FEATURES

- RF bandwidth to 6 GHz
- 2.7 V to 3.3 V power supply
- Separate Vp pin allows extended tuning voltage
- Programmable fractional modulus
- Programmable charge-pump currents
- 3-wire serial interface
- Digital lock detect
- Power-down mode
- Pin compatible with ADF4110/ADF4111/ADF4112/ADF4113, ADF4106, ADF4153, and ADF4154 frequency synthesizers
- Programmable RF output phase
- Loop filter design possible with ADIsimPLL
- Cycle slip reduction for faster lock times

APPLICATIONS

- CATV equipment
- Base stations for mobile radio (WiMAX, GSM, PCS, DCS, SuperCell 3G, CDMA, WCDMA)
- Wireless handsets (GSM, PCS, DCS, CDMA, WCDMA)
- Wireless LANs, PMR
- Communications test equipment

GENERAL DESCRIPTION

The ADF4156 is a 6 GHz fractional-N frequency synthesizer that implements local oscillators in the upconversion and downconversion sections of wireless receivers and transmitters. It consists of a low noise digital phase frequency detector (PFD), a precision charge pump, and a programmable reference divider. There is a Σ-Δ based fractional interpolator to allow programmable fractional-N division. The INT, FRAC, and MOD registers define an overall N divider (N = (INT + (FRAC/MOD))). The RF output phase is programmable for applications that require a particular phase relationship between the output and the reference. The ADF4156 also features cycle slip reduction circuitry, leading to faster lock times without the need for modifications to the loop filter.

Control of all on-chip registers is via a simple 3-wire interface. The device operates with a power supply ranging from 2.7 V to 3.3 V and can be powered down when not in use.

FUNCTIONAL BLOCK DIAGRAM

![Functional Block Diagram](image)
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REVISION HISTORY

5/09—Rev. 0 to Rev. A
Added Low Power Sleep Mode Parameter and Changes to
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5/06—Revision 0: Initial Version
SPECIFICATIONS

AVDD = DVDD = 2.7 V to 3.3 V, VP = AVDD to 5.5 V, AGND = DGND = 0 V, TA = TMIN to TMAX, dBm referred to 50 Ω, unless otherwise noted.

Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>B Version</th>
<th>Unit</th>
<th>Test Conditions/Comments¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF CHARACTERISTICS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RF Input Frequency (RFIN)</td>
<td>0.5/6.0</td>
<td>GHz min/max</td>
<td>−10 dBm min to 0 dBm max. For lower frequencies, ensure slew rate (SR) &gt; 400 V/μs.</td>
</tr>
<tr>
<td>REFERENCE CHARACTERISTICS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>REFN Input Frequency</td>
<td>10/250</td>
<td>MHZ min/max</td>
<td>For f &lt; 10 MHz, use a dc-coupled CMOS-compatible square wave, slew rate &gt; 25 V/μs. Biased at AVDD/2.²</td>
</tr>
<tr>
<td>REFN Input Sensitivity</td>
<td>0.4/AVDD</td>
<td>V p-p min/max</td>
<td></td>
</tr>
<tr>
<td>REFN Input Capacitance</td>
<td>10</td>
<td>pF max</td>
<td></td>
</tr>
<tr>
<td>REFN Input Current</td>
<td>±100</td>
<td>μA max</td>
<td></td>
</tr>
<tr>
<td>PHASE DETECTOR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase Detector Frequency³</td>
<td>32</td>
<td>MHz max</td>
<td></td>
</tr>
<tr>
<td>CHARGE PUMP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICP Sink/Source</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Value</td>
<td>5</td>
<td>mA typ</td>
<td>Programmable. With RSET = 5.1 kΩ.</td>
</tr>
<tr>
<td>Low Value</td>
<td>312.5</td>
<td>μA typ</td>
<td></td>
</tr>
<tr>
<td>Absolute Accuracy</td>
<td>2.5</td>
<td>% typ</td>
<td>With RSET = 5.1 kΩ.</td>
</tr>
<tr>
<td>RSET Range</td>
<td>2.7/10</td>
<td>kΩ min/max</td>
<td></td>
</tr>
<tr>
<td>ICP Three-State Leakage Current</td>
<td>1</td>
<td>nA typ</td>
<td>Sink and source current.</td>
</tr>
<tr>
<td>Matching</td>
<td>2</td>
<td>% typ</td>
<td>0.5 V &lt; VCP &lt; VP − 0.5.</td>
</tr>
<tr>
<td>ICP vs. VCP</td>
<td>2</td>
<td>% typ</td>
<td>0.5 V &lt; VCP &lt; VP − 0.5.</td>
</tr>
<tr>
<td>ICP vs. Temperature</td>
<td>2</td>
<td>% typ</td>
<td>VCP = VP/2.</td>
</tr>
<tr>
<td>LOGIC INPUTS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VINH, Input High Voltage</td>
<td>1.4</td>
<td>V min</td>
<td>Open-drain output chosen; 1 kΩ pull-up to 1.8 V.</td>
</tr>
<tr>
<td>VINL, Input Low Voltage</td>
<td>0.6</td>
<td>V max</td>
<td>CMOS output chosen.</td>
</tr>
<tr>
<td>IINH/IINL, Input Current</td>
<td>±1</td>
<td>μA max</td>
<td></td>
</tr>
<tr>
<td>CIN, Input Capacitance</td>
<td>10</td>
<td>pF max</td>
<td></td>
</tr>
<tr>
<td>LOGIC OUTPUTS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VOH, Output High Voltage</td>
<td>1.4</td>
<td>V min</td>
<td></td>
</tr>
<tr>
<td>V0H, Output High Voltage</td>
<td>VDD − 0.4</td>
<td>V min</td>
<td></td>
</tr>
<tr>
<td>IOH, Output High Current</td>
<td>100</td>
<td>μA max</td>
<td></td>
</tr>
<tr>
<td>VOL, Output Low Voltage</td>
<td>0.4</td>
<td>V max</td>
<td>IOL = 500 μA.</td>
</tr>
<tr>
<td>POWER SUPPLIES</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AVDD</td>
<td>2.7/3.3</td>
<td>V min/max</td>
<td></td>
</tr>
<tr>
<td>DVDD</td>
<td>AVDD</td>
<td>V min/max</td>
<td></td>
</tr>
<tr>
<td>VP</td>
<td>AVDD/5.5</td>
<td>V min/max</td>
<td></td>
</tr>
<tr>
<td>IO</td>
<td>32</td>
<td>mA max</td>
<td>26 mA typical.</td>
</tr>
<tr>
<td>Low Power Sleep Mode</td>
<td>1</td>
<td>μA typ</td>
<td></td>
</tr>
<tr>
<td>NOISE CHARACTERISTICS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normalized Phase Noise Floor⁴</td>
<td>−211</td>
<td>dBc/Hz typ</td>
<td>@ VCO output.</td>
</tr>
<tr>
<td>Phase Noise Performance³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5800 MHz Output⁵</td>
<td>−89</td>
<td>dBc/Hz typ</td>
<td>@ 5 kHz offset, 25 MHz PFD frequency.</td>
</tr>
</tbody>
</table>

¹ Operating temperature for B version: −40°C to +85°C.  
² AC coupling ensures AVDD/2 bias.  
³ Guaranteed by design. Sample tested to ensure compliance.  
⁴ This value can be used to calculate the phase noise for any application. Use the formula −211 + 10 log(fREF) + 20 log N to calculate the in-band phase noise performance as seen at the VCO output. The value given is the lowest noise mode.  
⁵ The phase noise is measured with the EVAL-ADF4156EBZ1 evaluation board and the Agilent E5500 phase noise system.  
⁶ fREFIN = 100 MHz, fREF = 25 MHz, offset frequency = 5 kHz, RFOUT = 5800 MHz, N = 232, loop bandwidth = 20 kHz, ICP = 313 μA, and lowest noise mode.


**TIMING SPECIFICATIONS**

AVDD = DVDD = 2.7 V to 3.3 V, VP = AVDD to 5.5 V, AGND = DGND = 0 V, TA = TMIN to TMAX, dBm referred to 50 Ω, unless otherwise noted.

Table 2.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Limit at TMIN to TMAX (B Version)</th>
<th>Unit</th>
<th>Test Conditions/Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>t1</td>
<td>20</td>
<td>ns min</td>
<td>LE setup time</td>
</tr>
<tr>
<td>t2</td>
<td>10</td>
<td>ns min</td>
<td>DATA to CLOCK setup time</td>
</tr>
<tr>
<td>t3</td>
<td>10</td>
<td>ns min</td>
<td>DATA to CLOCK hold time</td>
</tr>
<tr>
<td>t4</td>
<td>25</td>
<td>ns min</td>
<td>CLOCK high duration</td>
</tr>
<tr>
<td>t5</td>
<td>25</td>
<td>ns min</td>
<td>CLOCK low duration</td>
</tr>
<tr>
<td>t6</td>
<td>10</td>
<td>ns min</td>
<td>CLOCK to LE setup time</td>
</tr>
<tr>
<td>t7</td>
<td>20</td>
<td>ns min</td>
<td>LE pulse width</td>
</tr>
</tbody>
</table>

**Timing Diagram**

![Timing Diagram](image)

*Figure 2. Timing Diagram*
ABSOLUTE MAXIMUM RATINGS

$T_A = 25^\circ C$, GND = AGND = DGND = 0 V, $V_{DD} = AV_{DD} = DV_{DD}$, unless otherwise noted.

Table 3.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{DD}$ to GND</td>
<td>$-0.3$ V to $+4$ V</td>
</tr>
<tr>
<td>$V_{DD}$ to $V_{DD}$</td>
<td>$-0.3$ V to $+0.3$ V</td>
</tr>
<tr>
<td>$V_{P}$ to GND</td>
<td>$-0.3$ V to $+5.8$ V</td>
</tr>
<tr>
<td>$V_{P}$ to $V_{DD}$</td>
<td>$-0.3$ V to $V_{DD} + 0.3$ V</td>
</tr>
<tr>
<td>Digital I/O Voltage to GND</td>
<td>$-0.3$ V to $V_{DD} + 0.3$ V</td>
</tr>
<tr>
<td>Analog I/O Voltage to GND</td>
<td>$-0.3$ V to $V_{DD} + 0.3$ V</td>
</tr>
<tr>
<td>REF$<em>{IN}$, RF$</em>{IN}$ to GND</td>
<td>$-0.3$ V to $V_{DD} + 0.3$ V</td>
</tr>
<tr>
<td>Operating Temperature Range</td>
<td>$-40^\circ$ C to $+85^\circ$ C</td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>$-65^\circ$ C to $+125^\circ$ C</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>150°C</td>
</tr>
<tr>
<td>Reflow Soldering</td>
<td></td>
</tr>
<tr>
<td>Peak Temperature</td>
<td>260°C</td>
</tr>
<tr>
<td>Time at Peak Temperature</td>
<td>40 sec</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>150°C</td>
</tr>
</tbody>
</table>

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

This device is a high performance RF integrated circuit with an ESD rating of $<2$ kV, and it is ESD sensitive. Proper precautions should be taken for handling and assembly.

THERMAL IMPEDANCE

Table 4. Thermal Impedance

<table>
<thead>
<tr>
<th>Package Type</th>
<th>$\theta_{JA}$</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSSOP</td>
<td>112</td>
<td>°C/W</td>
</tr>
<tr>
<td>LFCSP_VQ (Paddle Soldered)</td>
<td>30.4</td>
<td>°C/W</td>
</tr>
</tbody>
</table>

ESD CAUTION

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.
Table 5. Pin Function Descriptions

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>TSSOP</th>
<th>LFCSP</th>
<th>Mnemonic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19</td>
<td></td>
<td>RSET</td>
<td>Connecting a resistor between this pin and ground sets the maximum charge-pump output current. The relationship between ICP and RSET is $I_{CP_{\text{max}}} = \frac{25.5}{R_{\text{SET}}}$ where $R_{\text{SET}} = 5.1 \text{ kΩ}$ and $I_{CP_{\text{max}}} = 5 \text{ mA}$.</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td></td>
<td>CP</td>
<td>Charge-Pump Output. When enabled, this pin provides ±ICP to the external loop filter, which in turn drives the external VCO.</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td></td>
<td>CPGND</td>
<td>Charge-Pump Ground. This is the ground return path for the charge pump.</td>
</tr>
<tr>
<td>4</td>
<td>2, 3</td>
<td></td>
<td>AGND</td>
<td>Analog Ground. This is the ground return path of the prescaler.</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td></td>
<td>RFINB</td>
<td>Complementary Input to the RF Prescaler. Decouple this point to the ground plane with a small bypass capacitor, typically 100 pF.</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td></td>
<td>RFINA</td>
<td>Input to the RF Prescaler. This small-signal input is normally ac-coupled from the VCO.</td>
</tr>
<tr>
<td>7</td>
<td>6, 7</td>
<td></td>
<td>AVDD</td>
<td>Positive Power Supply for the RF Section. Decoupling capacitors to the digital ground plane should be placed as close as possible to this pin. AVDD has a value of 3 V ± 10%. AVDD must have the same voltage as DVDD.</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td></td>
<td>REFIN</td>
<td>Reference Input. This is a CMOS input with a nominal threshold of $V_{DD}/2$ and an equivalent input resistance of 100 kΩ. This input can be driven from a TTL or CMOS crystal oscillator, or it can be ac-coupled.</td>
</tr>
<tr>
<td>9</td>
<td>9, 10</td>
<td></td>
<td>DGND</td>
<td>Digital Ground.</td>
</tr>
<tr>
<td>10</td>
<td>11</td>
<td></td>
<td>CE</td>
<td>Chip Enable. A logic low on this pin powers down the device and puts the charge-pump output into three-state mode.</td>
</tr>
<tr>
<td>11</td>
<td>12</td>
<td></td>
<td>CLOCK</td>
<td>Serial Clock Input. This serial clock is used to clock in the serial data to the registers. The data is latched into the shift register on the CLOCK rising edge. This input is a high impedance CMOS input.</td>
</tr>
<tr>
<td>12</td>
<td>13</td>
<td></td>
<td>DATA</td>
<td>Serial Data Input. The serial data is loaded MSB first with the three LSBs serving as the control bits. This input is a high impedance CMOS input.</td>
</tr>
<tr>
<td>13</td>
<td>14</td>
<td></td>
<td>LE</td>
<td>Load Enable, CMOS Input. When LE is high, the data stored in the shift registers is loaded into one of the five latches. The control bits are used to select the latch.</td>
</tr>
<tr>
<td>14</td>
<td>15</td>
<td></td>
<td>MUXOUT</td>
<td>Multiplexer Output. This multiplexer output allows either the RF lock detect, the scaled RF, or the scaled reference frequency to be accessed externally.</td>
</tr>
<tr>
<td>15</td>
<td>16, 17</td>
<td></td>
<td>DVDD</td>
<td>Positive Power Supply for the Digital Section. Decoupling capacitors to the digital ground plane should be placed as close as possible to this pin. DVDD has a value of 3 V ± 10%. DVDD must have the same voltage as AVDD.</td>
</tr>
<tr>
<td>16</td>
<td>18</td>
<td></td>
<td>VP</td>
<td>Charge-Pump Power Supply. This should be greater than or equal to VDD. In systems where VDD is 3 V, it can be set to 5.5 V and used to drive a VCO with a tuning range of up to 5.5 V.</td>
</tr>
</tbody>
</table>
TYPICAL PERFORMANCE CHARACTERISTICS

PFD = 25 MHz, loop bandwidth = 20 kHz, reference = 100 MHz, I_{CP} = 313 \mu A, phase noise measurements taken on the Agilent E5500 phase noise system.

Figure 5. RF Input Sensitivity

Figure 6. Phase Noise and Spurs, Low Noise Mode

Figure 7. Phase Noise and Spurs, Low Spur Mode

Figure 8. Lock Time for 200 MHz Jump, from 5705 MHz to 5905 MHz, with CSR On and Off

Figure 9. Lock Time for 200 MHz Jump, from 5905 MHz to 5705 MHz, with CSR On and Off

Figure 10. Charge-Pump Output Characteristics

(Note that Fractional Spurs Are Removed and Only the Integer Boundary Spur Remains in Low Spur Mode)
CIRCUIT DESCRIPTION

REFERENCE INPUT SECTION

The reference input stage is shown in Figure 11. While the device is operating, SW1 and SW2 are usually closed switches and SW3 is open. When a power-down is initiated, SW3 is closed and SW1 and SW2 are opened. This ensures that the REFIN pin is not loaded while the device is powered down.

RF INPUT STAGE

The RF input stage is shown in Figure 12. It is followed by a two-stage limiting amplifier to generate the current-mode logic (CML) clock levels needed for the prescaler.

RF INT DIVIDER

The RF INT counter allows a division ratio in the PLL feedback counter. Division ratios from 23 to 4095 are allowed.

INT, FRAC, MOD, AND R RELATIONSHIP

The INT, FRAC, and MOD values, in conjunction with the R-counter, enable generating output frequencies that are spaced by fractions of the phase frequency detector (PFD). See the RF Synthesizer: A Worked Example section for more information. The RF VCO frequency ($RF_{out}$) equation is

$$RF_{out} = FPFD \times (INT + (FRAC/MOD))$$

where $RF_{out}$ is the output frequency of an external voltage-controlled oscillator (VCO).

$$FPFD = \frac{REFIN \times [(1 + D)/(R \times (1 + T))]}{2}$$

where:

- $REFIN$ is the reference input frequency.
- $D$ is the $REFIN$ doubler bit.
- $T$ is the $REFIN$ divide-by-2 bit (0 or 1).
- $R$ is the preset divide ratio of the binary 5-bit programmable reference counter (1 to 32).
- $INT$ is the preset divide ratio of the binary 12-bit counter (23 to 4095).
- $MOD$ is the preset fractional modulus (2 to 4095).
- $FRAC$ is the numerator of the fractional division (0 to MOD - 1).

RF R-COUNTER

The 5-bit RF R-counter allows the input reference frequency ($REFIN$) to be divided down to produce the reference clock to the PFD. Division ratios from 1 to 32 are allowed.
PHASE FREQUENCY DETECTOR (PFD) AND CHARGE PUMP

The PFD takes inputs from the R-counter and N-counter and produces an output proportional to the phase and frequency difference between them. Figure 14 is a simplified schematic of the phase frequency detector. The PFD includes a fixed-delay element that sets the width of the antit backlash pulse, which is typically 3 ns. This pulse ensures that there is no dead zone in the PFD transfer function and results in a consistent reference spur level.

MUXOUT AND LOCK DETECT

The output multiplexer on the ADF4156 allows the user to access various internal points on the chip. The state of MUXOUT is controlled by M4, M3, M2, and M1 (for details, see Figure 16). Figure 15 shows the MUXOUT section in block diagram form.

INPUT SHIFT REGISTERS

The ADF4156 digital section includes a 5-bit RF R-counter, a 12-bit RF N-counter, a 12-bit FRAC counter, and a 12-bit modulus counter. Data is clocked into the 32-bit shift register on each rising edge of CLOCK. The data is clocked in MSB first. Data is transferred from the shift register to one of five latches on the rising edge of LE. The destination latch is determined by the state of the three control bits (C3, C2, and C1) in the shift register. These bits are the three LSBSs (DB2, DB1, and DB0), as shown in Figure 2. The truth table for these bits is shown in Table 6. Figure 16 shows a summary of how the latches are programmed.

PROGRAM MODES

Table 6 and Figure 16 through Figure 21 show how to set up the program modes in the ADF4156.

Several settings in the ADF4156 are double buffered, including the modulus value, phase value, R-counter value, reference doubler, reference divide-by-2, and current setting. This means that two events must occur before the part can use a new value for any of the double buffered settings. The new value must first be latched into the device by writing to the appropriate register, and then a new write must be performed on Register R0. For example, after the modulus value is updated, Register R0 must be written to in order to ensure that the modulus value is loaded correctly.

Table 6. C3, C2, and C1 Truth Table

<table>
<thead>
<tr>
<th>Control Bits</th>
<th>Register</th>
</tr>
</thead>
<tbody>
<tr>
<td>C3  C2  C1</td>
<td></td>
</tr>
<tr>
<td>0   0   0</td>
<td>Register R0</td>
</tr>
<tr>
<td>0   0   1</td>
<td>Register R1</td>
</tr>
<tr>
<td>0   1   0</td>
<td>Register R2</td>
</tr>
<tr>
<td>0   1   1</td>
<td>Register R3</td>
</tr>
<tr>
<td>1   0   0</td>
<td>Register R4</td>
</tr>
</tbody>
</table>
## REGISTER MAPS

### FRAC/INT REGISTER (R0)

<table>
<thead>
<tr>
<th>Register</th>
<th>Bits</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MUXOUT CONTROL</td>
<td>DB31-DB0</td>
<td>12-BIT INTEGER VALUE (INT)</td>
</tr>
<tr>
<td>MOD/R</td>
<td>DB31-DB0</td>
<td>12-BIT FRACTIONAL VALUE (FRAC)</td>
</tr>
<tr>
<td>CONTROL BITS</td>
<td>DB31-DB0</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

### PHASE REGISTER (R1)

<table>
<thead>
<tr>
<th>Register</th>
<th>Bits</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>12-BIT PHASE VALUE (PHASE)</td>
<td>DB31-DB0</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

### MOD/R REGISTER (R2)

<table>
<thead>
<tr>
<th>Register</th>
<th>Bits</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>12-BIT MODULUS WORD</td>
<td>DB31-DB0</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

### FUNCTION REGISTER (R3)

<table>
<thead>
<tr>
<th>Register</th>
<th>Bits</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>12-BIT CLOCK DIVIDER VALUE</td>
<td>DB31-DB0</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

### CLK DIV REGISTER (R4)

<table>
<thead>
<tr>
<th>Register</th>
<th>Bits</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>12-BIT CLOCK DIVIDER VALUE</td>
<td>DB31-DB0</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

---

**Figure 16. Register Summary**
FRAC/INT REGISTER, R0

With the control bits (Bits[2:0]) of Register R0 set to 000, the on-chip FRAC/INT register is programmed. Figure 17 shows the input data format for programming this register.

12-Bit Integer Value (INT)

These 12 bits control what is loaded as the INT value. This determines the overall feedback division factor. It is used in Equation 1 (see the INT, FRAC, MOD, and R Relationship section).

12-Bit Fractional Value (FRAC)

These 12 bits control what is loaded as the FRAC value into the fractional interpolator. This is part of what determines the overall feedback division factor. It is also used in Equation 1. The FRAC value must be less than the value loaded into the MOD register.

MUXOUT

The on-chip multiplexer is controlled by DB30, DB29, DB28, and DB27 on the ADF4156. See Figure 17 for the truth table.

Figure 17. FRAC/INT Register (R0) Map
PHASE REGISTER, R1

With the control bits (Bits[2:0]) of Register R1 set to 001, the on-chip phase register is programmed. Figure 18 shows the input data format for programming this register.

12-Bit Phase Value

These 12 bits control what is loaded as the phase word. The word must be less than the MOD value programmed in the MOD/R register (R2). The word is used to program the RF output phase from 0° to 360° with a resolution of 360°/MOD.

See the Phase Resync section for more information. In most applications, the phase relationship between the RF signal and the reference is not important. In such applications, the phase value can be used to optimize the fractional and subfractional spur levels. See the Spur Consistency and Fractional Spur Optimization section for more information.

If neither the phase resync nor the spurious optimization functions are being used, it is recommended that the phase value be set to 1.

<table>
<thead>
<tr>
<th>Reserved</th>
<th>12-Bit Phase Value (Phase)</th>
<th>Control Bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>DB31 DB30 DB29 DB28 DB27 DB26 DB25 DB24 DB23 DB22 DB21 DB20 DB19 DB18 DB17 DB16 DB15 DB14 DB13 DB12 DB11 DB10 DB9 DB8 DB7 DB6 DB5 DB4 DB3 DB2 DB1 DB0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P12 P11 P10 P9 P8 P7 P6 P5 P4 P3</td>
<td>PHASE VALUE (PHASE)</td>
<td>C3(0) C2(0) C1(1)</td>
</tr>
<tr>
<td>0 0</td>
<td>1 (RECOMMENDED)</td>
<td></td>
</tr>
<tr>
<td>0 0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>0 0</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>. .</td>
<td>.</td>
<td></td>
</tr>
<tr>
<td>. .</td>
<td>.</td>
<td></td>
</tr>
<tr>
<td>. .</td>
<td>.</td>
<td></td>
</tr>
<tr>
<td>1 1</td>
<td>4092</td>
<td></td>
</tr>
<tr>
<td>1 1</td>
<td>4093</td>
<td></td>
</tr>
<tr>
<td>1 1</td>
<td>4094</td>
<td></td>
</tr>
<tr>
<td>1 1</td>
<td>4095</td>
<td></td>
</tr>
</tbody>
</table>

Figure 18. Phase Register (R1) Map
MOD/R REGISTER, R2

With the control bits (Bits[2:0]) of Register R1 set to 010, the on-chip MOD/R register is programmed. Figure 19 shows the input data format for programming this register.

Noise and Spur Mode

The noise modes on the ADF4156 are controlled by DB30 and DB29 in the MOD/R register. See Figure 19 for the truth table. The noise modes allow the user to optimize a design either for improved spurious performance or for improved phase noise performance.

When the lowest spur setting is chosen, dither is enabled. This randomizes the fractional quantization noise so that it resembles white noise, rather than spurious noise. As a result, the part is optimized for improved spurious performance. This operation is typically used when the PLL closed-loop bandwidth is wide for fast-locking applications. Wide loop bandwidth is defined as a loop bandwidth greater than 1/10 of the RFOUT channel step resolution (fRES). A wide loop filter does not attenuate the spurs to the same level as a narrow loop bandwidth.

For best noise performance, use the lowest noise setting option. As well as disabling the dither, using the lowest noise setting ensures that the charge pump is operating in an optimum region for noise performance. This setting is useful if a narrow loop filter bandwidth is available. The typical performance characteristics show the trade-offs in a typical WCDMA setup for various noise and spur settings.

CSR Enable

Setting this bit to 1 enables cycle slip reduction, which can improve lock times. Note that the signal at the phase frequency detector (PFD) must have a 50% duty cycle for cycle slip reduction to work. The charge-pump current setting must also be set to a minimum value. See the Fast Lock Times section for more information. Note that CSR cannot be used if the phase detector polarity is set to negative.

Charge-Pump Current Setting

DB[27:24] set the charge-pump current setting. These bits should be set to the charge-pump current as indicated by the loop filter design (see Figure 19).

Prescaler (P/P + 1)

The dual-modulus prescaler (P/P + 1), along with the INT, FRAC, and MOD counters, determines the overall division ratio from the RFIN to the PFD input.

Operating at CML levels, the prescaler uses the clock from the RF input stage and divides it down for the counters. The prescaler is based on a synchronous 4/5 core. When it is set to 4/5, the maximum RF frequency allowed is 3 GHz. Therefore, when operating the ADF4156 with frequencies greater than 3 GHz, the prescaler must be set to 8/9. The prescaler limits the INT value as follows:

\[ P = 4/5, N_{MIN} = 23 \]
\[ P = 8/9, N_{MIN} = 75 \]

RDIV/2

Setting this bit to 1 inserts a divide-by-2 toggle flip-flop between the R-counter and PFD, which extends the maximum REFIN input rate.

Reference Doubler

Setting DB20 to 0 feeds the REFIN signal directly into the 5-bit RF R-counter, disabling the doubler. Setting this bit to 1 multiplies the REFIN frequency by a factor of 2 before feeding it into the 5-bit R-counter. When the doubler is disabled, the REFIN falling edge is the active edge at the PFD input to the fractional synthesizer. When the doubler is enabled, both the rising and falling edges of REFIN become active edges at the PFD input.

When the doubler is enabled and the lowest spur mode is chosen, the in-band phase noise performance is sensitive to the REFIN duty cycle. The phase noise degradation can be as much as 5 dB for REFIN duty cycles that are outside a 45% to 55% range. The phase noise is insensitive to the REFIN duty cycle when the device is in the lowest noise mode and when the doubler is disabled. The maximum allowable REFIN frequency when the doubler is enabled is 30 MHz.

5-Bit R-Counter

The 5-bit R-counter allows the input reference frequency (REFIN) to be divided down to produce the reference clock to the phase frequency detector (PFD). Division ratios from 1 to 32 are allowed.

12-Bit Interpolator MOD Value

This programmable register sets the fractional modulus, which is the ratio of the PFD frequency to the channel step resolution on the RF output. Refer to the RF Synthesizer: A Worked Example section for more information.
Figure 19. MOD/R Register (R2) Map

\[ \text{Figure 19. MOD/R Register (R2) Map} \]
FUNCTION REGISTER, R3

With the control bits (Bits[2:0]) of Register R2 set to 011, the on-chip function register is programmed. Figure 20 shows the input data format for programming this register.

**Counter Reset**

DB3 is the counter reset bit for the ADF4156. When this bit is set to 1, the synthesizer counters are held in reset. For normal operation, this bit should be 0.

**Charge-Pump Three-State**

When programmed to 1, DB4 puts the charge pump into three-state mode. This bit should be set to 0 for normal operation.

**Power-Down**

DB5 on the ADF4156 provides the programmable power-down mode. Setting this bit to 1 performs a power-down. Setting this bit to 0 returns the synthesizer to normal operation. While in software power-down mode, the part retains all information in its registers. Only when supplies are removed are the register contents lost.

When a power-down is activated, the following events occur:

1. The synthesizer counters are forced to their load state conditions.
2. The charge pump is forced into three-state mode.
3. The digital lock detect circuitry is reset.
4. The RF\textsubscript{IN} input is debiased.
5. The input register remains active and capable of loading and latching data.

**Phase Detector Polarity**

DB6 in the ADF4156 sets the phase detector polarity. When the VCO characteristics are positive, this bit should be set to 1. When the characteristics are negative, DB6 should be set to 0. Note that the cycle slip reduction function cannot be used if the phase detector polarity is set to negative.

**Lock Detect Precision (LDP)**

When DB7 is programmed to 0, the digital lock detect is set high when the phase error on 40 consecutive phase detector cycles is less than 10 ns each. When this bit is programmed to 1, 40 consecutive phase detector cycles of less than 6 ns each must occur before the digital lock detect is set.

**Σ-Δ Reset**

For most applications, DB14 should be programmed to 0. When DB14 is programmed to 0, the Σ-Δ modulator is reset to its starting point, or starting phase word, on every write to Register R0. This has the effect of producing consistent spur levels.

If it is not required that the Σ-Δ modulator be reset on each write to Register R0, DB14 should be set to 1.

---

**Figure 20. Function Register (R3) Map**
CLK DIV REGISTER, R4

With the control bits (Bits[2:0]) of Register R3 set to 100, the on-chip clock divider register (R4) is programmed. Figure 21 shows the input data format for programming this register.

12-Bit Clock Divider Value

The 12-bit clock divider value sets the timeout counter for activation of the fast-lock mode or a phase resync. See the Phase Resync section for more information.

Clock Divider Mode

DB[20:19] control the mode of the clock divider in the ADF4156. These bits should be set to 01 to activate the fast-lock mode, or to 10 to activate a phase resync. In most applications, neither a fast lock nor a phase resync is required. In this case, DB[20:19] should be set to 00.

<table>
<thead>
<tr>
<th>RESERVED</th>
<th>CLK DIV MODE</th>
<th>12-BIT CLOCK DIVIDER VALUE</th>
<th>RESERVED</th>
<th>CONTROL BITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td>M2 M1 M12 D11 D10 D9 D8 D7 D6 D5 D4 D3 D2 D1</td>
<td>R4 R3 R2 R1 C3(1) C2(0) C1(0)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 21. CLK DIV Register (R4) Map

Reserved Bits

All reserved bits should be set to 0 for normal operation.

Initialization Sequence

After powering up the part, the correct register programming sequence is as follows:

1. CLK DIV register (R4)
2. Function register (R3)
3. MOD/R register (R2)
4. Phase register (R1)
5. FRAC/INT register (R0)
RF SYNTHESIZER: A WORKED EXAMPLE

The following equation governs how the synthesizer should be programmed:

\[ RF_{OUT} = \left[ INT + \frac{FRAC}{MOD}\right] \times [FPFD] \]  \hspace{1cm} (3)

where:
- \( RF_{OUT} \) is the RF frequency output.
- \( INT \) is the integer division factor.
- \( FRAC \) is the fractionality.
- \( MOD \) is the modulus.

The PFD frequency can be calculated as follows:

\[ FPFD = \frac{REFIN \times ((1 + D)/(R \times (1 + T)))}{13 \text{ MHz}} \]  \hspace{1cm} (4)

where:
- \( REFIN \) is the reference frequency input.
- \( D \) is the RF \( \text{REFIN} \) doubler bit.
- \( T \) is the reference divide-by-2 bit, which is set to 0 or 1.
- \( R \) is the RF reference division factor.

For example, in a GSM 1800 system, 1.8 GHz RF frequency output (\( RF_{OUT} \)) is required, 13 MHz reference frequency input (\( REFIN \)) is available, and 200 kHz channel resolution (\( f_{RES} \)) is required on the RF output.

\[ MOD = \frac{REFIN}{f_{RES}} \]
\[ MOD = 13 \text{ MHz}/200 \text{ kHz} = 65 \]

Therefore, from Equation 4,

\[ FPFD = \frac{13 \text{ MHz} \times (1 + 0)/(1)}{13 \text{ MHz}} = 13 \text{ MHz} \]  \hspace{1cm} (5)
\[ 1.8 \text{ GHz} = 13 \text{ MHz} \times (INT + \frac{FRAC}{65}) \]  \hspace{1cm} (6)

where \( INT = 138 \) and \( FRAC = 30 \).

MODULUS

The choice of modulus (MOD) depends on the reference signal (\( REFIN \)) available and the channel resolution (\( f_{RES} \)) required at the RF output. For example, a GSM 1800 system with 13 MHz \( REFIN \) sets the modulus to 65, resulting in the required RF output resolution (\( f_{RES} \)) of 200 kHz (13 MHz/65). With dither off, the fractional spur interval depends on the modulus values chosen. See Table 7 for more information.

REFERENCE DOUBLER AND REFERENCE DIVIDER

The on-chip reference doubler allows the input reference signal to be doubled. This is useful for increasing the PFD comparison frequency, which in turn improves the noise performance of the system. Doubling the PFD frequency usually improves noise performance by 3 dB. It is important to note that the PFD cannot operate with frequencies greater than 32 MHz due to a limitation in the speed of the \( \Sigma \Delta \) circuit of the \( N \)-divider.

The reference divide-by-2 divides the reference signal by 2, resulting in a 50% duty cycle PFD frequency. This is necessary for the correct operation of the cycle slip reduction (CSR) function. See the Fast Lock Times section for more information.

12-BIT PROGRAMMABLE MODULUS

Unlike most other fractional-N PLLs, the ADF4156 allows the user to program the modulus over a 12-bit range. Therefore, several configurations of the ADF4156 are possible for an application by varying the modulus value, the reference doubler, and the 5-bit \( R \)-counter.

For example, consider an application that requires 1.75 GHz RF and 200 kHz channel step resolution. The system has a 13 MHz reference signal.

One possible setup is feeding the 13 MHz directly into the PFD and programming the modulus to divide by 65. This results in the required 200 kHz resolution.

Another possible setup is using the reference doubler to create 26 MHz from the 13 MHz input signal. The 26 MHz signal is then fed into the PFD, which programs the modulus to divide by 130. This setup also results in 200 kHz resolution, but offers superior phase noise performance compared with the previous setup.

The programmable modulus is also useful for multistandard applications. If a dual-mode phone requires PDC and GSM 1800 standards, the programmable modulus is a great benefit. The PDC requires 25 kHz channel step resolution, whereas GSM 1800 requires 200 kHz channel step resolution.

A 13 MHz reference signal can be fed directly into the PFD, and the modulus can be programmed to 520 when in PDC mode (13 MHz/520 = 25 kHz). However, the modulus must be reprogrammed to 65 for GSM 1800 operation (13 MHz/65 = 200 kHz).

It is important that the PFD frequency remains constant (13 MHz). This allows the user to design one loop filter that can be used in both setups without running into stability issues. It is the ratio of the RF frequency to the PFD frequency that affects the loop design. By keeping this relationship constant, the same loop filter can be used in both applications.

FAST LOCK TIMES WITH THE ADF4156

As mentioned in the Noise and Spur Mode section, the ADF4156 can be optimized for noise performance. However, in fast-locking applications, the loop bandwidth needs to be wide; therefore, the filter does not provide much attenuation of the spurs.

There are two methods of achieving a fast lock time for the ADF4156: using cycle slip reduction or using dynamic bandwidth switching mode. In both cases, the idea is to keep the loop bandwidth narrow to attenuate spurs while obtaining a fast lock time.

Cycle slip reduction mode is the preferred technique because it does not require modifications to the loop filter or optimization of the timeout counter values and is therefore easier to implement.
In most cases, this method also provides faster lock times than the bandwidth switching mode method. In extreme cases, where cycle slips do not exist in the settling transient, the bandwidth switching mode can be used.

**Cycle Slip Reduction Mode**

Cycle slips occur in integer-N/fractional-N synthesizers when the loop bandwidth is narrow compared with the PFD frequency. The phase error at the PFD inputs accumulates too fast for the PLL to correct, and the charge pump temporarily pumps in the wrong direction. This slows down the lock time dramatically. The ADF4156 contains a cycle slip reduction circuit to extend the linear range of the PFD, allowing faster lock times without requiring loop filter changes.

When the ADF4156 detects that a cycle slip is about to occur, it turns on an extra charge-pump current cell. This either outputs a constant current to the loop filter or removes a constant current from the loop filter, depending on whether the VCO tuning voltage needs to increase or decrease to acquire the new frequency. As a result, the linear range of the PFD is increased. Stability is maintained because the current is constant, not pulsed.

If the phase error increases to a point where another cycle slip is likely, the ADF4156 turns on another charge-pump cell. This process continues until the ADF4156 detects that the VCO frequency is beyond the desired frequency. The extra charge-pump cells then begin to turn off one by one until they are all turned off and the frequency is settled.

Up to seven extra charge-pump cells can be turned on. In most applications, this is sufficient to eliminate cycle slips altogether, resulting in much faster lock times.

Setting Bit DB28 in the MOD/R register (R2) to 1 enables cycle slip reduction. A 45% to 55% duty cycle is needed on the signal at the PFD for CSR to operate correctly. Note that CSR cannot be used if the phase detector polarity is set to negative; therefore, a noninverting loop filter topology should be used with CSR.

**Dynamic Bandwidth Switching Mode**

The dynamic bandwidth switching mode involves increasing the loop filter bandwidth for a set time at the beginning of the locking transient. This is achieved by boosting the charge-pump current from the set value in Register R2 to the maximum setting. To maintain loop stability during this period, it is necessary to modify the loop filter by adding a switch and resistor. When the new frequency is programmed to the ADF4156 in this mode, three events occur simultaneously to put the device in wideband mode:

- A timeout counter is started.
- The charge-pump current is boosted from its set current to the maximum setting.
- The fast-lock switch (available via MUXOUT) is activated.

The timeout counter in Register R4 defines the period that the device is kept in wideband mode. During wideband mode, the PLL acquires lock faster due to the wider loop filter bandwidth. Stability is maintained at the optimal 45° setting due to the use of the extra resistor in the loop filter.

When the timeout counter times out, the charge-pump current is reduced from the maximum setting to its set current, and the fast-lock switch is deactivated. The device is then in narrow-band mode, and spurs are attenuated.

To ensure optimum lock time, the timeout counter should be set to time out when the PLL is close to the final frequency. If the switch is deactivated, a spike in the settling transient will be observed due to charge insertion from the switch. Because the PLL is in narrow-band mode, this spike can take some time to settle out. This is one of the disadvantages of the bandwidth switching mode compared with the cycle slip reduction mode.

**Fast Lock: An Example**

If a PLL has a reference frequency of 13 MHz, a f\text{PFD} of 13 MHz, and a required lock time of 50 μs, the PLL is set to wide bandwidth for 40 μs.

If the time set for the wide bandwidth is 40 μs, then

$$\text{Fast-Lock Timer Value} = \text{Time in Wide Bandwidth} \times f_{\text{PFD}}$$

$$\text{Fast-Lock Timer Value} = 40 \mu s \times 13 \text{ MHz} = 520$$

Therefore, 520 must be loaded into Bits DB[18:7] of Register R4. The clock divider mode bits (DB[20:19]) in Register R4 must also be set to 01 to activate this mode. To activate the fast-lock switch on the MUXOUT pin, the MUXOUT control bits (DB[30:27]) in Register R0 must be set to 1100.

**Fast Lock: Loop Filter Topology**

To use fast-lock mode, an extra connection from the PLL to the loop filter is needed. The damping resistor in the loop filter must be reduced to ¼ of its value while in wide bandwidth mode. This is required because the charge-pump current is increased by 16 while in wide bandwidth mode and stability must be ensured. When the ADF4156 is in fast-lock mode (that is, when the fast-lock switch is programmed to appear at the MUXOUT pin), the MUXOUT pin is automatically shorted to ground. The following two topologies can be used:

- **Topology 1**: Divide the damping resistor (R1) into two values (R1 and R1A) that have a ratio of 1:3 (see Figure 22).
- **Topology 2**: Connect an extra resistor (R1A) directly from MUXOUT, as shown in Figure 23. The extra resistor must be chosen such that the parallel combination of an extra resistor and the damping resistor (R1) is reduced to ¼ of the original value of R1 (see Figure 23).
SPUR MECHANISMS

This section describes the three spur mechanisms that arise with a fractional-N synthesizer and how to minimize these spurs in the ADF4156.

Fractional Spurs

The fractional interpolator in the ADF4156 is a third-order Σ-Δ modulator with a modulus (MOD) that is programmable to any integer value from 2 to 4095. In low spur mode (dither enabled), the minimum allowable value of MOD is 50. The Σ-Δ modulator is clocked at the PFD reference rate \( f_{PFD} \) that allows PLL output frequencies to be synthesized at a channel step resolution of \( f_{PFD}/\text{MOD} \).

In low noise mode (dither off), the quantization noise from the Σ-Δ modulator appears as fractional spurs. The interval between spurs is \( f_{PFD}/L \), where \( L \) is the repeat length of the code sequence in the digital Σ-Δ modulator. For the third-order modulator used in the ADF4156, the repeat length depends on the value of MOD, as listed in Table 7.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Repeat Length</th>
<th>Spur Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>If MOD is divisible by 2, but not 3</td>
<td>2 × MOD</td>
<td>Channel step/2</td>
</tr>
<tr>
<td>If MOD is divisible by 3, but not 2</td>
<td>3 × MOD</td>
<td>Channel step/3</td>
</tr>
<tr>
<td>If MOD is divisible by 6</td>
<td>6 × MOD</td>
<td>Channel step/6</td>
</tr>
<tr>
<td>Otherwise</td>
<td>MOD</td>
<td>Channel step</td>
</tr>
</tbody>
</table>

In low spur mode (dither enabled), the repeat length is extended to \( 2^{21} \) cycles, regardless of the value of MOD, which makes the quantization error spectrum look like broadband noise. As a result, the in-band phase noise at the PLL output can be degraded by as much as 10 dB. Therefore, for lowest noise, keeping dither off is a better choice, particularly when the final loop bandwidth is low enough to attenuate even the lowest frequency fractional spur.

Integer Boundary Spurs

Another mechanism for fractional spur creation is interactions between the RF VCO frequency and the reference frequency. When these frequencies are not integer related (as is the case with fractional-N synthesizers), spur sidebands appear on the VCO output spectrum at an offset frequency that corresponds to the beat note or the difference in frequency between an integer multiple of the reference and the VCO frequency.

These spurs are attenuated by the loop filter and are more noticeable on channels close to integer multiples of the reference, where the difference frequency can be inside the loop bandwidth, hence the name integer boundary spurs.

Reference Spurs

Reference spurs are generally not a problem in fractional-N synthesizers because the reference offset is far outside the loop bandwidth. However, any reference feedthrough mechanism that bypasses the loop can cause a problem. One such mechanism is feedthrough of low levels of switching noise from the on-chip reference through the RF\(_{\text{IN}}\) pin and back to the VCO, resulting in reference spur levels as high as −90 dBc. Care should be taken in the PCB layout to ensure that the VCO is well separated from the input reference to avoid a possible feedthrough path on the board.

SPUR CONSISTENCY AND FRACTIONAL SPUR OPTIMIZATION

With dither off, the fractional spur pattern due to the quantization noise of the Σ-Δ modulator also depends on the phase word set as the starting point of the modulator. Setting the Σ-Δ reset bit (DB14 in Register R3) to 0 ensures that this starting point is used for the Σ-Δ modulator on every write to Register R0.

The phase word can be varied to optimize the fractional and subfractional spur levels on any particular frequency. Therefore, a look-up table of phase values corresponding to each frequency can be constructed for use when programming the ADF4156.

The evaluation software has a sweep function to sweep the phase word so that the user can observe the spur levels on a spectrum analyzer.

If a look-up table is not used, keep the phase word at a constant value to ensure consistent spur levels on a particular frequency.
**PHASE RESYNC**

The output of a fractional-N PLL can settle to any MOD phase offset with respect to the input reference, where MOD is the fractional modulus. The phase resync feature in the ADF4156 is used to produce a consistent output phase offset with respect to the input reference. This is necessary in applications where the output phase and frequency are important, such as digital beam forming. See the Phase Programmability section for information about how to program a specific RF output phase when using the phase resync feature.

Phase resync is enabled by setting Bits DB[20:19] in Register R4 to 10. When phase resync is enabled, an internal timer generates sync signals at intervals of $t_{SYNC}$ as indicated by the following formula:

$$t_{SYNC} = \text{CLK\_DIV\_VALUE} \times \text{MOD} \times t_{PFD}$$

where:

- $t_{PFD}$ is the PFD reference period.
- $\text{CLK\_DIV\_VALUE}$ is the decimal value programmed in Bit DB[18:7] of Register R4. This value can be any integer in the range of 1 to 4095.
- MOD is the modulus value programmed in Bit DB[14:3] of Register R2.

When a new frequency is programmed, the second sync pulse after the LE rising edge is used to resynchronize the output phase to the reference. The $t_{SYNC}$ time should be programmed to a value that is at least as long as the worst-case lock time. Doing so guarantees that the phase resync occurs after the last cycle slip in the PLL settling transient.

In the example shown in Figure 24, the PFD reference is 25 MHz and the MOD value is 125 for a 200 kHz channel spacing. Therefore, $t_{SYNC}$ is set to 400 μs by programming $\text{CLK\_DIV\_VALUE}$ to 80.

**Phase Programmability**

To program a specific RF output phase, change the phase word in Register R1. As this word is swept from 0 to MOD, the RF output phase sweeps over a 360°/MOD range in steps of 360°/MOD.

**LOW FREQUENCY APPLICATIONS**

The specification on the RF input is 0.5 GHz minimum; however, lower RF frequencies can be used if the minimum slew rate specification of 400 V/μs is met. An appropriate LVDS driver, such as the FIN1001 from Fairchild Semiconductor, can be used to square up the RF signal before it is fed back into the ADF4156 RF input.

**FILTER DESIGN—ADIsimPLL**

A filter design and analysis program is available to help implement the PLL design. Visit [www.analog.com/pll](http://www.analog.com/pll) for a free download of the ADIsimPLL™ software. This software designs, simulates, and analyzes the entire PLL frequency domain and time domain response. Various passive and active filter architectures are allowed. When designing the loop filter, keep the ratio of the PFD frequency to the loop bandwidth $>200:1$ to attenuate the Σ-Δ modulator noise.
INTERFACING

The ADF4156 has a simple SPI-compatible serial interface for writing to the device. CLOCK, DATA, and LE control the data transfer. When latch enable (LE) is high, the 29 bits that have been clocked into the input register on each rising edge of serial clock are transferred to the appropriate latch. The maximum allowable serial clock rate is 20 MHz. See Figure 2 for the timing diagram and Table 6 for the latch truth table.

PCB DESIGN GUIDELINES FOR CHIP SCALE PACKAGE

The lands on the lead frame chip scale package (CP-20-1) are rectangular. The printed circuit board pad for these lands should be 0.1 mm longer than the package land length and 0.05 mm wider than the package land width. The package land should be centered on the pad to ensure that the solder joint size is maximized.

The bottom of the chip scale package has a central thermal pad. The thermal pad on the printed circuit board should be at least as large as this exposed pad. On the printed circuit board, there should be a clearance of at least 0.25 mm between the thermal pad and the inner edges of the pad pattern to ensure that shorting is avoided. Thermal vias can be used on the printed circuit board thermal pad to improve thermal performance of the package. If vias are used, they should be incorporated in the thermal pad on a 1.2 mm pitch grid. The via diameter should be between 0.3 mm and 0.33 mm, and the via barrel should be plated with 1 oz of copper to plug the via. In addition, the printed circuit board thermal pad should be connected to AGND.
OUTLINE DIMENSIONS

Figure 25. 16-Lead Thin Shrink Small Outline Package [TSSOP] (RU-16)
Dimensions shown in millimeters

Figure 26. 20-Lead Lead Frame Chip Scale Package [LFCSP_VQ]
4 mm x 4 mm Body, Very Thin Quad (CP-20-1)
Dimensions shown in millimeters
<table>
<thead>
<tr>
<th>Model</th>
<th>Temperature Range</th>
<th>Package Description</th>
<th>Package Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADF4156BRUZ(^1)</td>
<td>−40°C to +85°C</td>
<td>16-Lead Thin Shrink Small Outline Package [TSSOP]</td>
<td>RU-16</td>
</tr>
<tr>
<td>ADF4156BRUZ-RL(^1)</td>
<td>−40°C to +85°C</td>
<td>16-Lead Thin Shrink Small Outline Package [TSSOP]</td>
<td>RU-16</td>
</tr>
<tr>
<td>ADF4156BRUZ-RL7(^1)</td>
<td>−40°C to +85°C</td>
<td>16-Lead Thin Shrink Small Outline Package [TSSOP]</td>
<td>RU-16</td>
</tr>
<tr>
<td>ADF4156BCPZ(^1)</td>
<td>−40°C to +85°C</td>
<td>20-Lead Lead Frame Chip Scale Package [LFCSP_VQ]</td>
<td>CP-20-1</td>
</tr>
<tr>
<td>ADF4156BCPZ-RL(^1)</td>
<td>−40°C to +85°C</td>
<td>20-Lead Lead Frame Chip Scale Package [LFCSP_VQ]</td>
<td>CP-20-1</td>
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<tr>
<td>ADF4156BCPZ-RL7(^1)</td>
<td>−40°C to +85°C</td>
<td>20-Lead Lead Frame Chip Scale Package [LFCSP_VQ]</td>
<td>CP-20-1</td>
</tr>
<tr>
<td>EVAL-ADF4156EBZ(^1)</td>
<td>−40°C to +85°C</td>
<td>Evaluation Board</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Z = RoHS Compliant Part.