

AN1292: Si5332-AM SmartClock™ Fault Detection and Monitoring

What is the Si5332-AM family and why use it in automotive applications?

Automotive electronics system designs have traditionally depended on multiple pieces of quartz crystals and quartz crystal oscillators to provide timing references for all the required system clocks. One of the largest drawbacks to this approach is that quartz-based components have the highest FIT rates of any electronic systems component, which greatly affects system reliability. As designs continue to adopt processors with greater functionality with higher speed SerDes, Ethernet connectivity, and PCI-Express data buses, the need for more reference clocks arises, with both single-ended and differential formats, and lower RMS phase jitter.

The Si5332-AM family of clock generators is designed to overcome the challenges associated with increasingly complex clock tree design in automotive electronics. These devices are capable of supporting up to 12 unique frequency outputs, all of which can be individually programmed to its own electrical format (i.e., LVCMOS, LVDS, HCSL, etc.). By consolidating the functionality of many pieces of quartz-based components into a silicon-based clock generator, system designers can eliminate many points of failure and greatly improve overall system reliability.

In addition to component count reduction and reliability improvements, clock generators offer numerous additional benefits that are not available from quartz-based timing components. The Si5332-AM clock generators provide in-system programming capability, spread spectrum modulation, output enable control, and frequency selection capabilities. To help system designers meet system level safety goals, the Si5332-AM devices also come equipped with SmartClock features that include redundant reference inputs, health monitoring, fault detection, communication with an external safety manager, primary/back-up reference source switching, and AlwaysON outputs. This application note provides an overview of the SmartClock features and outlines system level examples on how to implement them.

KEY POINTS

- SmartClock features
- System implementation examples

1. Focus of this Application Note: Si5332-AM SmartClock Features

This application note will specifically focus on the integrated clock fault detection features of the Si5332- AM Clock Generator family. For more details on the many other features and benefits of the Si5332-AM device family and other automotive timing products, please browse the link below.

<https://www.skyworksinc.com/en/Products/Timing-Automotive-Timing>

The Si5332-AM programmable clock generators can be easily customized to individual design clock tree requirements by creating a configuration file using the ClockBuilder Pro Software Utility. Users can enable the Si5332-AMs SmartClock features during configuration file development. ClockBuilder Pro can be downloaded for free:

<https://www.skyworksinc.com/en/Application-Pages/Clockbuilder-Pro-Software>

2. SmartClock Health Monitoring and Fault Detection Features within Si5332-AM

Shown below is a generic block diagram of the Si5332-AM clock generator family of devices. The three devices in this family are as follows:

- Si5332-AM1: 2 input (xtal + 1 CLKIN), 6 output
- Si5332-AM2: 3 input (xtal + 2 CLKIN), 8 output
- Si5332-AM3: 3 input (xtal + 2 CLKIN), 12 output

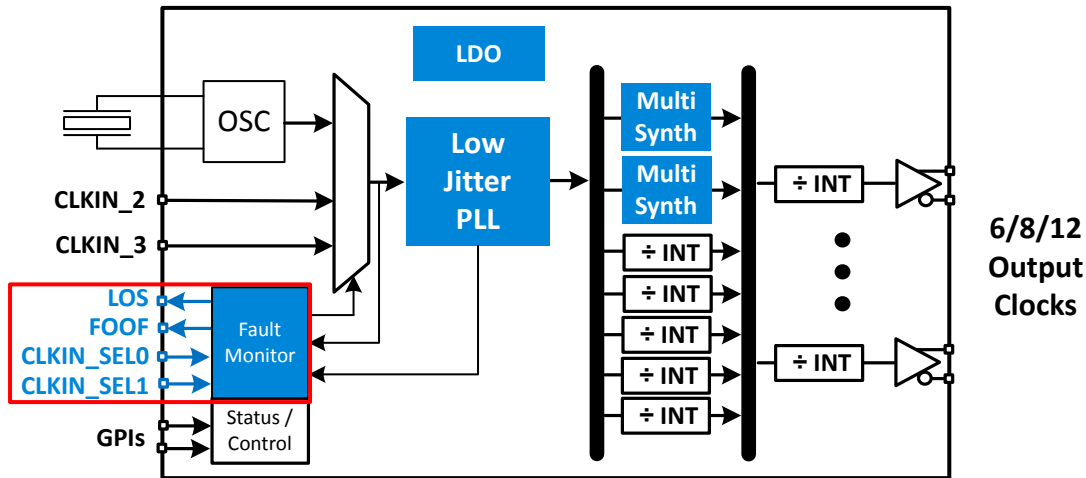


Figure 2.1. Si5332-AM Block Diagram

2.1 Fault Monitor Block Overview

The Si5332-AM includes a bank of Universal GPIO pins that can be assigned to numerous functions during configuration file development in ClockBuilder Pro. System designers can choose to enable SmartClock features using some of the Universal GPIO pins, as highlighted within the red box in [Figure 2.1 Si5332-AM Block Diagram on page 3](#). When enabling these features, Skyworks recommends the use of a crystal reference source, as well as a backup input clock reference source. The Si5332-AM2 (8-output) and Si5332-AM3 (12-output) include a third reference input.

The Fault Monitor continuously monitors the status of the input clock reference to the PLL. If a fault condition is detected, a signal is provided to an external system safety manager or MCU, which can then direct the Si5332-AM to switch the reference source from the primary to the backup input source. The Fault Monitor block provides 4 signals, 2 input and 2 output, as follows:

- LOS (Loss of Signal) output: This output asserts when the frequency of the selected input clock falls below a set threshold. This frequency threshold is set by our CBPro configuration software based on input clock frequency.
- FOOF (Fast Out of Frequency) output: This output asserts when the difference between the PLL input reference frequency and PLL feedback frequency falls outside of a set band. FOOF assertion is an indication the PLL has either fallen out of lock or other PLL fault condition has occurred and the PLL may either be unlocked or otherwise not operational. The band limits are automatically set by CBPro.
- CLKIN_SEL[1:0]: Two logic inputs used to select one of 4 possible input clock sources for PLL reference.

2.2 External Action Required on Either LOS or FOOF Assertion

The LOS and FOOF signal outputs indicate that a fault condition has occurred. No action is automatically taken by the Si5332-AM as a result of these fault indications. An external device, such as an MCU or other system safety manager, must monitor LOS and FOOF outputs from the Si5332-AM, and can make a system level decision on potential courses of action for maintaining acceptable levels of system safety. The external device can then provide instructions back to the Si5332-AM to migrate from the faulted input reference to the backup input reference, or take action at the system level based on the severity of the detected fault.

2.3 CLKIN_SEL[1:0] Input Clock Selects: Input Clock Selection and Validation

CLKIN_SEL1	CLKIN_SEL0	Clock Selected	Note
0	0	Input disabled	To test input clock fault condition.
0	1	Crystal Oscillator	
1	0	Clock 2 Input	
1	1	Clock 3 Input	Only on -AM2 and -AM3 devices.

The CLKIN_SEL[1:0] inputs can be used to select which input clock source is to be used by the on-chip PLL for its clock reference. With this input selection capability an external device, such as an MCU, can be used to intelligently select an alternate (redundant) input clock reference as part of a fault recovery plan. For example, if assertion of the LOS signal is detected by an MCU, the MCU software can attempt to recover from this fault condition by selecting an alternate clock source.

In addition, when running system power-up or other diagnostics, the MCU software can test the functionality of LOS and FOOF by selecting the Input Disabled setting and then confirming assertion of LOS and FOOF as a result. Similarly, the MCU software can also confirm proper operation of any alternate clock input sources by selecting the alternate source(s) and confirming LOS and FOOF are not asserted.

3. System Implementation Examples Of Using Si5332-AM SmartClock Features

Several different use-case examples are presented below, complete with system level block diagrams showing how the Si5332-AM device can be implemented with the SmartClock features enabled. When coupled with an external MCU or system safety manager, the device provides the highest degrees of health monitoring, fault detection, and redundancy. These configurations highlight the flexibility in tailoring a solution to meet different levels of clocking fault detection and redundancy.

Devices noted in the block diagram that are highlighted in dark orange are the external devices and signals that support the various fault detection and control scenarios. For each configuration scenario, an associated example software flowchart of operations is provided. These flowcharts are meant to show how the input reference health monitoring and fault detection/recovery plan can be implemented.

3.1 Example #1: Single Device, No secondary Clock Sources

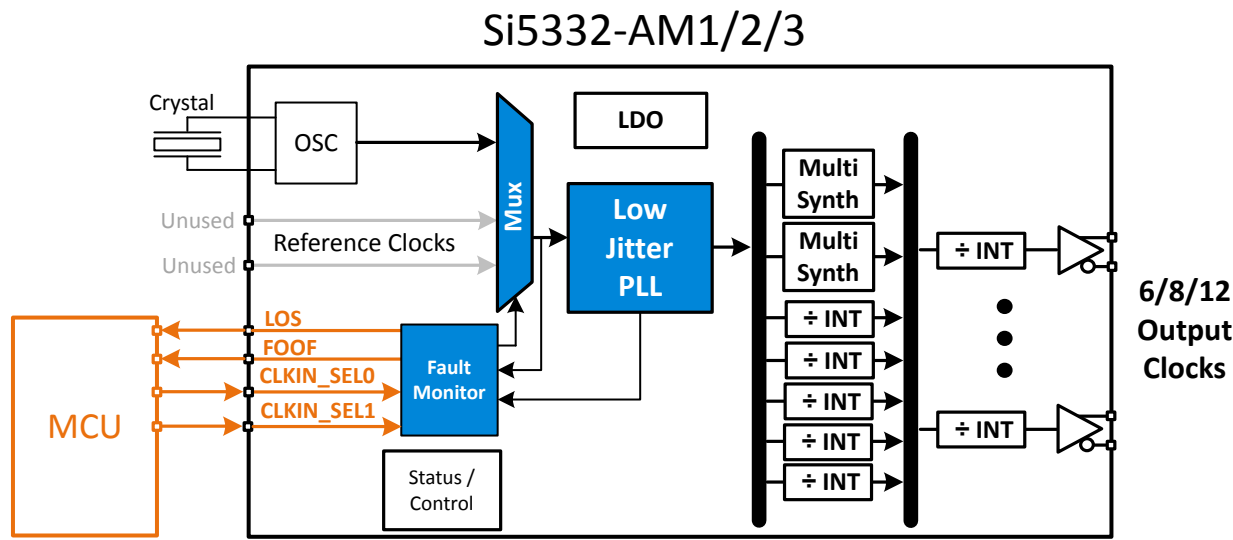


Figure 3.1. Si5332-AM Device without Secondary Reference Clock Sources

The figure above represents the simplest use case scenario where a single Si5332-AM is used without any secondary backup/redundant clock, but does have communication with an external MCU. In this scenario the Si5332-AM can communicate LOS and/or FOOF signal to the MCU if a fault condition is detected. The external MCU software can then decide what action to take based on the fault detected and overall system safety goals. The flowchart below is one example of how an external MCU could use the Fault Monitor control signals to implement a fault detection and control strategy.

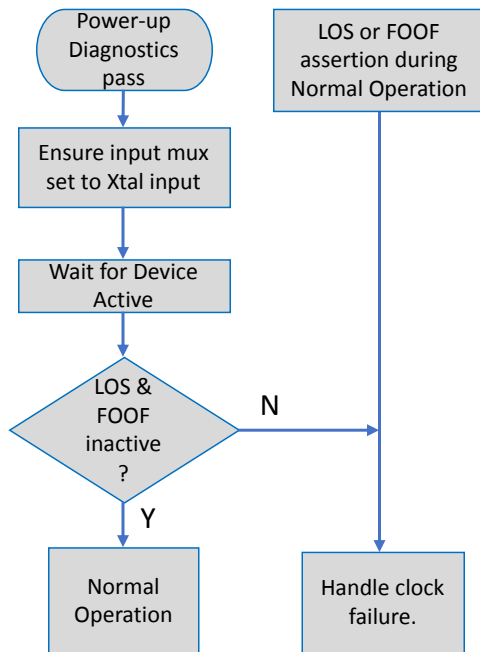


Figure 3.2. Example Control Software Flowchart for Si5332-AM without Secondary Clock Sources

3.2 Example #2: Single Device with Secondary Clock Sources

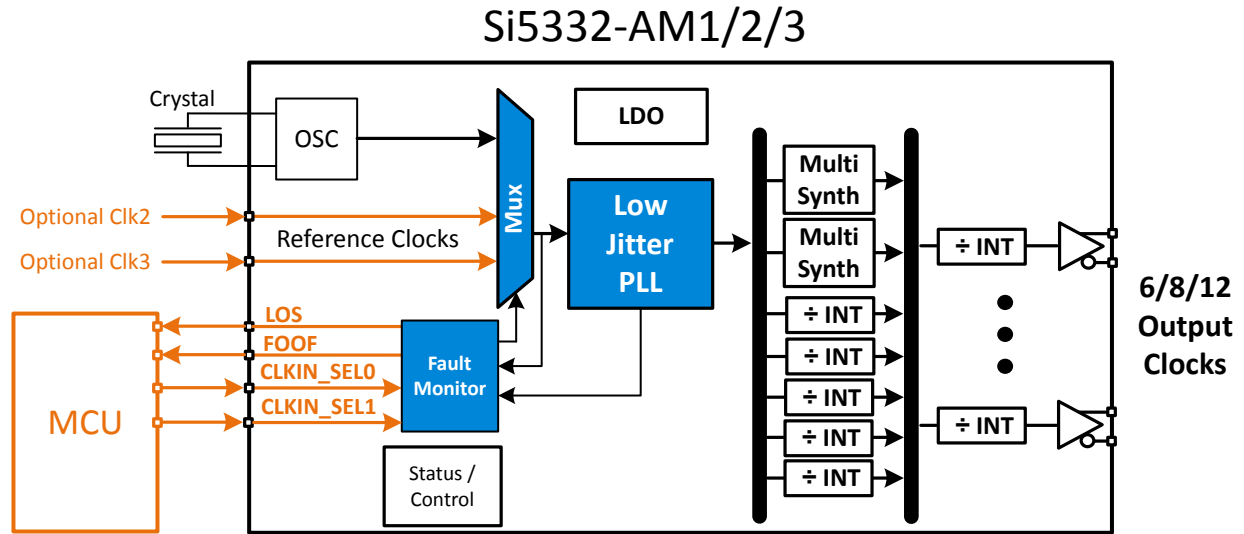


Figure 3.3. Si5332-AM Device with Secondary Reference Clock Sources

The figure above represents an optimal use case scenario where the SmartClock features are enabled and utilized, including a primary reference source and one or more secondary/redundant reference clock sources.

In this scenario the Si5332-AM can communicate LOS and/or FOOF signals to the external MCU if a fault condition is detected. The external MCU software can then decide what action to take, such as toggling the CLKSEL[1:0] pins to switch from the primary reference source (which has faulted) to one of the secondary reference clock sources. If switching to a secondary clock source removes the fault, the MCU code can signal the fault was corrected and then take appropriate system action for this case. Below is an example flowchart of the MCU software for this scenario.

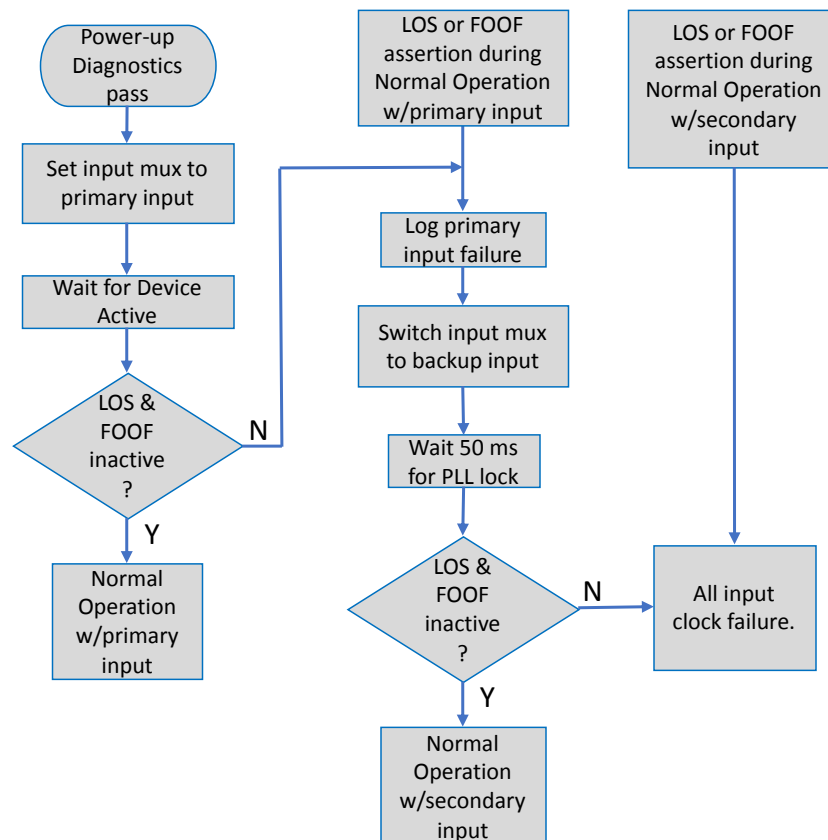


Figure 3.4. Example Control Software Flowchart for Si5332-AM with Secondary Clock Sources

3.3 Example #3 - Dual Redundant Devices, no Secondary Clock Sources

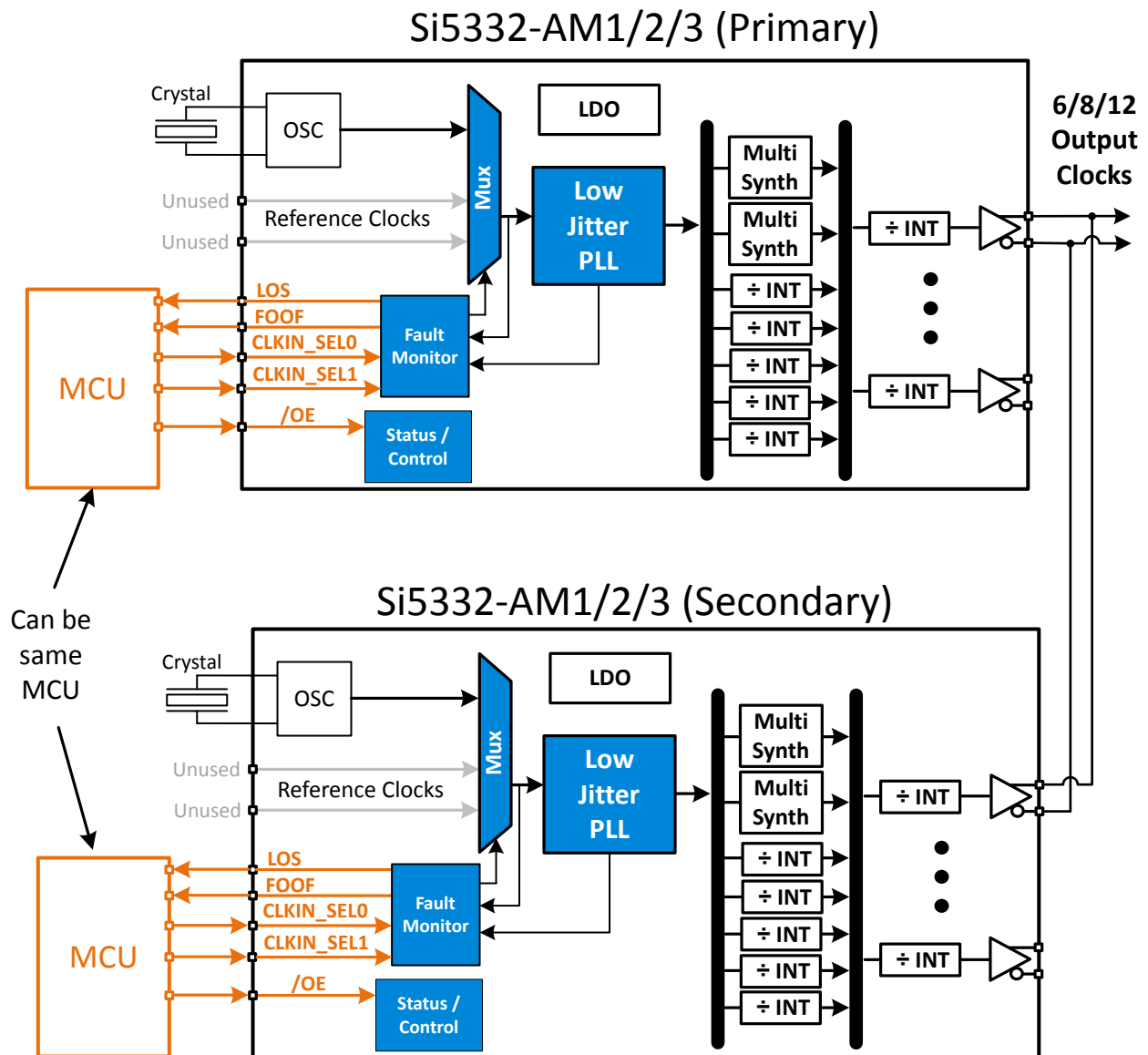


Figure 3.5. Redundant Si5332-AM Devices without Secondary Reference Clock Sources

The figure above represents a use case scenario where multiple Si5332-AM devices are operated in parallel for redundancy, but without any secondary/redundant input reference clock sources. In this scenario, the primary Si5332-AM (top) can communicate an LOS and/or FOOF signal to the MCU if a fault has been detected. The external MCU software can then decide if switching to the secondary Si5332-AM devices is appropriate based on the fault detected and overall system safety goals. If switching to a secondary device removes the fault condition, the MCU code can signal the fault was corrected and then take appropriate system action for this case. Below is an example flowchart of the MCU software for this scenario.

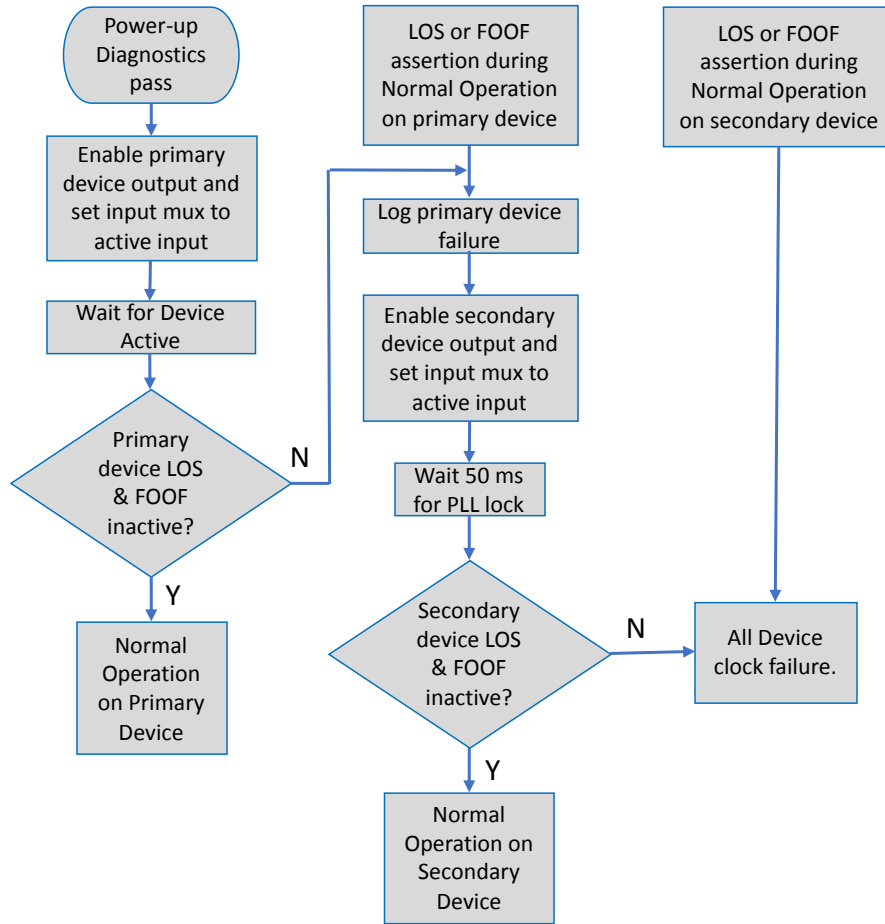


Figure 3.6. Example Control Software Flowchart of Redundant Si5332-AM Devices without Secondary Clock Sources

3.4 Example #4 - Dual Redundant Devices with Secondary Input Clocks

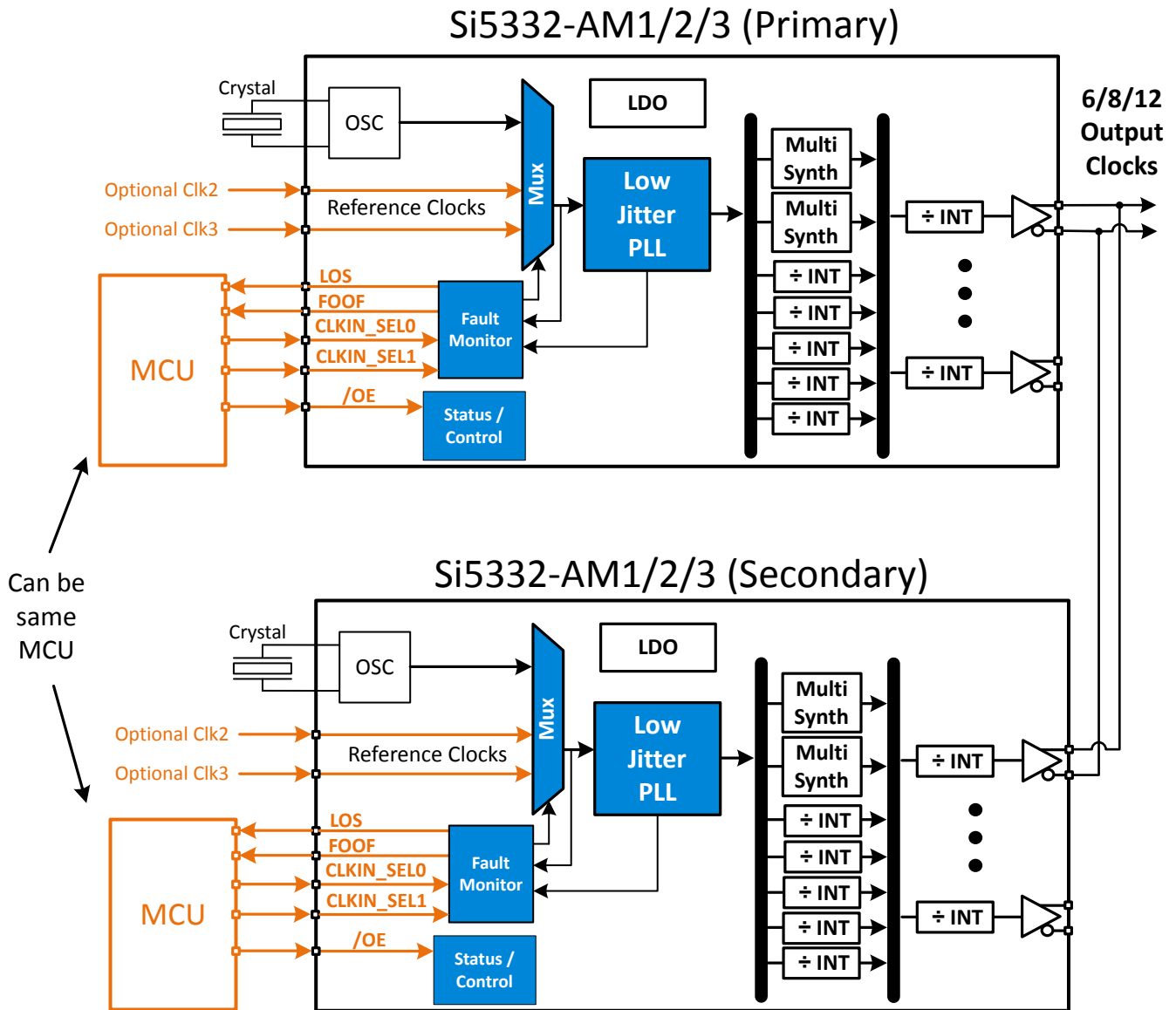


Figure 3.7. Redundant Si5332-AM Devices with Secondary Clock Sources

The figure above represents a use case scenario where multiple Si5332-AM devices are operated in parallel, and include secondary/redundant reference clock sources. In this scenario the primary Si5332-AM (top) can communicate an LOS and/or FOOF signal to the MCU if a fault has been detected on the crystal oscillator or PLL block. The external MCU software can then decide if switching to the secondary Si5332-AM device or secondary input clock source is appropriate based on the fault detected and overall system safety goals. If switching to a secondary device or secondary input clock source removes the fault condition, the MCU code can signal the fault was corrected and then take appropriate system action for this case. Below is an example flowchart of the MCU software for this scenario.

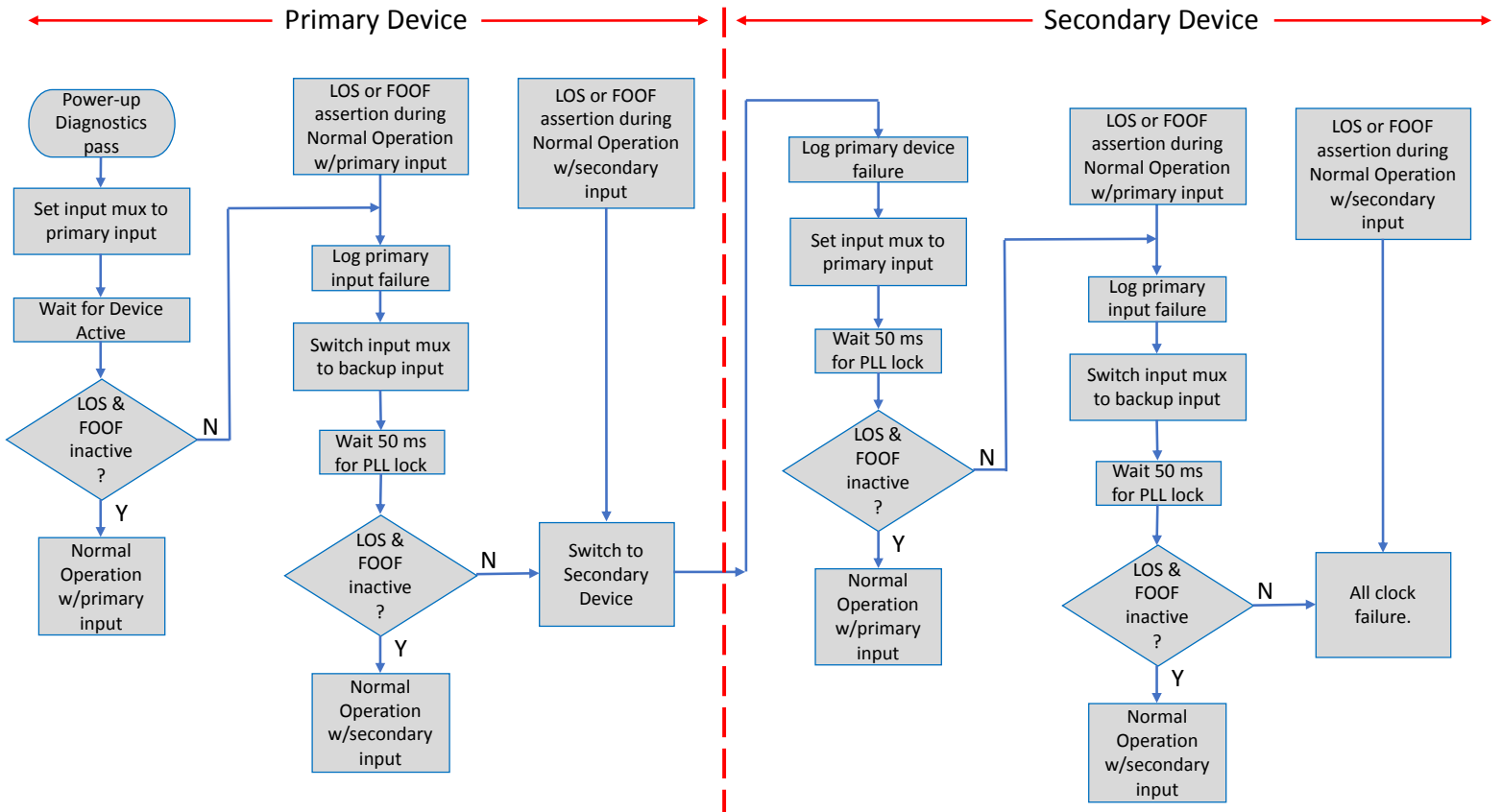


Figure 3.8. Example Control Software Flowchart of Redundant Si5332-AM devices with Secondary Clock Sources

3.5 Example #5 - Dual Redundant Devices with Cross-Coupled Reference Clocks

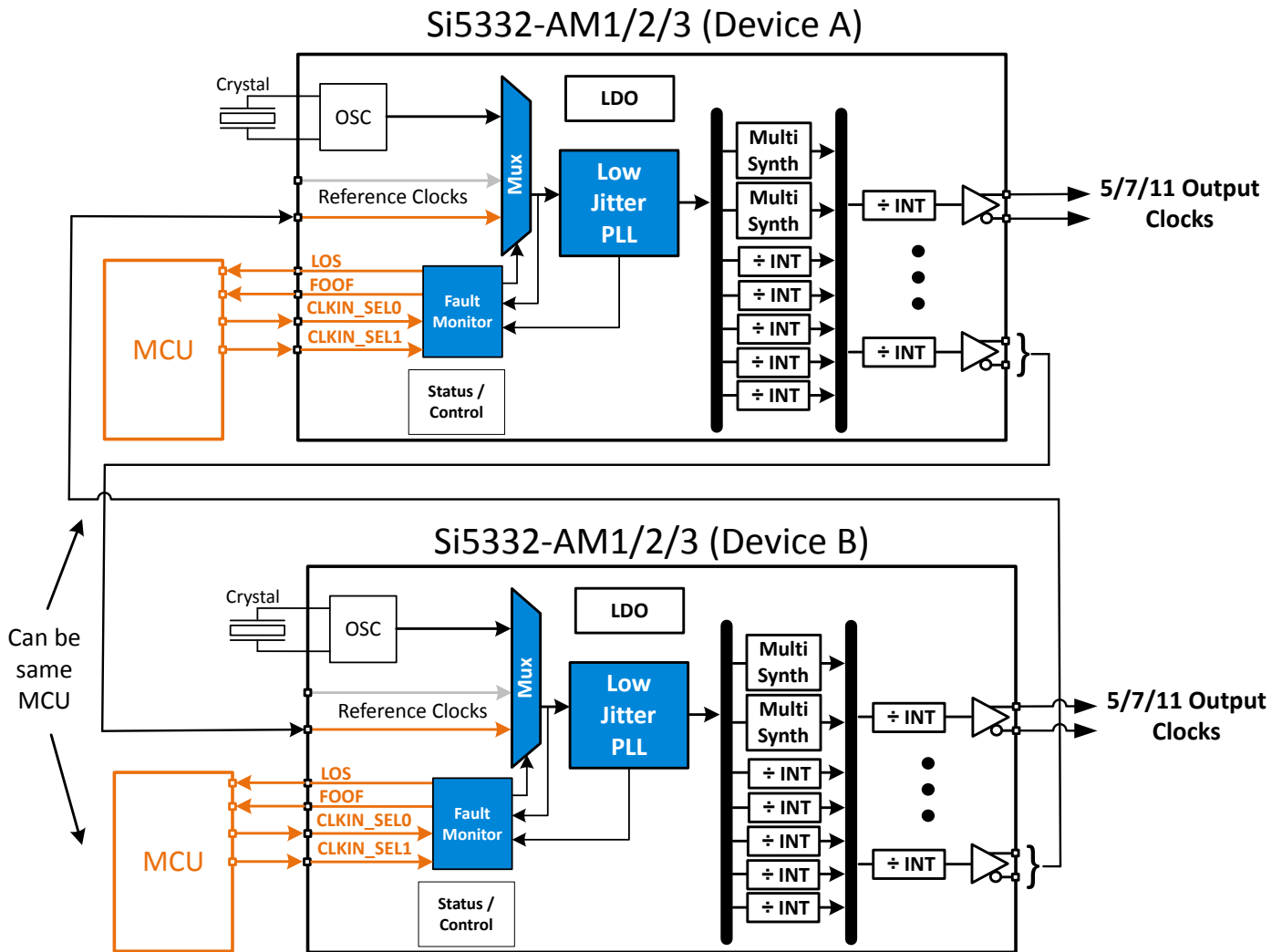


Figure 3.9. Redundant Si5332-AM Devices with Cross-Coupled References

The figure above represents a use case scenario where multiple Si5332-AM devices are operated, with one Si5332-AM device providing the alternate input reference clock to the other Si5332-AM device. One output from each Si5332-AM must be used as an input to the other Si5332-AM, reducing the total number of output reference clocks that can be used for endpoints, however this topology provides added redundancy and no other reference input clocks external to the Si5332-AM devices are required. In this scenario either device (A or B) can communicate an LOS and/or FOOF signal to the MCU if a fault has been detected on the crystal oscillator or PLL block. The external MCU software can then decide if switching to the other Si5332-AM device (A or B) reference clock source is appropriate based on the fault detected, and overall system safety goals. If switching to the other reference clock removes the fault condition, the MCU code can then signal the fault was corrected and then take appropriate system action for this case. Below is an example flowchart of the MCU software for this scenario.

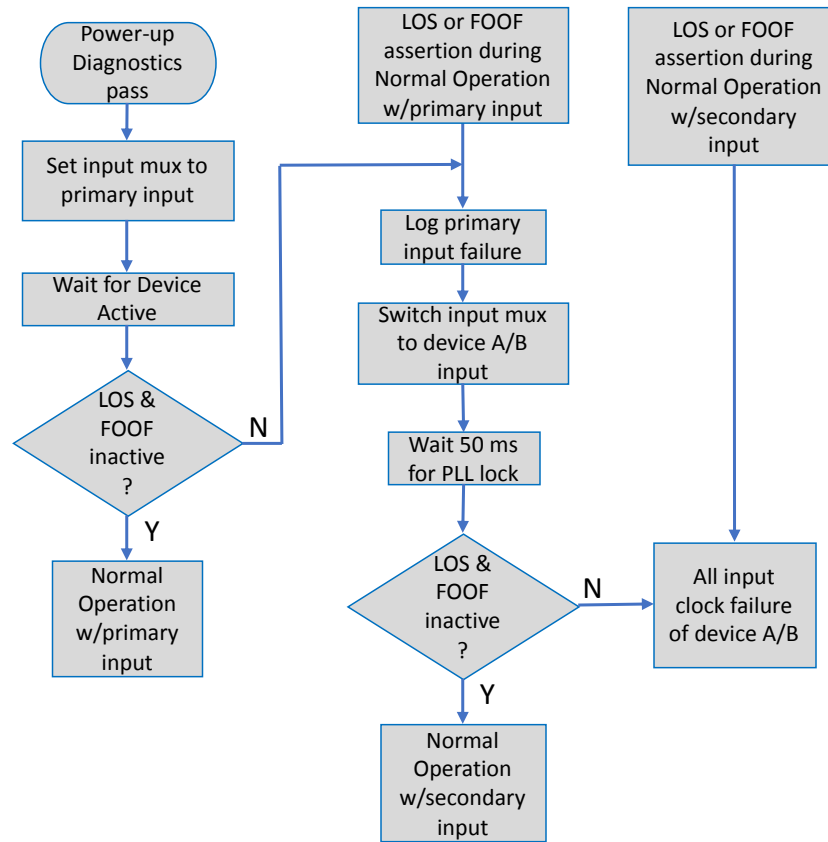


Figure 3.10. Example Control Software flowchart of each Si5332-AM Device with Cross-Coupled Reference Clock Sources

The figure above represents the software flow used on each Si5332 device. The MCU must keep track of which device (A or B) has the fault condition and appropriately handle the condition.

4. Output Clock Frequency Behavior at Input Reference Loss/Restoration (Si5332 and Si5118)

4.1 Output Clock Frequency Behavior at Loss of Input Clock (Si5332 and Si5118)

When the Si5332's input clock reference is lost, and before a new input clock selection is made, all device outputs will start to fall in frequency towards a value determined by the PLL's minimum operating frequency. The frequency vs. time plot shown below is an example of typical device behavior for a 100 MHz output upon loss of input reference clock. The 100 MHz output will start to fall in frequency and settle at a minimum frequency of ~99.2 MHz about 140 μ s later.

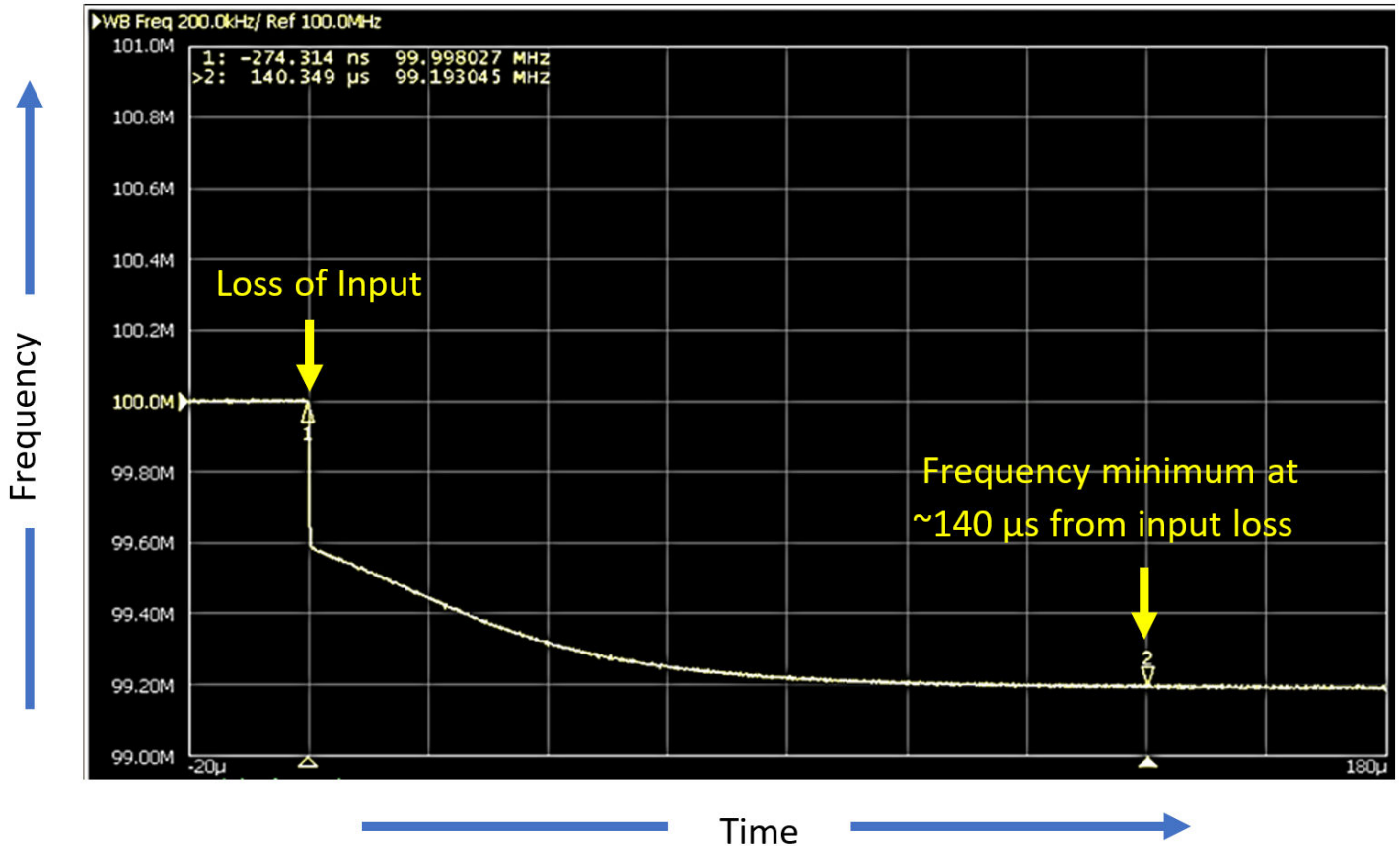


Figure 4.1. Output Frequency Plot after Loss of Input Reference Clock

For outputs at frequencies other than 100 MHz the timing will be the same as shown above, but the frequency minimum will be at the same frequency ratio as for the frequency difference in the above 100 MHz example (i.e., same ppm difference).

For timing details of LOS and/or FOOF output signals upon **loss** of input clock, please refer to the respective device data sheet.

4.2 Output Clock Frequency Behavior at Restoration of Input Clock (Si5332 and Si5118)

When the Si5332's input clock reference is restored all device outputs will start to rise in frequency towards the nominal output frequency for each output. The frequency vs. time plot shown below is an example of typical device behavior for a nominal 100 MHz output upon restoration of the lost input clock reference. Upon input clock restoration, the nominal 100 MHz output will start to rise in frequency and settle back at 100 MHz after about 78 μ s.

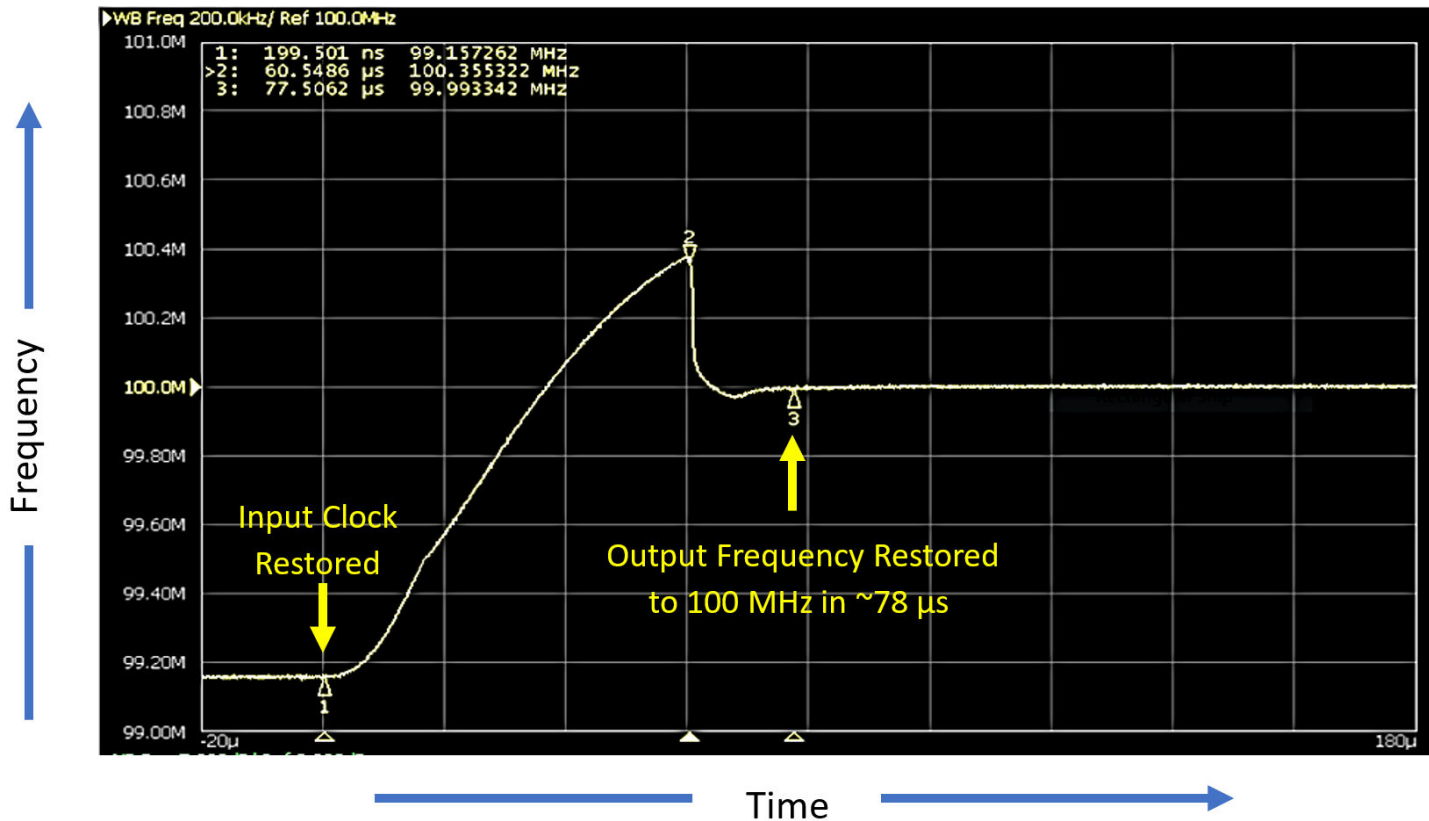


Figure 4.2. Output Frequency Plot upon Restoration of Input Reference Clock

For outputs at frequencies other than 100 MHz the time to output frequency restoration will be the same as shown in the above 100 MHz example.

For timing details of LOS and/or FOOF output signals upon **restoration** of input clock, please refer to the respective device data sheet.

5. Conclusion

The Si5332-AM automotive clock generators provide numerous benefits and advantages over quartz crystals and quartz crystal oscillator based timing solutions. Si5332-AM clock generators can support up to 12 unique frequency outputs, allowing system designers to eliminate quartz-based points of failures and greatly improving system reliability. Si5332-AM clock generators also include added features that help simplify clock tree design, including input reference health monitoring, fault detection, and recovery features that can switch to alternate/redundant inputs in the event of fault via communication with an external MCU or system safety manager IC.

The Si5332-AM family system clocking scenarios presented in this application note are examples of how the Si5332-AM clock generator family can be used to implement different levels of health monitoring, fault detection, and intelligent recovery using SmartClock features. These example scenarios also illustrate the flexibility that is available when configuring anywhere from simple to full redundant clocking systems. This flexibility gives the system designer the ability to use the Si5332-AM family, along with system software, to tailor the level of fault tolerance and fault recovery necessary to meet a wide range of system safety requirements

For more information, feel free to contact us at <https://www.skyworksinc.com/support>.



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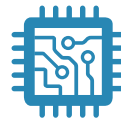
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