Introduction

This document provides a general board-level hardware design guide for the 8V19N470, 8V19N472 and 8V19N474 devices. The main difference between these devices is the VCO frequency (see Table 1). The IDT8V19N470 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>8V19N470</td>
<td>~2.94912GHz and ~2.4576 GHz</td>
</tr>
<tr>
<td>8V19N472</td>
<td>~2.94912GHz and ~2.4576 GHz</td>
</tr>
<tr>
<td>8V19N474</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 8V19N47x devices. A general schematic example for the 8V19N470 is shown in Figure 1. A larger schematic version is available upon request.

Figure 1. 8V19N470 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 spur 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
Figure 5. Example of a Smaller Value (100pF) 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 6uVrms from 10Hz to 100kHz.

To reduce output frequency interference for VDDO output supplies, the power rails between the output banks that operate at different output frequencies can be isolated using a separate 1Ω resistor if they share the same power source. Additional smaller value capacitors (e.g. 100pF) in parallel with the existing 0.1uF 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:
\[
R_z = \frac{2 \times \pi \times f_c \times N}{I_{cp} \times K_{vco}}
\]
Where:
- Icp = Charge pump current
- K_{vco} = VCO gain
- N = Effective feedback divider

\[
N = \frac{F_{vco}}{F_{pd}}
\]
Where:
- F_{vco} = VCO frequency
- F_{pd} = Phase detector input frequency

3. Calculate Cz:
\[
C_z = \frac{\alpha}{2 \times \pi \times f_c \times R_z}
\]
Where:
- f_z = Frequency at zero
- \alpha = Ratio between the loop bandwidth and the zero frequency at zero; \alpha = f_c + f_z (\alpha > 3 is recommended)
4. Calculate \( C_p \):

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

Where:
- \( f_p \) = Frequency at pole
- \( \beta \) = Ratio between frequency at pole and loop bandwidth; \( \beta = f_p / f_c \) (\( \beta > 3 \) 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 Rz, Cz, and Cp can be the actual values used in the 2nd order loop filter. To determine the 3rd order loop filter, \( R_p^2 \) and \( C_p^2 \), refer to the following equation:

Select an \( R_p^2 \) value (\( R_p^2 \sim 1.5xR_z \) is used in the example below).

\[ C_p^2 = \frac{R_z \times C_p}{R_p^2 \times \gamma} \]

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

A spreadsheet is provided to calculate the loop filter component values. To use the spreadsheet, the user can enter the following parameters: \( f_c \), \( F_{pd} \), \( f_{vco} \), \( \alpha \), and \( \beta \).

The spreadsheet will provide the component values, Rz, Cz, and Cp, as a result. The spreadsheet can also calculate the maximum phase margin for verification. The 3rd order loop filter \( R_p^2 \) and \( C_p^2 \) 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 8V19N470 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. 8V19N470 VCXO Phase Lock Loop Block Diagram

Figure 9. Typical 2nd Order Loop Filter

To calculate the loop filter component value for loop bandwidth, Fc = 40Hz with the reference CLK input frequency equal to 30.72MHz, set the input pre-divider Pv = 256. The phase detector input frequency Fpd = 0.12MHz. This satisfies the condition of Fpd ÷ Fc >> 20.

The VCXO frequency is: Fvcxo = 122.88MHz, and the effective feedback divider is: N = Mv = Fvcxo ÷ Fpd = 1024.

Rz can be calculated from the equation:

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

\[ R_z = 33k\Omega \]

Kvco 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, Kvco = 10kHz/V was applied.
The 8V19N470 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:

$$C_z = \frac{\alpha}{2 \times \pi \times f_c \times R_z}$$

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:

$$C_p = \frac{C_z}{\alpha \times \beta}$$

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 3rd order loop filter for the 8V19N470 VCXO PLL. A general 3rd order loop filter is shown in *Figure 10*.

*Figure 10. Typical 3rd Order Loop Filter*

The $R_z$, $C_z$, and $C_p$ are actual standard values from the 2nd order loop filter. In this example, the actual values are: $R_z = 33k\Omega$, $C_z = 1\mu F$, and $C_p = 27nF$. The 3rd 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 $\sim2.5xR_z$ 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 8V19N470 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)

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

Calculate the loop filter component values for loop bandwidth, Fc = 80kHz. The phase detector input frequency is: F\textsubscript{pd} = 122.88MHz. This satisfies the condition of F\textsubscript{pd} / Fc >> 20.

The VCO gain for this part is: Kvco = 30MHz/V
The charge pump current is: Icp = 2mA

RZ can be calculated from the following equation:

\[
RZ = \frac{2 \times \Pi \times fc \times N}{Icp \times Kvco}
\]

RZ = 201Ω

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

\[
Cz = \frac{\alpha}{2 \times \Pi \times fc \times RZ}
\]

Select an \(\alpha\) value, where \(\alpha\) must be greater than 3. In this example, \(\alpha = 10\) is selected and Cz is calculated at 99nF. A capacitor greater than this value should be used for Cz to ensure \(\alpha\) is greater than 10 (e.g. the selected value, Cp, can be 100nF from a standard capacitor value). For Cp capacitor value, since this is compensated by the internal partial loop filtering, suggest install Cp = 40pF.
Input Output Interface

Input Termination for Reference Clock Input

The 8V19N470 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 – 8V19N470 Input Reference Clock CLK, nCLK Driven by a 3.3V LVPECL Driver

![Diagram of input termination example with LVPECL driver]

Figure 14. Input Termination Example – 8V19N470 Input Reference Clock CLK, nCLK Driven by a 3.3V LVDS Driver

![Diagram of input termination example with LVDS driver]
Figure 15. 8V19N470 Input Reference Clock CLK, nCLK AC Coupling Termination Example 1

Figure 16. 8V19N470 Input Reference Clock CLK, nCLK AC Coupling Termination Example 2
Output Terminations for QCLK and QREF Drivers

The output stage of the 8V19N470 QCLK drivers can be configured to an LVPECL-style driver or an LVDS-style driver. The output power supply VDD_v can also be ranged from 1.8V to 3.3V.

LVPECL Driver Terminations

When the 8V19N470 output is configured to LVPECL-style driver, the driver is an open emitter type and requires pull-down resistors to provide DC current path in order for the output to switch. A typical standard LVPECL style driver termination for characterization is shown in Figure 17. The VTT value will depend on the programmed amplitude and the VDD_v power supply voltage. Table 2 shows the recommend VTT values for the amplitudes setting. There are various ways to terminate the LVPECL driver. Examples of LVPECL-style driver terminations are shown in Figure 18 to Figure 21. Table 3 to Table 5 show recommend component values for each amplitude setting and VDD_v power supply voltages.

Figure 17. Standard LVPECL Driver Termination

![LVPECL Driver Termination Diagram]

Table 2. VTT Values for Figure 17

<table>
<thead>
<tr>
<th>Amplitude</th>
<th>VTT</th>
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<tbody>
<tr>
<td>850mV</td>
<td>VDD_v – 2.10V</td>
</tr>
<tr>
<td>700mV</td>
<td>VDD_v – 1.95V</td>
</tr>
<tr>
<td>500mV</td>
<td>VDD_v – 1.75V</td>
</tr>
<tr>
<td>350mV</td>
<td>VDD_v – 1.60V</td>
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</tbody>
</table>
Figure 18. LVPECL Termination Example 1

Table 3. Suggested Component Values for Figure 18

<table>
<thead>
<tr>
<th>VDD_v</th>
<th>Amplitude</th>
<th>R1, R3 (Ohm)</th>
<th>R2, R4 (Ohm)</th>
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</thead>
<tbody>
<tr>
<td>3.3V</td>
<td>850mV</td>
<td>137.5</td>
<td>78.6</td>
</tr>
<tr>
<td>3.3V</td>
<td>750mV</td>
<td>122</td>
<td>84.6</td>
</tr>
<tr>
<td>3.3V</td>
<td>500mV</td>
<td>106.5</td>
<td>94.3</td>
</tr>
<tr>
<td>3.3V</td>
<td>350mV</td>
<td>97.1</td>
<td>103.1</td>
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<tr>
<td>2.5V</td>
<td>850mV</td>
<td>312.5</td>
<td>59.5</td>
</tr>
<tr>
<td>2.5V</td>
<td>750mV</td>
<td>227.3</td>
<td>64.1</td>
</tr>
<tr>
<td>2.5V</td>
<td>500mV</td>
<td>166.7</td>
<td>71.4</td>
</tr>
<tr>
<td>2.5V</td>
<td>350mV</td>
<td>138.8</td>
<td>78.1</td>
</tr>
<tr>
<td>1.8V</td>
<td>500mV</td>
<td>No-Pop</td>
<td>50</td>
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<tr>
<td>1.8V</td>
<td>250mV</td>
<td>450</td>
<td>56.3</td>
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Table 4. Suggested Component Values for Figure 19

<table>
<thead>
<tr>
<th>VDD_v</th>
<th>Amplitude</th>
<th>R3 (Ohm)</th>
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</thead>
<tbody>
<tr>
<td>3.3V</td>
<td>850mV</td>
<td>50</td>
</tr>
<tr>
<td>3.3V</td>
<td>750mV</td>
<td>50</td>
</tr>
<tr>
<td>3.3V</td>
<td>500mV</td>
<td>50</td>
</tr>
<tr>
<td>3.3V</td>
<td>350mV</td>
<td>50</td>
</tr>
<tr>
<td>2.5V</td>
<td>850mV</td>
<td>18</td>
</tr>
<tr>
<td>2.5V</td>
<td>750mV</td>
<td>18</td>
</tr>
<tr>
<td>2.5V</td>
<td>500mV</td>
<td>18</td>
</tr>
<tr>
<td>2.5V</td>
<td>350mV</td>
<td>18</td>
</tr>
<tr>
<td>1.8V</td>
<td>500mV</td>
<td>0</td>
</tr>
<tr>
<td>1.8V</td>
<td>350mV</td>
<td>0</td>
</tr>
</tbody>
</table>
Figure 20. LVPECL Termination Example 3

![LVPECL Termination Example 3](image)

Table 5. Suggested Component Values for Figure 20

<table>
<thead>
<tr>
<th>VDD_v</th>
<th>Amplitude</th>
<th>R1, R2 (Ohm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3V</td>
<td>850mV</td>
<td>100 to 200</td>
</tr>
<tr>
<td>3.3V</td>
<td>750mV</td>
<td>100 to 200</td>
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<tr>
<td>3.3V</td>
<td>500mV</td>
<td>100 to 200</td>
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<tr>
<td>3.3V</td>
<td>350mV</td>
<td>100 to 200</td>
</tr>
<tr>
<td>2.5V</td>
<td>850mV</td>
<td>80 to 150</td>
</tr>
<tr>
<td>2.5V</td>
<td>750mV</td>
<td>80 to 150</td>
</tr>
<tr>
<td>2.5V</td>
<td>500mV</td>
<td>80 to 150</td>
</tr>
<tr>
<td>2.5V</td>
<td>350mV</td>
<td>80 to 150</td>
</tr>
<tr>
<td>1.8V</td>
<td>500mV</td>
<td>50 to 100</td>
</tr>
<tr>
<td>1.8V</td>
<td>350mV</td>
<td>50 to 100</td>
</tr>
</tbody>
</table>

Figure 21. LVPECL Driver DC Coupling Termination for the Receiver with Built-in 100Ω Termination

![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 23. A termination example with AC coupling is shown in Figure 24.
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>May 28, 2017</td>
<td>Initial release.</td>
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Corporate Headquarters
TOYOSU FORESIA, 3-2-24 Toyosu, Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

Contact Information
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