundary · host MCU · external pins · certification

1 · Identify the Receiver

Record the exact SoC, transceiver, module, host MCU, FEM or RF-filter position together with the relevant pins and schematic node.

2 · Classify the Domain

Evaluate the HF oscillator loop, external CLKIN, LF timebase and RF signal path as separate component-selection problems.

3 · Apply the Interface Limits

Define CL / ESR for crystals, waveform / VDD for driven clocks, or the complete RF mask and impedance for filters.

Recommended sequence: Platform documentation → replaceable node → electrical / RF interface → frequency or band → performance budget → environment → package → final FCom configuration.

03

Frequency & Component Placement Matrix

Frequency becomes meaningful only when it is mapped to the physical clock or RF position defined by the selected platform.

Frequency / Band	Representative System Position	Applicability	Selection Interpretation
32.768 kHz	RTC / sleep oscillator loop or driven LF input	Common Low-Power Reference	External tuning-fork crystal or low-current clock only where the receiver supports the corresponding topology.
24 / 26 MHz	Wireless-IC HFXO / transceiver reference	Platform-Dependent	Exact CL, ESR, C0, drive level and total ppm budget are taken from the receiving IC.
32 MHz	2.4 GHz multiprotocol SoC HFXO	Representative Public Platform	Illustrated by the nRF52840 architecture; FCX-1M is evaluated as a configurable series, not an automatic cross-reference.
38.4 / 40 MHz	Selected wireless / UWB transceiver reference	Platform-Dependent	The bare-transceiver design guide and oscillator interface determine the usable component class.
48 MHz	Wireless SoC HFXO or supported external clock	Representative Public Platform	Illustrated by TI CC1352P7 and ESP32-C5; the complete 48 MHz specification differs by platform.
315 MHz	Sub-1 GHz RF receive / transmit path	Frequency-Specific SAW	FSF3030-315M-1M-2-50: 1 MHz BW, 2 dB insertion loss and 50 dB stopband attenuation.
433.92 MHz	Sub-1 GHz telemetry / control RF path	Frequency-Specific SAW	FSF3030-433M92-1M71-2.5-50: 1.71 MHz BW, 2.5 dB insertion loss and 50 dB stopband attenuation.
868 / 915 MHz	Regional ISM / SRD preselection path	Regional RF Reference	FSF3030-868M-10M-1.9-40 or FSF1109-915M-26M-1.5-50 , subject to the complete channel and rejection mask.
2.4 GHz	BLE / 802.15.4 / Wi-Fi RF path	Conditional Discrete Filter	FSF1109-2442M-79M-1.2-40 is considered only after topology, RF power, impedance, matching and loss-budget review.
5 GHz / UWB	Separate RF port, duplexer, module or antenna path	Architecture Boundary	Requires a separate RF assessment; no 2.4 GHz filter or module-internal component should be carried across by assumption.

32 / 48 MHz Representative wireless-SoC reference-clock positions.	32.768 kHz Optional always-on, sleep and RTC timebase domain.	315-915 MHz Regional Sub-1 GHz RF-filter positions.	2.4 / 5 / UWB Distinct RF paths and integration boundaries.
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Reference-clock interpretation: the radio carrier, channel spacing, data rate and protocol symbol rate do not directly define the crystal or oscillator frequency. The external reference is specified by the receiving clock interface.

04

Representative Platform & Architecture Matrix

Four public platforms illustrate different clock, low-power, RF-path and module-integration boundaries.

NORDIC SEMICONDUCTOR

nRF52840 · 2.4 GHz Multiprotocol SoC

1

Architecture: Bluetooth LE, Thread, Zigbee and IEEE 802.15.4 share the 2.4 GHz radio platform.

Public clock evidence: the product specification identifies a 32 MHz external AT-cut crystal for the HFXO and an optional 32.768 kHz crystal for the LFXO.

32 MHz HFXO → Radio / MCU → 2.4 GHz RF

Selection insight: FCX-1M and FCT-1S address different oscillator loops. CL, C0, ESR, drive level, startup margin and final board validation remain platform-specific.

TEXAS INSTRUMENTS

CC1352P7 · Sub-1 GHz + 2.4 GHz Wireless MCU

2

Architecture: one wireless MCU supports multiple Sub-1 GHz ranges together with a 2.4 GHz radio path.

Public clock evidence: radio operation uses an external 48 MHz crystal; a 32.768 kHz crystal or external low-frequency clock is optional.

48 MHz Crystal → Radio / MCU → Sub-1 + 2.4 GHz

Selection insight: the HF crystal, LF timebase and regional RF filter are independent decisions and must be matched to the applicable TI clock and RF implementation limits.

ESPRESSIF SYSTEMS

ESP32-C5 · 2.4 / 5 GHz Dual-Band Wi-Fi 6 MCU

3

Architecture: Wi-Fi, Bluetooth LE and IEEE 802.15.4 coexist with separate 2.4 GHz and 5 GHz antenna / matching paths.

Public clock evidence: the hardware guidance specifies a 48 MHz crystal within ± 10 ppm and an optional 32.768 kHz RTC crystal with ESR ≤ 70 k Ω .

48 MHz Crystal → Wireless SoC → 2.4 / 5 GHz Ports

Selection insight: FCX-1M, FCT-3M-A and a conditional 2.4 GHz SAW occupy separate nodes; the 5 GHz path receives its own RF assessment.

QORVO

DWM3000 · Integrated UWB Module

4

Architecture: the customer host MCU communicates with an integrated UWB module that supports channels 5 and 9.

Public integration evidence: the module incorporates the UWB IC, chip antenna, power management and crystal, moving those component positions inside the module boundary.

Host MCU → SPI / Control → DWM3000 Module

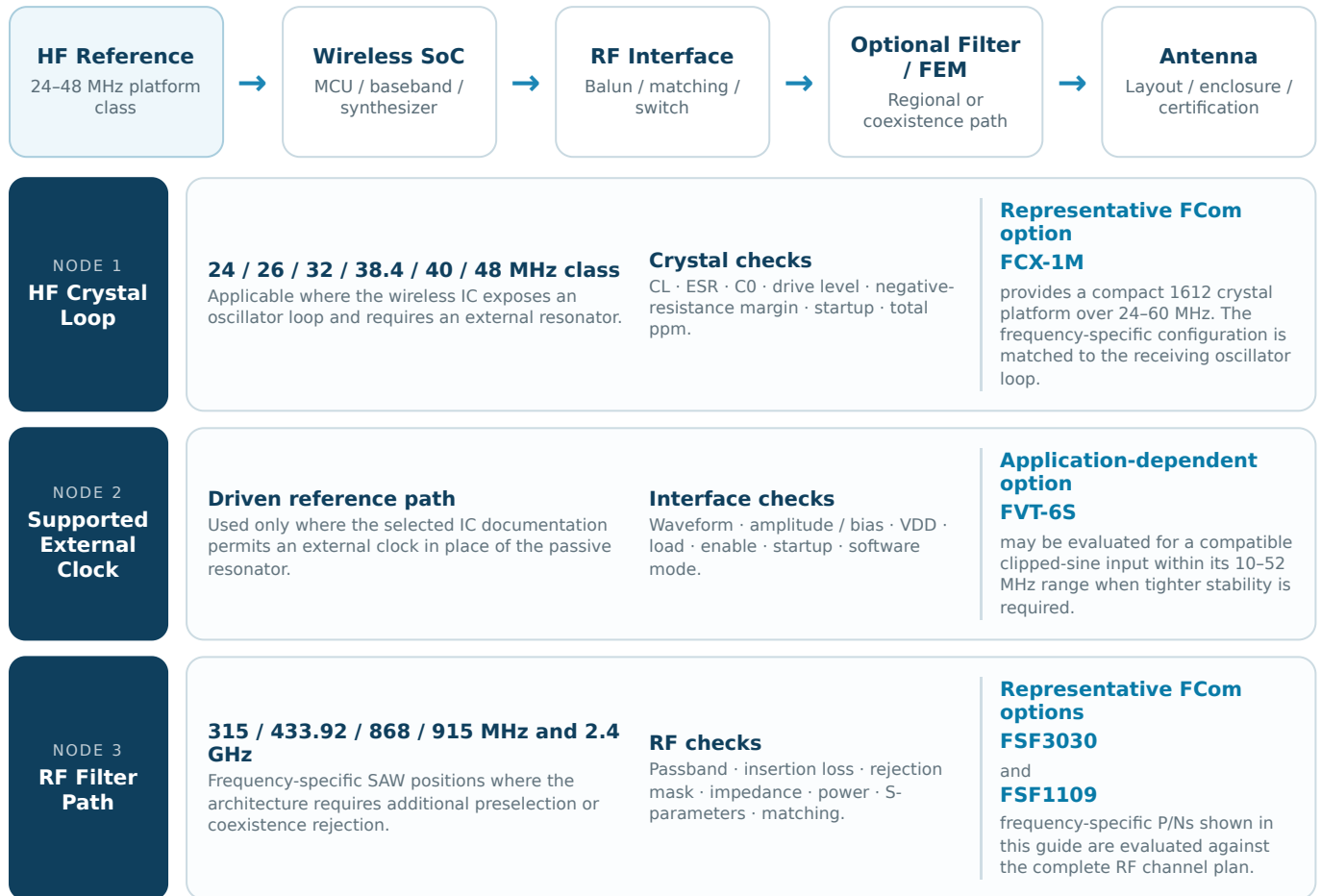
Selection insight: no discrete FCom clock or RF filter is proposed inside the module. Evaluation remains relevant to the host clock or to a separate bare-transceiver design.

Platform interpretation: these public examples illustrate representative architectures only. They do not indicate FCom adoption, qualification, compatibility or drop-in replacement. Final selection is based on the current target-device documentation, schematic and complete system requirements.

05

Wireless SoC + RF Front-End Architecture

Representative placement of the high-frequency reference and RF-filter functions around a bare wireless SoC or transceiver.

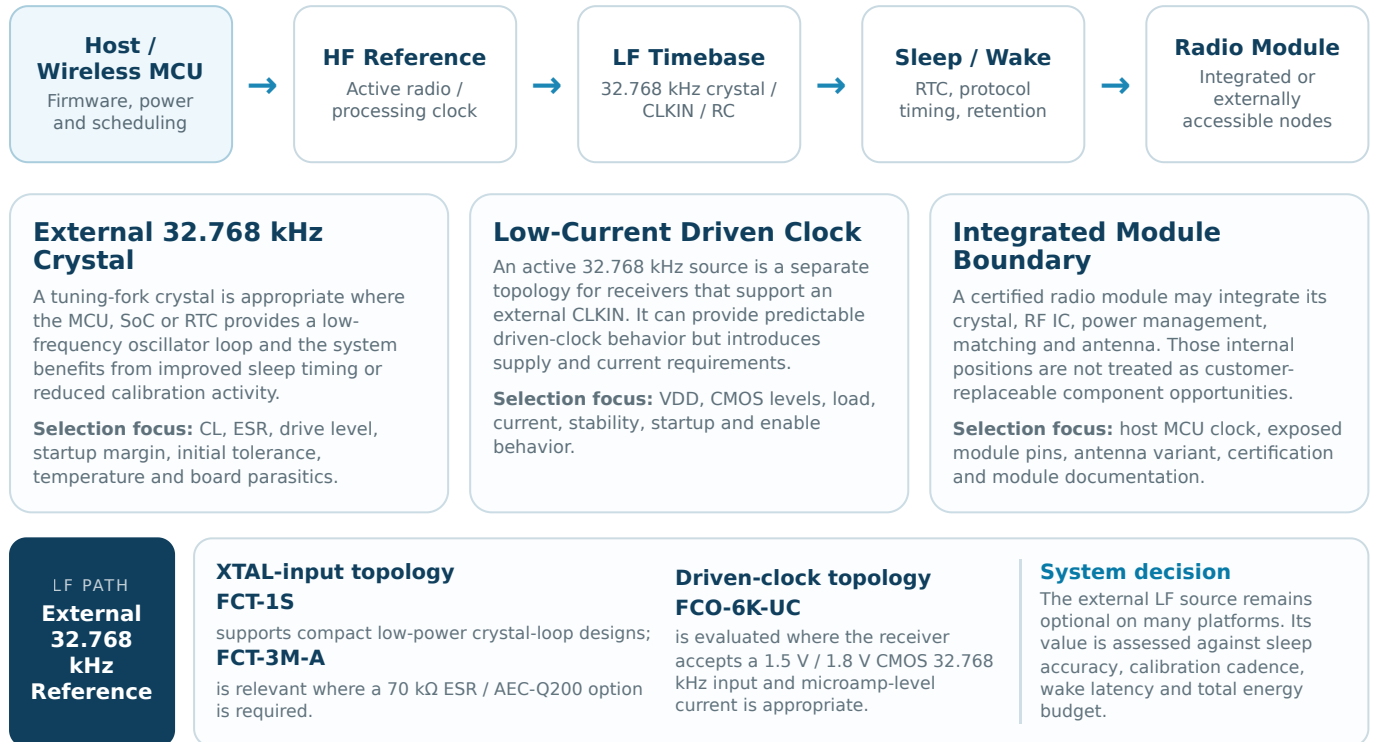


Architecture note: a discrete SAW filter is not a default requirement for every wireless design. The correct decision follows the radio-port topology, FEM / balun integration, insertion-loss budget, coexistence blockers, RF power and antenna path.

06

Always-On Timebase + Module Integration Architecture

Representative low-power timing around a wireless host, radio device and module boundary.



Architecture note: the high-frequency radio reference and low-frequency sleep timebase are independent clock domains. A device can use its HFXO during active radio operation while the LF source remains active through sleep or retention states.

07

FCom Selection Guidance by Design Condition

The following options correspond to defined, externally accessible clock or RF-filter positions. Exact configurations are confirmed after the receiving interface is documented.

Wireless HFXO

24–60 MHz configurable compact crystal platform.

Low-Power LF Crystal

32.768 kHz oscillator-loop options for RTC / sleep timing.

Driven LF Clock

Low-current 32.768 kHz CMOS source for supported CLKIN.

RF Selectivity

Frequency-specific Sub-1 GHz and 2.4 GHz SAW references.

Design Condition	FCom Selection	Representative Series / Portfolio Data	Key Check Before RFQ
Wireless IC exposes HF XTAL pins	FCX-1M	1612 · 24–60 MHz · best tolerance / stability ± 5 / ± 10 ppm · -40 to $+125^{\circ}\text{C}$ · 18 pF or specified CL · 30–60 Ω ESR by frequency.	Exact frequency · CL · ESR · C0 · drive · startup
Receiver supports a clipped-sine external clock	FVT-6S application-dependent	2016 · 10–52 MHz · clipped sine · tightest stability option ± 0.5 ppm · -40 to $+85^{\circ}\text{C}$.	Receiver CLKIN mode · amplitude / bias · VDD · software
32.768 kHz XTAL loop prioritizes compact size	FCT-1S	1210 · 32.768 kHz · best tolerance ± 5 ppm · -40 to $+125^{\circ}\text{C}$ · CL 6–12.5 pF · ESR 70–90 k Ω .	CL · ESR · drive · startup · temperature
LF loop requires 70 k Ω ESR / AEC-Q200 option	FCT-3M-A	3215 · 32.768 kHz · ± 10 ppm · -40 to $+125^{\circ}\text{C}$ · CL 6–12.5 pF · 70 k Ω · AEC-Q200.	Qualification scope · CL · drive · oscillator margin
Receiver accepts low-current driven LF CLKIN	FCO-6K-UC	2016 · 32.768 kHz · 1.5 / 1.8 V · CMOS · ± 20 ppm · -40 to $+105^{\circ}\text{C}$ · 1.4–1.8 μA .	VDD · CMOS thresholds · load · current · enable
Regional Sub-1 GHz path needs fixed filtering	FSF3030 / FSF1109 fixed P/Ns	315, 433.92, 868 and 915 MHz frequency-specific options listed in the frequency matrix.	Channel plan · bandwidth · loss · rejection · impedance · power
2.4 GHz path justifies a discrete SAW	FSF1109-2442M-79M-1.2-40	CSP1109 · 2442 MHz center · 79 MHz BW · 1.2 dB insertion loss · 40 dB stopband attenuation.	Topology · RF power · S-parameters · matching · blockers

Application-specific boundary: 5 GHz and UWB paths require separate engineering review; no 2.4 GHz filter is carried across by assumption. A module-integrated crystal or RF component is not proposed as an external replacement unless the module documentation exposes that function.

ENGINEERING SELECTION SUPPORT

Request an FCom Wireless Clock & RF Review

Provide the target SoC / transceiver / module, exact clock or RF node, frequency or band, electrical / RF limits, temperature, package and project stage.

[Start Engineering Review →](#)

08 Engineering Validation & Minimum RFQ

Wireless component selection is defined by the circuit node, clock / RF topology and end-product environment in addition to frequency.

HF Crystal / External Clock

- Exact SoC / transceiver P/N
- XTAL loop or external CLKIN
- Frequency, CL, ESR, C0 and drive
- Waveform, amplitude, VDD and load for an active clock
- Startup, ppm budget and temperature

Low-Frequency / Sleep Domain

- MCU / SoC / RTC P/N
- XTAL pins, external CLKIN or internal RC
- 32.768 kHz CL / ESR / drive or VDD / current
- Sleep accuracy and calibration cadence
- Wake latency and retention-power objective

RF Filter Position

- Center frequency and occupied bandwidth
- Maximum insertion loss and ripple
- Rejection zones, harmonics and blockers
- Source / load impedance and matching
- RF power, S-parameters and temperature

Module & Program Boundary

- Bare IC, module or certified end product
- Externally accessible clock / RF nodes
- Antenna / FEM / duplexer architecture
- Certification region and qualification scope
- Samples, schedule, annual volume and lifecycle

Minimum RFQ Information

Information Category	What to Provide
Application / System Node	Wireless SoC HFXO, supported external clock, 32.768 kHz loop / CLKIN, Sub-1 GHz filter, 2.4 / 5 GHz path, UWB design or host-side module clock.
Target Device	Exact SoC, transceiver, module, FEM, host MCU or RTC part number and the relevant schematic pins / location.
Clock Topology	External resonator, clipped-sine / CMOS clock input, internal RC source or shared / distributed reference.
Crystal / XO Requirements	Frequency, package, CL, ESR, C0, drive and ppm budget; or VDD, waveform, amplitude, load, enable, startup and phase-noise requirements.
RF Requirements	Center, occupied bandwidth, passband loss / ripple, rejection mask, impedance, power, S-parameters, matching and antenna topology.
Program Requirements	Operating environment, qualification / certification, prototype quantity, sample date, validation plan, annual volume, production location and lifecycle.

Equal Frequency Does Not Mean Equal Crystal

Two 32 or 48 MHz oscillator loops may specify different CL, ESR, C0, drive, startup and total frequency-error limits.

RF Band Does Not Define the Clock

A 2.4 GHz or 5 GHz radio normally uses a lower reference clock and generates the RF carrier within the synthesizer.

Module Boundary Changes the Opportunity

When the module integrates the crystal, RF IC, matching and antenna, selection moves to externally accessible host functions.

Frequency alone does not define the final part: the receiving interface, oscillator-loop limits, RF topology, power budget, environment and integration boundary determine the appropriate FCom series or frequency-specific P/N.

09

Engineering FAQ & Application Review

Common wireless clock and RF-front-end questions, representative public references and the information required for FCom engineering review.

Is 2.4 GHz the oscillator frequency used by a wireless SoC?

No. It is the RF carrier band. The SoC uses a lower reference clock and synthesizes the carrier internally.

Can the same 32 or 48 MHz crystal be used across different SoCs?

Not automatically. CL, ESR, C0, drive, tolerance, stability, startup margin and PCB parasitics must match the oscillator loop.

Is an external 32.768 kHz crystal always required?

No. Many SoCs provide an internal LFRC source. The external timebase is selected when timing, power or calibration objectives justify it.

Can a TCXO directly replace a passive crystal?

Only when the IC supports a compatible external clock input with the required waveform, amplitude, bias, startup and software configuration.

Can one 2.4 GHz SAW serve BLE, Thread, Zigbee and Wi-Fi?

Only after the passband, loss, RF power, matching, blocker, coexistence and antenna requirements are verified for the complete path.

Is bandwidth plus insertion loss enough to select a SAW?

No. Rejection mask, impedance, S-parameters, ripple, group delay, power, matching, temperature and layout also affect qualification.

Should a discrete crystal be proposed inside every UWB module?

No. If the module integrates the crystal and RF path, only exposed host-side or external functions should receive a component recommendation.

Does AEC-Q200 alone qualify the complete wireless product?

No. Component qualification is one input; the complete system still requires electrical, RF, EMC, thermal, manufacturing and end-product validation.

Representative Public Technical References

1. **Nordic Semiconductor:** nRF52840 product overview — Bluetooth LE, Thread, Zigbee, IEEE 802.15.4 and proprietary 2.4 GHz operation.
2. **Nordic Semiconductor:** nRF52840 Product Specification · CLOCK — 32 MHz HFXO and 32.768 kHz LFXO requirements.
3. **Texas Instruments:** CC1352P7 Datasheet — Sub-1 GHz / 2.4 GHz bands, 48 MHz crystal and optional low-frequency sources.
4. **Texas Instruments:** CC13xx / CC26xx Hardware Configuration and PCB Design Considerations — crystal, TCXO and RF implementation guidance.
5. **Espressif Systems:** ESP32-C5 product overview — 2.4 / 5 GHz Wi-Fi 6, Bluetooth LE and IEEE 802.15.4 platform.
6. **Espressif Systems:** ESP32-C5 schematic checklist — 48 MHz crystal, optional 32.768 kHz source and separate RF paths.
7. **Qorvo:** DWM3000 product page — integrated UWB module supporting channels 5 and 9.
8. **Qorvo:** DW3000 / QM33100 Hardware Design Guide — bare-transceiver reference and RF implementation context.

FCom product specification note: configurable product information in this guide is presented at series or representative-configuration level. Exact ordering codes, guaranteed limits and availability are confirmed against the applicable FCom product specification and quotation.

ENGINEERING REVIEW

Wireless Connectivity & RF Front-End Review

Provide the target SoC / transceiver / module, replaceable node, clock-loop or CLKIN requirements, RF band / filter mask, temperature, package and project stage. FCom can recommend the most relevant timing or RF-filter configuration for system validation.

[Request Engineering Review →](#)
[FCom Solutions](#)

This guide provides representative application and product-selection guidance. Final component selection is confirmed against the latest target-device documentation and the applicable FCom product specification, followed by validation on the complete board, RF path, antenna and end product.