

SMART APPLIANCES & HOME CONTROLLERS

Smart Appliances & Home Controllers

This guide supports the selection of practical timing and RF components for appliance control, retained-time functions, connected HMI, motor and sensor control, and regional remote-control links.

Cost-Optimized MCU Timing + RTC + Connected HMI + Sub-GHz RF

Refrigerators

Washing Machines

Air Conditioners

Robot Vacuums

Smart Kitchen

Home Controllers

Application Scope

White goods, HVAC controllers, coffee machines, robot vacuums, connected kitchen appliances, remote controls and home-control panels combining MCU control, RTC, display / touch, wireless connectivity and motor / sensor functions.

Selection Philosophy

Selection begins with the receiving clock node. A passive crystal is generally evaluated first for an MCU oscillator loop; a CMOS XO may be considered when the controller expects a driven clock or the architecture benefits from a dedicated source.

Control

MCU, motor-control and sensor-processing references.

Retained-Time

RTC, schedules, event records and power-loss recovery.

Connected HMI

Display, touch, voice and Wi-Fi / Bluetooth functions.

Remote RF

Regional Sub-GHz links and conditional narrowband IF filtering.

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Application Scope & Engineering Domains

Smart appliances combine cost-sensitive control timing with RTC, connected HMI and, in selected products, regional Sub-GHz RF functions.

One appliance, several timing domains. The system MCU, wireless controller, display / touch subsystem and RTC may each use a separate reference. Motor PWM, ADC sampling and sensor rates are normally generated inside the controller and should not be confused with the external crystal frequency.

Typical Equipment

White Goods & HVAC

Refrigerators, washing machines, air conditioners, heat-pump controllers and other motorized appliances with power, motor, sensor and user-interface domains.

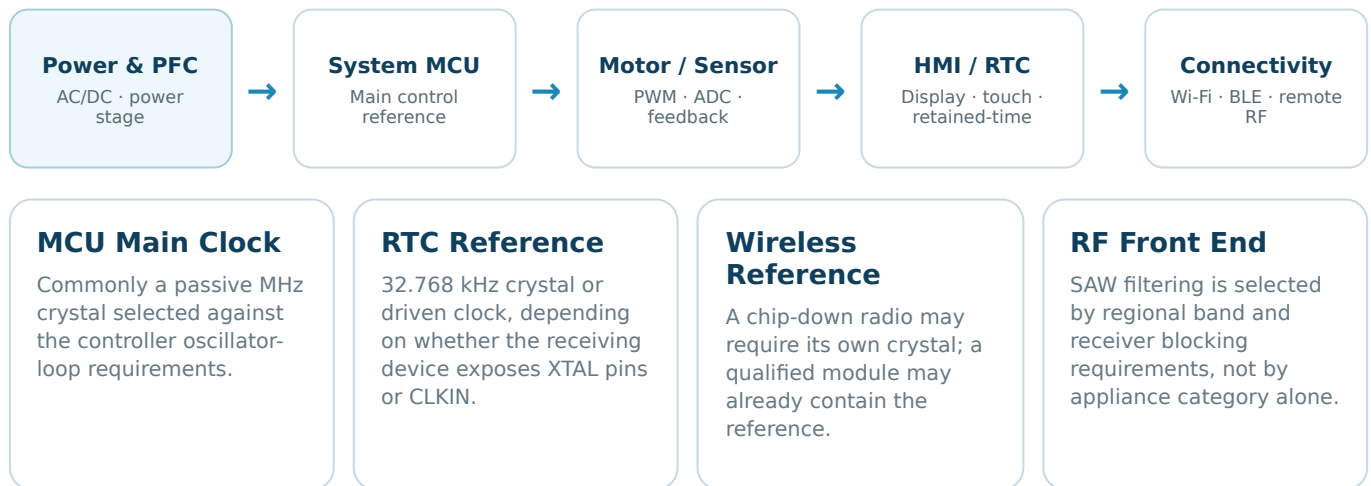
Kitchen & Cleaning

Coffee machines, cooking appliances, robot vacuums and countertop products combining control, sensing, display and optional wireless connectivity.

Home Control & Remote

Touch panels, voice-enabled controllers, appliance remotes and gateways using Wi-Fi, Bluetooth, Zigbee / Thread or regional Sub-GHz links.

Representative System Architecture



Primary engineering priorities: cost, stable startup, high-volume consistency, long-term supply, automated SMT compatibility, operating-temperature margin and reliable wireless connectivity. Ultra-low jitter is not normally a primary selection criterion for this application class.

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Select by System Node First

Confirm the receiving IC and clock interface before choosing a crystal, oscillator or RF filter.

XTAL / XIN-XOUT Pins

The receiving IC provides the oscillator loop. Select a passive crystal by frequency, CL, ESR, drive level, startup margin, package and temperature.

Typical path for cost-sensitive MCU control

CLKIN / Oscillator Input

The node expects a driven clock. Confirm VDD, CMOS threshold, load, duty cycle, output enable and stability before selecting an XO.

Applicable when the architecture requires a driven source

RF / IF Signal Path

A SAW or crystal filter is not a clock source. Select it by center / IF frequency, bandwidth, insertion loss, rejection, impedance and receiver topology.

Regional and architecture dependent

System Node	Common Public Frequencies	Typical Component Class	Primary Selection Checks
General MCU / Motor Controller	8 · 10 · 12 · 16 · 20 · 24 · 25 MHz	MHz quartz crystal	Oscillator-loop topology, CL, ESR, drive level, startup and conducted / radiated noise.
Wireless MCU / Radio	24 · 26 · 32 · 40 · 48 MHz	Crystal for chip-down design; module-integrated reference when applicable	Radio accuracy, layout, load tuning, temperature drift and certification margin.
Display / Touch / Connected HMI	12 · 24 · 25 · 27 · 40 MHz	Crystal or standard CMOS XO	XTAL versus CLKIN, source direction, VDD, load and EMI behavior.
RTC / Calendar / Scheduler	32.768 kHz	Tuning-fork crystal or low-power CMOS oscillator	XTAL loop versus CLKIN, CL, ESR, backup supply, current and timekeeping objective.
Sub-GHz Remote RF	315 · 433.92 · 868 / 869 · 915 MHz	Conditional SAW filter	Region, modulation, channel bandwidth, blocking, coexistence, impedance and certification.
Defined Narrowband IF Receiver	10.7 · 21.4 · 45 MHz classes	Conditional monolithic crystal filter	Actual IF, 3 dB bandwidth, stopband, termination and receiver gain / noise budget.

High-Volume Consistency

Use the complete tolerance and temperature budget; nominal frequency and package alone do not define a production-ready selection.

Module Boundary

An integrated wireless module may already include its crystal and RF network. External timing or RF components should be considered only for a module-level redesign or chip-down implementation.

Performance Discipline

TCXO, OCXO or low-jitter products should be evaluated when the receiving specification or system accuracy budget establishes a corresponding requirement.

Practical rule: FCom generally recommends a passive crystal where the controller provides an oscillator loop, a standard CMOS XO where a driven reference is documented, and SAW filtering after the Sub-GHz front-end requirements have been defined.

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Frequency & Component Placement Matrix

The same nominal frequency can serve different functions; the receiving node and clock topology determine the component class.

Frequency / Band	Representative System Position	Architecture Interpretation	FCom Application Direction
8–12 MHz	Motor-control MCU, PFC controller, cost-sensitive system MCU	Normally a passive resonator connected to the controller oscillator loop.	Evaluate an MHz crystal with suitable low-frequency ESR and startup margin.
16–25 MHz	General MCU, HMI controller, Ethernet-capable appliance controller	May be a crystal or a driven source, depending on the receiving IC.	Confirm XTAL versus CLKIN before selecting a crystal or standard CMOS XO.
24 / 26 / 32 MHz	Application processor, Zigbee / Thread / BLE controller, connectivity subsystem	Often local to the chip-down processor or radio; module products may integrate it.	Consider a compact MHz crystal where the external oscillator loop is exposed.
40 MHz	Wi-Fi / Bluetooth MCU, connected HMI	Radio reference accuracy and load tuning affect RF frequency error and certification margin.	Match crystal accuracy, CL, ESR and PCB tuning to the radio vendor guidance.
48 MHz	Multi-band Sub-GHz / 2.4 GHz wireless MCU	May be required for radio operation even when an internal RC source is available for digital functions.	Use the target radio data sheet to define the external crystal requirements.
32.768 kHz	RTC, calendar, scheduler, event log and low-power wake timing	External crystal loop and driven CLKIN are separate architectures.	Choose a tuning-fork crystal or low-power oscillator only after confirming the receiver interface.
315 / 433.92 / 868 / 915 MHz	Remote-control and regional Sub-GHz receiver front end	RF filtering decision based on region, channel plan, blocking and antenna / matching design.	Evaluate a published SAW filter configuration after the complete RF requirements are known.
10.7 / 21.4 / 45 MHz IF	Discrete narrowband receiver intermediate-frequency path	Not applicable to direct-conversion or fully integrated radio SoCs without a matching IF.	Evaluate a crystal filter only when the IF frequency, bandwidth and termination are explicitly defined.

10 MHz

The public RA6T2 motor-control board illustrates a defined external MCU-reference node.

24 / 32 MHz

Representative processor and low-power mesh-radio reference domains.

40 / 48 MHz

Representative integrated wireless-MCU reference domains.

32.768 kHz

Independent retained-time and low-power timing domain.

The external reference cannot be inferred from CPU speed, wireless carrier frequency or motor PWM rate. A 240 MHz MCU may use a 10 MHz crystal, while a 2.4 GHz radio may use a 40 or 48 MHz reference.

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Representative Platform & Architecture Matrix

Four publicly documented platforms illustrate motorized white goods, a rich home-control panel, a cost-optimized connected HMI and a multi-band remote / controller node.

RENESAS · MOTORIZED WHITE GOODS

Integrated Washer-Dryer + MCB-RA6T2

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Public architecture combines PFC, coordinated BLDC control for drum, fan and heat-pump motors, and Wi-Fi / Bluetooth LE connectivity. The MCB-RA6T2 board specifies a 10 MHz external MCU reference.

10 MHz reference → RA6T2 control → PFC / BLDC

Architecture takeaway: the example contains a defined external MCU-reference node; component selection depends on CL, ESR, drive level and startup margin.

NXP · RICH HOME HMI

Home Control Panel

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Public block diagram combines i.MX 8M Mini, PCA9450 PMIC, Zigbee / Thread / Bluetooth and Wi-Fi options. It separates a 24 MHz MPU reference, 32.768 kHz retained-time path and 32 MHz / 32.768 kHz low-power radio references.

24 MHz MPU + 32.768 kHz RTC + 32 MHz radio

Architecture takeaway: the processor, RTC and chip-down radio are separate clock nodes; a common source should not be assumed.

ESPRESSIF · CONNECTED APPLIANCE HMI

ESP32-S3-BOX-3

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Representative AIoT platform combines Wi-Fi / Bluetooth, LCD, microphone, speaker and HMI functions. ESP32-S3 chip-down guidance specifies a required 40 MHz crystal and an optional 32.768 kHz RTC crystal.

40 MHz crystal → ESP32-S3 → HMI / Wi-Fi / BLE

Architecture takeaway: the external-crystal node applies to chip-down or custom-module implementations; a finished module may already incorporate its timing components.

TEXAS INSTRUMENTS · MULTI-BAND REMOTE

LP-CC1352P7 / CC1352P7

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Public platform supports concurrent Sub-GHz and 2.4 GHz operation. Radio operation requires an external 48 MHz crystal; a 32.768 kHz watch crystal is one option for RTC and low-power timing.

48 MHz crystal → CC1352P7 → Sub-GHz + 2.4 GHz

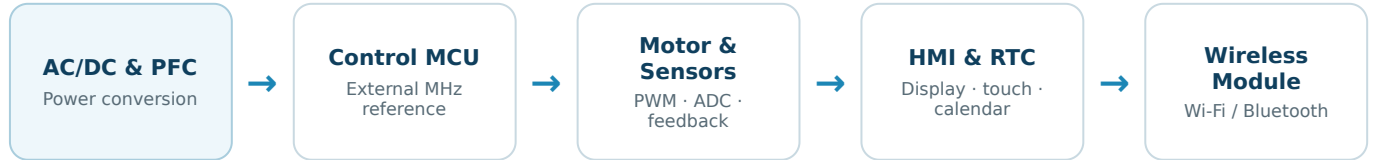
Architecture takeaway: regional SAW filtering should be considered after the 433 or 868 / 915 MHz variant, blocking target and complete RF network are defined.

Public-platform boundary: these references illustrate clock and RF architectures only. Their inclusion does not indicate that FCom components were used, qualified, endorsed or verified as compatible, nor does it imply pin-to-pin replacement.

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Cost-Optimized Appliance Control Architecture

Representative component placement for a motorized appliance with system control, sensors, retained-time and optional wireless connectivity.



NODE 1 MCU Main Reference

8-80 MHz crystal domain

Covers common cost-sensitive control frequencies, including the 10 MHz public motor-control example.

Selection checks

Frequency · CL · ESR · drive level · startup · temperature · package.

Representative FCom option FCX-3M

· 3225 4-SMD · 8-80 MHz · tolerance options as tight as ± 5 ppm · stability options as tight as ± 10 ppm · -40°C to $+125^{\circ}\text{C}$ · CL specified by application.

NODE 2 Motor & Sensor Timing

Derived control timing

PWM, ADC sampling, commutation and sensor intervals are normally generated by MCU timers.

Noise environment

Verify startup and frequency margin near switching power, gate-drive and motor-current paths.

Component interpretation

A separate oscillator is not added for each motor or sensor unless the downstream device exposes an independent clock input.

NODE 3 RTC / Scheduler

32.768 kHz crystal path

Supports calendars, delayed start, maintenance records and retained-time through backup-power states.

Selection checks

XTAL topology · CL · ESR · negative resistance · backup voltage · timekeeping budget.

Representative FCom option FCT-2M

· 2012 2-SMD · 32.768 kHz · tolerance options as tight as ± 5 ppm · -40°C to $+125^{\circ}\text{C}$ · CL 6-12.5 pF · ESR 70-90 k Ω .

Main Control Board

Where the MCU provides a documented oscillator loop and no distributed clock is required, the passive-crystal path is generally preferred.

Wireless Module

Where a certified module already includes its reference, no external board-level crystal is normally required. Confirm the module boundary before defining the BOM.

Production & Assembly

Confirm reflow profile, board cleaning, vibration, mechanical stress, grounding and switching-noise exposure during complete appliance validation.

Selection boundary: FCX-3M and FCT-2M are representative starting points rather than confirmed drop-in selections. FCom confirms the complete ordering configuration against the target MCU / RTC data sheet and the applicable FCom specification.

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Connected HMI + Remote RF Architecture

Representative timing and filtering around a home-control panel, connected appliance HMI or multi-protocol remote.



CLOCK PATH Crystal or CMOS XO

XTAL-input controller

Consider a passive crystal for 24 / 32 / 40 / 48 MHz-class chip-down processors and radios where the oscillator loop is exposed.

Driven CLKIN controller

Consider a standard CMOS source when VDD, threshold, load and output-enable behavior are defined.

Representative FCom options

FCX-2S

· 2016 · 16–96 MHz · –40°C to +125°C.

FCO-2C

· 2520 CMOS XO · 1.25–125 MHz · 1.8 / 2.5 / 3.3 V · ±20 ppm · –40°C to +125°C.

RTC PATH Driven 32.768 kHz

CLKIN-only RTC

A driven 32.768 kHz source is separate from the tuning-fork crystal oscillator-loop path.

Selection checks

Supply · CMOS threshold · current · load · backup behavior · startup.

Conditional FCom option FCO-6K-UC

· 2016 CMOS · 32.768 kHz · 1.5 / 1.8 V · ±20 ppm · –40°C to +105°C · 1.4–1.8 µA.

Representative Published Sub-GHz SAW Configurations

Region / Center	FCom P/N	Package	Bandwidth	Insertion Loss	Published Stopband Attenuation
315 MHz	FSF3030-315M-1M-2-50	SMD3030	1 MHz	2 dB	50 dB
433.92 MHz	FSF3030-433M92-1M71-2.5-50	SMD3030	1.71 MHz	2.5 dB	50 dB
868 MHz	FSF3030-868M-10M-1.9-40	SMD3030	10 MHz	1.9 dB	40 dB
915 MHz	FSF1411-915M-26M-1.5-50	CSP1411	26 MHz	1.5 dB	50 dB

RF boundary: the listed SAW filters are representative published configurations, not default replacements for every regional radio. Final selection requires the complete passband definition, impedance, matching network, antenna environment, blocking test and regulatory target. A SAW resonator is not interchangeable with a receiver band-pass filter.

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FCom Selection Guidance by Design Condition

Representative FCom options are organized by the design conditions that materially change component selection. FCom confirms the complete ordering configuration during application review.

Control Crystal

Cost-sensitive MCU and motor-control oscillator loops.

Connected Node

Compact crystal or standard CMOS source for HMI and radio nodes.

RTC

Crystal-loop and driven-clock retained-time architectures.

RF / IF

Regional SAW filtering and conditional narrowband IF selection.

Design Condition	Representative FCom Option	Representative Series Data	Key Check Before RFQ
General MCU or 10 MHz-class motor controller exposes XTAL pins	FCX-3M	3225 4-SMD · 8–80 MHz · tolerance options as tight as ± 5 ppm · stability options as tight as ± 10 ppm · -40°C to $+125^{\circ}\text{C}$.	Frequency · CL · ESR · drive level · startup · package
Compact connected MCU / radio exposes XTAL pins	FCX-2S	2016 4-SMD · 16–96 MHz · tolerance options as tight as ± 5 ppm · stability options as tight as ± 10 ppm · -40°C to $+125^{\circ}\text{C}$.	Radio accuracy · CL · ESR · PCB tuning · module boundary
RTC exposes 32.768 kHz XTAL pins	FCT-2M	2012 2-SMD · tolerance options as tight as ± 5 ppm · -40°C to $+125^{\circ}\text{C}$ · CL 6–12.5 pF · ESR 70–90 k Ω .	RTC topology · negative resistance · CL · backup supply
RTC or low-power controller requires driven CLKIN	FCO-6K-UC	2016 CMOS · 32.768 kHz · 1.5 / 1.8 V · ± 20 ppm · -40°C to $+105^{\circ}\text{C}$ · 1.4–1.8 μA .	VDD · VIH / VIL · load · current · startup · OE
Complex controller requires local CMOS clock	FCO-2C	2520 4-SMD · 1.25–125 MHz · 1.8 / 2.5 / 3.3 V · ± 20 ppm · -40°C to $+125^{\circ}\text{C}$.	CLKIN topology · frequency · VDD · load · duty cycle · OE
Receiver has a defined 21.4 or 45 MHz narrowband IF	FCF-7M · type 21MQ15A / 45MQ15A	7050 6-SMD · 21.4 or 45 MHz · representative 3 dB bandwidth 7.5 kHz.	IF frequency · bandwidth · insertion loss · attenuation · termination

When to consider higher-performance timing: TCXO, VCXO, OCXO and low-jitter differential oscillators are normally evaluated when a documented synchronization, tuning, accuracy or jitter requirement calls for the additional device class.

APPLICATION ENGINEERING SUPPORT

Request an FCom Appliance Timing Review

Provide the target MCU / MPU / radio / RTC part number, clock pins, frequency, CL / ESR or supply / output, temperature, package, RF band / bandwidth and project volume.

[Start Engineering Review →](#)

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Engineering Validation & Minimum RFQ

A reliable high-volume selection requires the receiving interface, operating environment and production requirements in addition to nominal frequency.

Control MCU / Motor Controller

- Exact IC and package
- XTAL / XIN-XOUT or CLKIN
- Frequency and internal PLL use
- CL / ESR / drive or VDD / logic
- Startup and noise environment
- Operating temperature

RTC / Retained-Time

- MCU / RTC part number
- Crystal loop or driven input
- CL, ESR and negative resistance
- Backup voltage and current
- Required clock / calendar accuracy
- Power-state behavior

Wireless / Connected HMI

- Chip-down IC or module P/N
- 24 / 26 / 32 / 40 / 48 MHz requirement
- Load tuning and RF accuracy
- Display / touch clock topology
- Module certification boundary
- Board-space constraint

Sub-GHz RF / Narrowband IF

- Region and center / IF frequency
- Passband / 3 dB bandwidth
- Insertion-loss budget
- Stopband / blocking targets
- Source / load impedance
- Matching, antenna and certification plan

Minimum RFQ Information

Information Category	What to Provide
Application / System Node	Appliance type and exact node: system MCU, motor MCU, HMI, wireless radio, RTC, Sub-GHz front end or narrowband IF.
Target Device	Exact receiving IC / module part number, package, clock pins and schematic location.
Clock Topology	External resonator, local CMOS XO, module-integrated source, shared clock or external 32.768 kHz CLKIN.
Crystal Requirements	Frequency, package, CL, ESR, tolerance, stability, drive level, startup and operating temperature.
XO Requirements	Frequency, VDD, CMOS thresholds, load, duty cycle, stability, temperature, current and OE behavior.
RF / IF Requirements	Center / IF frequency, passband, insertion loss, attenuation masks, impedance, matching and regulatory region.
Program Requirements	Prototype quantity, sample date, annual volume, production location, lifecycle target, reflow profile and compliance documents.

Frequency Is Not a Complete Part Number

Load capacitance, ESR, tolerance / stability, package and temperature remain part of the crystal configuration.

Module and Chip-Down BOMs Differ

A module may already incorporate its timing and RF network, while a chip-down design includes device-level selection and validation responsibilities.

RF Filters Require System Testing

Published center frequency alone does not confirm passband suitability, impedance match, blocking performance or regulatory compliance.

High-volume validation: FCom recommends reviewing component distribution over temperature and production lots, oscillator startup at supply corners, PCB parasitics, reflow / mechanical stress, EMI exposure and complete-system wireless performance before release.

09

Engineering FAQ & Application Review

Common appliance timing questions, public architecture references and the information required for FCom engineering review.

Is the MCU operating frequency the external crystal frequency?

No. The crystal feeds the oscillator / PLL domain; the controller normally generates its higher CPU and peripheral clocks internally.

Does every appliance controller need an XO?

No. A passive crystal is normally preferred when the MCU provides an oscillator loop. An XO should be considered for a documented driven-clock input or system requirement.

Can an external crystal replace the one inside a wireless module?

A board-level external crystal normally does not replace a reference integrated within a completed module. Component selection becomes applicable within a module redesign or chip-down architecture.

When should a 32.768 kHz oscillator replace a crystal?

When the RTC or controller accepts a driven CLKIN, or when the system architecture requires a buffered source. Confirm supply, current and logic thresholds.

Does every Sub-GHz radio need a SAW filter?

No. It depends on regional band, radio architecture, blocking environment, coexistence, antenna / matching design and certification targets.

Is a SAW resonator equivalent to a SAW band-pass filter?

No. A resonator can set the frequency in selected RF oscillators; a filter shapes a receiver or transmitter signal path. Their functions are not interchangeable.

When is an MCF appropriate?

An MCF may be considered for a receiver with a defined narrowband intermediate frequency, bandwidth and termination. It is not normally used with integrated direct-conversion radios.

When is low jitter a first-order requirement?

Low jitter becomes a first-order requirement when the receiving device specifies an RMS-jitter or phase-noise limit. Typical appliance control is more often governed by accuracy, startup, cost and lifecycle.

Representative Public Technical References

1. **Renesas:** Integrated Washer-Dryer System with PFC — coordinated PFC, multi-motor BLDC control and wireless connectivity.
2. **Renesas:** MCB-RA6T2 User's Manual — public 10 MHz MCU input-clock reference and motor-control board architecture.
3. **NXP:** Home Control Panel — i.MX 8M Mini, PMIC, security, NFC and multi-radio functional blocks.
4. **NXP:** i.MX 8M Mini data sheet — 24 MHz primary reference and 32.768 kHz retained-time clock requirements.
5. **Espressif:** ESP32-S3 hardware guidelines — required 40 MHz crystal and optional 32.768 kHz RTC crystal.
6. **Texas Instruments:** CC1352P7 data sheet — external 48 MHz crystal for radio operation and optional 32.768 kHz low-frequency source.

FCom product specification note: information in this guide is presented at series or representative published-configuration level. FCom confirms exact ordering codes, guaranteed limits and availability against the applicable product specification and quotation for the required frequency and electrical configuration.

ENGINEERING REVIEW

Smart Appliances & Home Controllers Review

Provide the target controller / radio / RTC part number, clock input, frequency, CL / ESR or supply / output, operating temperature, package, RF / IF requirements, project stage and annual volume. FCom can recommend an appropriate component series and configuration for system validation.

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

This guide provides representative application and product-selection guidance. FCom confirms the proposed component configuration against the applicable product specification and the target-device information provided; final suitability must be validated on the complete customer board and appliance system.