Introduction

This document provides a general board-level hardware design guide for the 8V19N490, 8V19N490-19, and 8V19N490-24 devices. The main difference between these devices is the VCO frequency (see Table 1). The 8V19N490 is used for demonstration purposes in this document.

Table 1. VCO Frequencies

<table>
<thead>
<tr>
<th>Part Number</th>
<th>VCO Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>8V19N490</td>
<td>~2.94912GHz</td>
</tr>
<tr>
<td>8V19N490-19</td>
<td>~1.966GHz</td>
</tr>
<tr>
<td>8V19N490-24</td>
<td>~2.4G to ~2.5GHz</td>
</tr>
</tbody>
</table>

This document recommends power rail handling, loop filter calculation, and input/output termination for the 8V19N490/19/24 devices. A general schematic example for the 8V19N490 is shown in Figure 1. A larger schematic version is available upon request.

Figure 1. 8V19N490 Schematic Example
Power Rails

Bypass Capacitors

Bypass capacitors are required to filter out the system noise from switching power supplies, and switching signal interference from other parts of the system. Examples of bypass capacitors on the schematic are shown in Figure 1. The type of bypass capacitor will depend on the noise level and noise frequencies in the system environment. The synthesizer’s output driver switching can cause power rail noise. These noises can also interfere with other parts of the circuit, or cause spurs on other output channels. A PCB layout example will be provided upon request.

The bypass capacitor values usually range from 0.01uF to 0.1uF. Other values can also be used. Typical capacitor sizes with low ESR are: 0603, 0402, or 0201. The typical dielectric types are: X5R or X7R. A smaller size allows the capacitor to be placed close to the power pin to reduce the trace length. Some capacitor vendors such as AVX provide online tools and models to provide the frequency response of the capacitors. Figure 2 to Figure 5 show the frequency response of various value capacitors, provided by the capacitor supplier AVX. The frequency response plot shows that the smaller value capacitor can filter out high frequency noise, and a larger value capacitor can filter out lower frequency noise. Typical power supply switching frequencies can be approximately 50kHz to 2MHz. Switching noise from other parts of the system can be varied. IDT suggests a combination of various values to cover low-frequency and high-frequency noise, if necessary.

To minimize ESR between power pins and the bypass capacitors, IDT suggests at least one bypass cap per power pin, and to place the capacitors as close to the power pins as possible. A thicker trace width between the bypass capacitor and power pin can also help reduce the ERS.

Figure 2. Example of a 100nF Bypass Capacitor Frequency Response
Figure 3. Example of a 10nF Bypass Capacitor Frequency Response

Figure 4. Example of a Larger Value (4.7µF) Bypass Capacitor Frequency Response
Power Supply Isolation

An analog power rail requires cleaner power to optimize the jitter performance of the PLL. IDT suggests to isolate the analog power rail from other high noise power rails. The isolation can be implemented through an RC low-pass filter. The larger RC component values can further reduce the cutoff frequency and clean up lower frequency noise. To isolate a clean power rail from noise power, an ultra-low noise LDO is required for reducing power supply noise to a noise sensitive power line such as VDD_LCV and the external VCXO. IDT suggests an ultra-low noise LDO for the VDD_LCV pin noise level of less than 6μVrms from 10Hz to 100kHz.

To reduce output frequency interference for VDD output supplies, the power rails between the output banks that operate at different output frequencies can be isolated using separate LDOs, or by using a 1Ω resistor if they share the same power source. Additional smaller value capacitors (e.g. 100pF) in parallel with the existing 0.1μF near the power pins can provide additional higher frequency noise filtering.
Loop Filter

2nd Order Loop Filter

This section provides information about designing a 2nd order loop filter for the PLL. A typical 2nd order loop filter is shown in Figure 6. The following equations show a step-by-step calculation to determine Rz, Cz, and Cp values. The required parameters for this device are also provided. A spreadsheet for calculating the loop filter values is also available upon request.

**Figure 6. Typical 2nd Order Loop Filter**

1. The desired loop bandwidth, fc, must satisfy the following condition:

   \[
   \frac{F_{pd}}{fc} \gg 20
   \]

   Where, Fpd is the phase detector input frequency.

2. Calculate Rz:

   \[
   R_z = \frac{2 \times \pi \times fc \times N}{Icp \times K_{vco}}
   \]

   Where:
   - Icp = Charge pump current
   - K_{vco} = VCO gain
   - N = Effective feedback divider

   \[
   N = \frac{F_{vco}}{F_{pd}}
   \]

   Where:
   - F_{vco} = VCO frequency
   - Fpd = Phase detector input frequency

3. Calculate Cz:

   \[
   C_z = \frac{\alpha}{2 \times \pi \times fc \times R_z}
   \]

   Where:
   - \(f_z\) = Frequency at zero
   - \(\alpha\) = Ratio between the loop bandwidth and the zero frequency at zero; \(\alpha = fc / f_z\) (\(\alpha > 3\) is recommended)
4. Calculate \( C_p \):
\[
C_p = \frac{C_z}{\alpha \times \beta}
\]

Where:
- \( fp \) = Frequency at pole
- \( \beta \) = Ratio between frequency at pole and loop bandwidth; \( \beta = \frac{fp}{fc} \) (\( \beta > 3 \) is recommended)

5. Verify maximum Phase Margin (PM):
\[
PM = \arctan\left(\frac{b - 1}{2 \times \sqrt{b}}\right)
\]

Where:
- \( b = 1 + \frac{C_z}{C_p} \)

Note: the PM should be > 50°.

**3rd Order Loop Filter**

This section provides an example of a 3rd order loop filter. A typical 3rd order loop filter is shown in Figure 7.

Figure 7. Typical 3rd Order Loop Filter

The \( R_z \), \( C_z \), and \( C_p \) can be the actual values used in the 2nd order loop filter. To determine the 3rd order loop filter, \( R_p2 \) and \( C_p2 \), refer to the following equation:

Select an \( R_p2 \) value (\( R_p2 \sim 1.5 \times R_z \) is used in the example below).

\[
C_p2 = \frac{R_z \times C_p}{R_p2 \times y}
\]

Where:
- \( y \) = Ratio between the 1st pole frequency and the 2nd pole frequency (\( y > 3 \) is recommended).

A spreadsheet is provided to calculate the loop filter component values. To use the spreadsheet, the user can enter the following parameters: \( f_c \), \( Fpd \), \( fvco \), \( \alpha \), and \( \beta \).

The spreadsheet will provide the component values, \( R_z \), \( C_z \), and \( C_p \), as a result. The spreadsheet can also calculate the maximum phase margin for verification. The 3rd order loop filter \( R_p2 \) and \( C_p2 \) is also calculated using the actual 2nd order loop filter components values.
Loop Filter Calculation Examples

Loop Filter for VCXO PLL

Second Order Loop Filter for the VCXO PLL

This section provides calculation examples for the VCXO PLL loop filter value. The 8V19N490 VCXO phase lock loop block diagram is shown in Figure 8. A 2nd order loop filter for VCXO is shown in Figure 9. In this example, the reference CLK input frequency = 30.72MHz and a VCXO with output frequency of 122.88MHz is used.

Figure 8. 8V19N490 VCXO Phase Lock Loop Block Diagram

Figure 9. Typical 2nd Order Loop Filter

To calculate the loop filter component value for loop bandwidth, \( F_c = 40\, \text{Hz} \) with the reference CLK input frequency equal to 30.72MHz, set the input pre-divider \( P_v = 256 \). The phase detector input frequency \( F_{pd} = 0.12\, \text{MHz} \). This satisfies the condition of \( F_{pd} ÷ F_c >> 20 \).

The VCXO frequency is: \( F_{vcxo} = 122.88\, \text{MHz} \), and the effective feedback divider is: \( N = M_v = F_{vcxo} ÷ F_{pd} = 1024 \).

\[ R_z \text{ can be calculated from the equation: } R_z = \frac{2 \times \pi \times F_c \times N}{I_{cp} \times K_{vco}} \]

\[ R_z = 33\, \text{k}\Omega \]

\( K_{vco} \) VCO gain can be found or derived from the VCXO datasheet. The VCO gain can also be measured from a lab experiment. In this example, \( K_{vco} = 10\, \text{kHz/V} \) was applied.
The 8V19N490 charge pump current can be programmed from 50uA to 1.6mA. In the following example, the charge pump current is programmed to \( I_{cp} = 800\mu A \).

\[ C_z \] can be calculated from the following equation:

\[ C_z = \frac{\alpha}{2 \pi f_c R_z} \]

For \( \alpha = 8 \), \( C_z \) is calculated to be 0.99\( \mu F \). \( C_z \) greater than this value can be used to assure that the \( \alpha \) is > 12. For example, the actual determined value can be, 1\( \mu F \) from a standard capacitor value.

\[ C_p \] can be calculated from the following equation:

\[ C_p = \frac{C_z}{\alpha \beta} \]

For \( \beta = 4 \), \( C_p = 31nF \). Less than this value can be used for \( C_p \) to assure, \( \beta \) is > 4 (e.g. the actual determined value \( C_p \) can be 27nF).

**Third Order Loop Filter for the VCXO PLL**

This section provides information about designing a 3\(^{rd}\) order loop filter for the 8V19N490 VCXO PLL. A general 3\(^{rd}\) order loop filter is shown in **Figure 10**.

**Figure 10. Typical 3\(^{rd}\) Order Loop Filter**

The \( R_z \), \( C_z \), and \( C_p \) are actual standard values from the 2\(^{nd}\) order loop filter. In this example, the actual values are: \( R_z = 33k\Omega \), \( C_z = 1uF \), and \( C_p = 27nF \). The 3\(^{rd}\) order loop filter, \( R_p2 \) and \( C_p2 \), is determined in the following equation.

Select an \( R_p2 \) value (\( R_p2 \sim 1.5xR_z \) to ~2.5\( xR_z \) or greater is recommended; e.g. \( R_p2 = 51kHz \) is used in this example).

\( C_p2 \) can be calculated using the following equation:

\[ C_p2 = \frac{R_z \times C_p}{R_p2 \times \gamma} \]

In this example, \( \gamma = 4 \) was selected.

\( C_p2 \) is calculated at 4.37nF. A closer standard capacitor value can be used.
**Loop Filter for VCO PLL**

The 8V19N490 VCO phase lock loop diagram is shown in Figure 11. The Fvco frequency is 2.94912GHz. In this example, the 2949.12MHz VCO is used. A 2\textsuperscript{nd} order loop filter for VCXO is shown in Figure 12.

**Figure 11. VCO PLL Block Diagram**

![VCO PLL Block Diagram](image)

**Figure 12. 2\textsuperscript{nd} Order Loop Filter for VCO**

![2\textsuperscript{nd} Order Loop Filter for VCO](image)

In this example, the VCO phase detector input frequency is: \( F_{pd} = 122.88\text{MHz} \), which is driven from the VCXO output. The effective feedback divider is: \( N = MF = 20 \).

Calculate the loop filter component values for loop bandwidth, \( F_c = 80\text{kHz} \).

The phase detector input frequency is: \( F_{pd} = 122.88\text{MHz} \). This satisfies the condition of \( F_{pd} ÷ F_c >> 20 \).

The VCO gain for this part is: \( K_{vco} = 30\text{MHz/V} \)

The charge pump current is: \( I_{cp} = 2\text{mA} \)

\[ R_z = \frac{2 \times \Pi \times f_c \times N}{I_{cp} \times K_{vco}} \]

\[ R_z = 201\Omega \]

For \( \alpha = 10 \), the \( C_z \) is calculated from the following equation:

\[ C_z = \frac{\alpha}{2 \times \Pi \times f_c \times R_z} \]

Select \( \alpha \) value, where \( \alpha \) must be greater than 3. In this example, \( \alpha = 10 \) is selected and \( C_z \) is calculated at 99nF. A capacitor greater than this value should be used for \( C_z \) to ensure \( \alpha \) is greater than 10 (e.g. the selected value, \( C_p \), can be 100nF from a standard capacitor value).

\[ C_p = \frac{C_z}{\alpha \times \beta} \]

Select a \( \beta \) value, where \( \beta \) must be greater than 3. In this example, \( \beta = 6 \) is selected and \( C_p \) is calculated at 1.65F. A capacitor less than this value should be used for \( C_p \) to assure that \( \beta \) is greater than 6 (e.g. the actual selected value, \( C_p \), can be 1nF from a standard capacitor value).
Input Output Interface

Input Termination for Reference Clock Input

The 8V19N490 reference clock input CLK, nCLK is a high impedance differential receiver. The inverting input nCLK has weak bias to 1.2V. The input can accept a signal from a standard 3.3V LVPECL or an LVDS driver directly without AC coupling. The board-level termination at the CLK, nCLK input, is determined by the driver type. Figure 13 and Figure 14 provide examples of an input interface without AC coupling. Figure 15 and Figure 16 provide examples of an input driven by a differential driver with AC coupling. This section provides only a few examples; other termination topologies can also be used.

Figure 13. Input Termination Example – 8V19N490 Input Reference Clock CLK, nCLK Driven by a 3.3V LVPECL Driver

![Diagram of LVPECL Driver Termination](image)

Figure 14. Input Termination Example – 8V19N490 Input Reference Clock CLK, nCLK Driven by a 3.3V LVDS Driver

![Diagram of LVDS Driver Termination](image)
Output Terminations for QCLK and QREF Drivers

The output stage of the 8V19N490 QCLK drivers can be configured to an LVPECL-style driver or an LVDS-style driver.

**LVPECL Driver Terminations**

When the output is configured to an LVPECL-style driver, the driver is an open emitter type and requires pull-down resistors for the DC current path in order for the output to switch. A standard LVPECL driver termination is shown in Figure 17. There are various ways to terminate the LVPECL driver. Examples of LVPECL-style driver terminations are shown in Figure 18 to Figure 20.

**Figure 17. Standard LVPECL Driver Termination**

[Diagram showing a standard LVPECL driver termination]
Figure 18. LVPECL Termination Example 1

![Figure 18. LVPECL Termination Example 1](image)

Figure 19. LVPECL Termination Example 2

![Figure 19. LVPECL Termination Example 2](image)

Figure 20. LVPECL Driver DC Coupling Termination for the Receiver with Built-in 100Ω Termination

![Figure 20. LVPECL Driver DC Coupling Termination for the Receiver with Built-in 100Ω Termination](image)
LVDS-type Driver Terminations

An LVDS-type driver does not require a board-level pull-down resistor. A typical termination with DC coupling for the LVDS-type driver is shown in Figure 21. A termination example with AC coupling is shown in Figure 22.

Figure 21. Typical LVDS-style Driver Termination

Figure 22. 8V19N490 LVDS Driver Driving a Receiver with Built-in Termination (e.g. 8V79S680 CLK, nCLK and REF, nREF Inputs)
Schematic Example
The reference demo board schematic and board layout example are available upon request.

Revision History

<table>
<thead>
<tr>
<th>Revision Date</th>
<th>Description of Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 29, 2017</td>
<td>Initial release.</td>
</tr>
</tbody>
</table>
Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.

2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.

3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.

4. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.

5. Renesas Electronics products are classified according to the following two quality grades: "Standard" and "High Quality". The intended applications for each Renesas Electronics product depends on the product's quality grade, as indicated below.

   *Standard*: Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; industrial robots; etc.

   *High Quality*: Transportation equipment (automobiles, trains, ships, etc.); traffic control (traffic lights); large-scale communication equipment; key financial terminal systems; safety control equipment; etc.

6. Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implantations; etc.), or may cause serious property damage (space system; undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user's manual or other Renesas Electronics document.

7. When using Renesas Electronics products, refer to the latest product information (data sheets, user's manuals, application notes, "General Notes for Handling and Using Semiconductor Devices" in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.

8. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.

9. You must contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.

10. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.

11. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.

12. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.

   *Note1* "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.

   *Note2* "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.

(Rev.4.0-1 November 2017)