



## General Description

The ICS1523 is a low-cost, high-performance frequency generator. It is well suited to general purpose phase controlled clock synthesis as well as line-locked and genlocked high-resolution video applications. Using ICS's advanced low-voltage CMOS mixed-mode technology, the ICS1523 is an effective phase controlled clock synthesizer and also supports video projectors and displays at resolutions from VGA to beyond UXGA.

The ICS1523 offers clock outputs in both differential (to 250 MHz) and single-ended (to 150 MHz) formats. Dynamic Phase Adjust (DPA) allows I<sup>2</sup>C™ control of the output clock's phase relative to the input sync signal. A second, half speed set of outputs that can be separately enabled allows such applications as clocking analog-to-digital converters. The FUNC pin provides either the regenerated input from the phase-locked loop (PLL) divider chain output, or the input HSYNC after being sharpened by the Schmitt trigger. Both signals are then delayed by the DPA.

The advanced PLL uses either its internal programmable feedback divider or an external divider. Either the internal or external loop filters is software selectable. The COAST input pin disables the PLL's charge pump, causing the device to idle at the current speed for short periods of time, such as vertical blanking intervals.

The device is programmed by a standard I<sup>2</sup>C-bus serial interface and is available in a 24-pin, wide small-outline integrated circuit (SOIC) package.

## Features

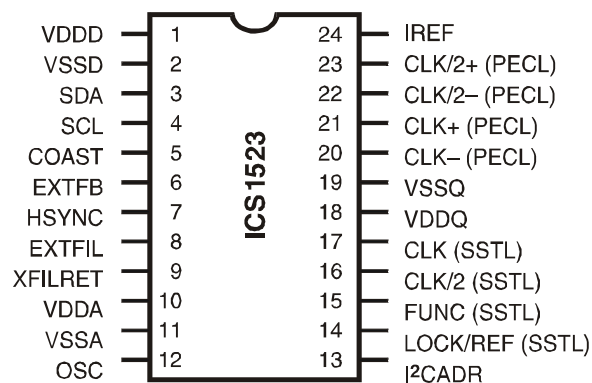
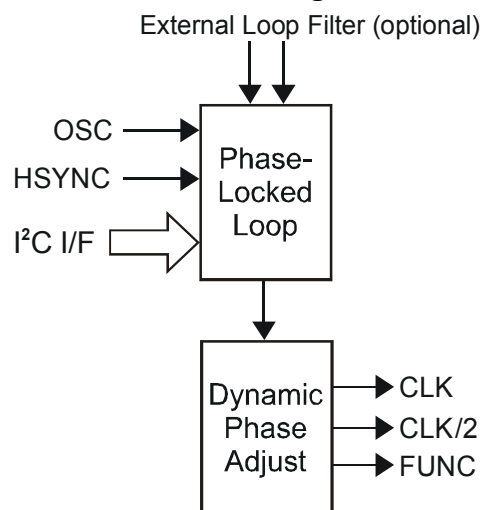
- Low Jitter
- Wide input frequency range
  - 15.734 kHz to 100 MHz
- PECL differential outputs
  - Up to 250 MHz
- SSTL\_3 Single-ended clock outputs
  - Up to 150 MHz
- Dynamic Phase Adjust (DPA) for all outputs
  - I<sup>2</sup>C controlled phase adjustment
  - Full clock cycle down to 1/64 of a clock
- Double-buffered control registers
- External or internal loop filter selection
- COAST input can disable charge pump
- 3.3 VDD
- 5 volt Tolerant Inputs
- Industry Standard I<sup>2</sup>C-bus programming interface
- PLL Lock detection via I<sup>2</sup>C or LOCK/REF output pin
- 24-pin 300-mil SOIC package
- Available in Pb-free packaging

## Applications

- Frequency synthesis
- LCD monitors, video projectors and plasma displays
- Genlocking multiple video subsystems

## Pin Configuration

### ICS1523 Functional Diagram



24-pin SOIC



## Section 1 Operational Description

### 1.1 Naming Conventions

0xY = Register Index Y(hex)

0xY:Z = Register Index Y(hex), bit Z

0xY:Z~Q = Register Index Y(hex), bit Z to Q

### 1.2 Overview

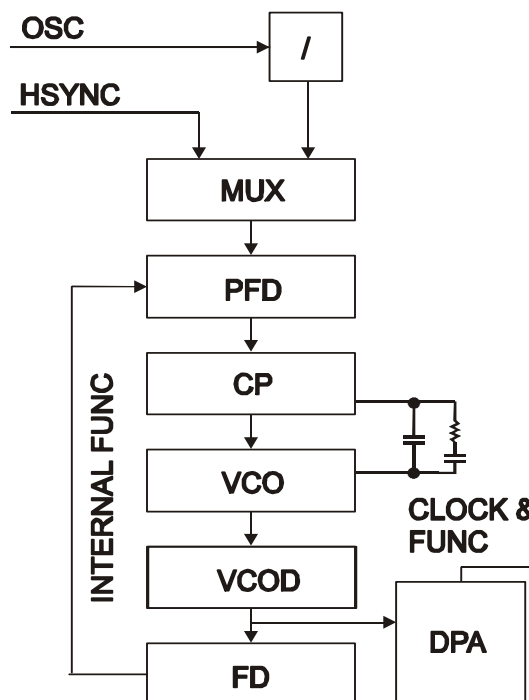
The ICS1523 is a general purpose, high-performance, I2C programmable clock generator. It also addresses stringent graphics system line-locked and genlocked applications and provides the clock signals required by high-performance analog-to-digital converters. Included are a phase-locked loop (PLL) with an over 500MHz voltage controlled oscillator (VCO), a Dynamic Phase Adjust to provide (DPA) output clocks with a programmable phase delay with respect to the input HSYNC. This delay occurs on all PLL outputs including the differential (PECL) and single-ended (SSTL\_3) high-speed clock outputs and the FUNC output.

The ICS1523 has the ability to operate in line-locked mode with the HSYNC input or in frequency synthesis mode with the OSC input with a 7 bit input divider. See [Section 6, "OSC Divider and REF"](#)

### 1.3 Phase-Locked Loop (PLL)

The phase-locked loop has a very wide input frequency range (8 kHz to 100 MHz). Not only is the ICS1523 an excellent, general purpose clock synthesizer, but it is also capable of line-locked operation.

Figure 1-1 PLL Functional Blocks



### 1.4 Voltage Controlled Oscillator (VCO)

The heart of the ICS1523 is a VCO. The VCOs speed is controlled by the voltage on the loop filter circuit. This voltage is controlled by the charge pump (CP) and will be further described later in this section.

### 1.5 Charge Pump (CP) and COAST Input

The CPen bit and COAST input pin can enable and disable the Charge Pump as needed. See Register 0:7-6. This is for maintaining the correct speed clock outputs in the absence of reliable HSYNC inputs and is useful for skipping vertical blanking intervals. These intervals can have double frequency serration pulses or even be missing HSYNC pulses completely. The charge pump is asynchronously disabled and synchronously re-enabled on the second input HSYNC after the disable signal goes invalid.

### 1.6 VCO Divider (VCOD)

The VCOs clock output is first passed through the VCO Divider (VCOD). The VCOD allows the VCO to operate at higher speeds than the required output clock. The VCOD has no effect on the speed of the output clocks, but it increases the VCO frequency, thereby reducing jitter and allowing VCO operation between 100 to 500



MHz even if a low output frequency is required. The output of the VCOD is the full speed output frequency seen on the CLK pins.

## 1.7 Dynamic Phase Adjust (DPA)

The VCOD output clock is then sent through the DPA for phase adjustment relative to the input HSYNC as well as the 12-bit internal Feedback Divider. An external divider may alternately be used and its output must be input on the EXTFB pin. The feedback divider controls how many clocks are seen during every cycle of the input reference.

The DPA allows a programmable delay between the input HSYNC to the clock and FUNC outputs, relative to the input HSYNC signal on a sub-pixel basis. A delay of up to one clock period is programmable: See Note 6 in [Section 5, "Register Set Details"](#) for more information.

## 1.8 Feedback Divider (FD) and FUNC

The 12-bit FD controls how many clocks are seen between successive HSYNCs.

The number of clocks per HSYNC is  $FB + 8$

The FD output is a 4 CLK wide, active high signal called FUNC. The FUNC signal is aligned with the output clocks via the DPA and is intended to be used by the system as a replacement for the HSYNC input, which is of in-determinate quality and is not aligned with the output clocks. Alternately, the post Schmitt-trigger HSYNC signal can also be DPA delayed and then output on the FUNC pin. See 0x0:5.

## 1.9 Phase Frequency Detector (PFD)

The PFD compares the FUNC signal to the selected input described below and controls the filter voltage by enabling and disabling the charge pump. The charge pump has programmable current drive and will source and sink current as appropriate to keep the input and the FUNC output aligned.

## 1.10 HSYNC and REF Inputs

One of the PFDs two possible inputs is HSYNC (pin 7). HSYNC is conditioned by a high-performance Schmitt-trigger. This preconditioned HSYNC signal, called REF, is provided as a reference signal with a short transition time. REF can be output on pin 14.

## 1.11 OSC Input

The high-frequency OSC input pin, has a 7-bit user programmable divider. OSC can also be selected as the loop input, allowing the loop to operate from any appropriate, single-ended source, typically a crystal oscillator.

## 1.12 FUNC Output

Either the conditioned HSYNC input or the loop output (recovered HSYNC) is available at the FUNC pin, and is aligned with the output clocks.

## 1.13 Logic Inputs

The ICS1523 uses Low-Voltage TTL (LVTTTL) inputs that are 5 volt tolerant such as most VESA compliant HSYNC and VSYNC signals.

## 1.14 Output Drivers

The ICS1523 also has SSTL\_3 (EIA/JESD8-8) and low-voltage PECL (Positive ECL) outputs, operating off the 3.3 V supply voltage.

The SSTL\_3 and differential PECL output drivers drive resistive terminations or transmission lines. At lower clock frequencies, the SSTL\_3 outputs can be operated unterminated. See [Section 9, "Output Termination"](#)

## 1.15 Power-On Reset Detection (POR)

The ICS1523 has automatic POR circuitry, meaning it resets itself if the supply voltage drops below a threshold values of approximately 1.8 V. No external connection to a reset signal is required.

## 1.16 I<sup>2</sup>C Bus Serial Interface

The ICS1523 uses a 5 V tolerant, industry-standard I<sup>2</sup>C-bus serial interface that runs at either low speed (100 kHz) or high speed (400 kHz). The interface uses 12 indexed registers: one write-only, eight read/write, and three read-only registers.

Two ICS1523 devices can be addressed according to the state of the I2CADR pin. When this pin is low the read address is 4Dh and the write address is 4Ch. When the pin is high, the read address is 4Fh and the write address is 4Eh. See [Section 11, "Programming"](#).



## Section 2 Pin Descriptions

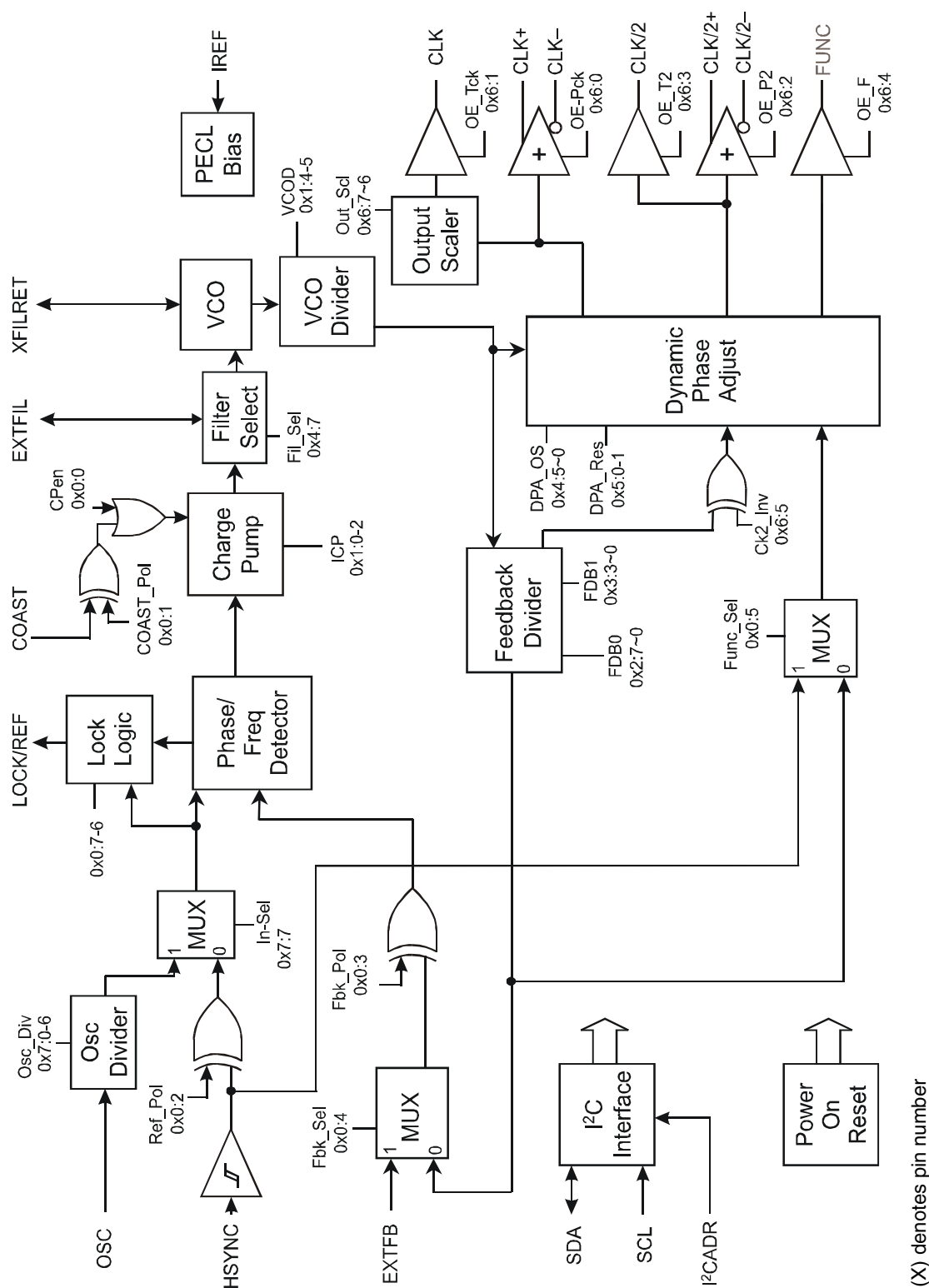
| PIN NO. | PIN NAME            | TYPE       | DESCRIPTION              | COMMENTS                                                                                                      | Notes |
|---------|---------------------|------------|--------------------------|---------------------------------------------------------------------------------------------------------------|-------|
| 1       | VDDD                | POWER      | Digital supply           | 3.3 V to digital sections                                                                                     |       |
| 2       | VSSD                | POWER      | Digital ground           |                                                                                                               |       |
| 3       | SDA                 | IN/OUT     | Serial data              | I <sup>2</sup> C-bus Data                                                                                     | 1     |
| 4       | SCL                 | IN         | Serial clock             | I <sup>2</sup> C-bus Clock                                                                                    | 1     |
| 5       | COAST               | IN         | Charge pump enable       | Enables\Disables the charge pump                                                                              | 1     |
| 6       | EXTFB               | IN         | External feedback in     | External feedback divider input                                                                               | 1     |
| 7       | HSYNC               | IN         | Horizontal sync          | Clock input to PLL                                                                                            | 1     |
| 8       | EXTFIL              | IN         | External filter          | External loop filter                                                                                          |       |
| 9       | XFILRET             | IN         | External filter return   | External loop filter return                                                                                   |       |
| 10      | VDDA                | POWER      | Analog supply            | 3.3 V for analog circuitry                                                                                    |       |
| 11      | VSSA                | POWER      | Analog ground            | Ground for analog circuitry                                                                                   |       |
| 12      | OSC                 | IN         | Oscillator               | Input from oscillator or other high frequency input                                                           | 1 & 2 |
| 13      | I <sup>2</sup> CADR | IN         | I <sup>2</sup> C address | Chip I <sup>2</sup> C address select<br>Low = 4Dh read, 4Ch write<br>High = 4Fh read, 4Eh write               |       |
| 14      | LOCK/REF            | SSTL_3 OUT | Lock / Reference         | REF (Schmitt conditioned HSYNC) or PLL lock output                                                            |       |
| 15      | FUNC                | SSTL_3 OUT | Function output          | Output selectable between a 4 clock wide, active high HSYNC-like output, and a Schmitt-trigger filtered HSYNC |       |
| 16      | CLK/2               | SSTL_3 OUT | Pixel clock/2 output     | Output driver for half speed clock                                                                            |       |
| 17      | CLK                 | SSTL_3 OUT | Pixel clock output       | Output driver for full speed clock                                                                            |       |
| 18      | VDDQ                | POWER      | Output driver supply     | 3.3 V to output drivers                                                                                       |       |
| 19      | VSSQ                | POWER      | Output driver ground     | Ground for output drivers                                                                                     |       |
| 20      | CLK-                | OD OUT     | Pixel clock outputs      | PECL driver for full-speed clock                                                                              |       |
| 21      | CLK+                |            |                          |                                                                                                               |       |
| 22      | CLK/2-              | OD OUT     | Pixel clock/2 outputs    | PECL driver for half-speed clock                                                                              |       |
| 23      | CLK/2+              |            |                          |                                                                                                               |       |
| 24      | IREF                | IN         | Reference current        | Reference current for PECL outputs                                                                            |       |

Note 1: These LVTTTL inputs are 5 V-tolerant.

Note 2: Connect to ground if unused.



## Section 3 Functional Block Diagram





## Section 4 Register Set Summary

| Reg. Index | Name          | Access | Bit Name   | Bit# | Reset Value | Description                                                                                                                                  | Note |
|------------|---------------|--------|------------|------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------|------|
| 0x0        | Input Control | R / W  | CPen       | 0    | 1           | Charge Pump Enable<br>0=External Enable via COAST Pin, 1=Always Enabled                                                                      | 3    |
|            |               |        | CP_Pol     | 1    | 0           | COAST Pin Charge Pump Enable Polarity<br>0=Active High, 1=Active Low                                                                         | 3    |
|            |               |        | Ref_Pol    | 2    | 0           | External Reference Polarity<br>0=Positive Edge, 1=Negative Edge                                                                              |      |
|            |               |        | Fbk_Pol    | 3    | 0           | External Feedback Polarity<br>0=Positive Edge, 1=Negative Edge                                                                               |      |
|            |               |        | Fbk_Sel    | 4    | 0           | External Feedback Select<br>0=Internal Feedback, 1=External                                                                                  |      |
|            |               |        | Func_Sel   | 5    | 0           | FUNC Pin Output Select (DPA delayed)<br>0=Recovered HSYNC, 1=Input HSYNC                                                                     |      |
|            |               |        | EnPLS      | 6    | 1           | Enable PLL Lock/Ref Status Output<br>0=Disable 1=Enable                                                                                      | 4    |
|            |               |        | EnRef      | 7    | 0           | 1=Enable Ref to Lock/Ref Output                                                                                                              | 4    |
| 0x1        | Loop Control  | R / W  | ICP0-2     | 0-2  | 0           | ICP (Charge Pump Current)<br>Bit 2,1,0=(000 = 1 uA, 001 = 2 uA, 010 = 4 uA, 011 = 8 uA, 100 = 16 uA, 101 = 32 uA, 110 = 64 uA, 111 = 128 uA) | 1, 6 |
|            |               |        | Reserved   | 3    | 0           | Reserved                                                                                                                                     |      |
|            |               |        | VCOD0-1    | 4-5  | 0           | VCO Divider Bit 5,4 =(00 = ÷2, 01=÷4, 10=÷8, 11=÷16)                                                                                         | 1, 7 |
|            |               |        | Reserved   | 6-7  | 0           | Reserved                                                                                                                                     |      |
| 0x2        | FdBk Div 0    | R / W  | FBD0-7     | 0-7  | FF          | Feedback Divider LSBs (Bit 7, 6, 5, 4, 3, 2, 1, 0)<br>Actual # of clocks = Programmed value + 8                                              | 1    |
| 0x3        | FdBk Div 1    | R / W  | FBD8-11    | 0-3  | F           | Feedback Divider MSBs (Bit 11, 10, 9, 8)                                                                                                     | 1    |
|            |               |        | Reserved   | 4-7  | 0           | Reserved                                                                                                                                     |      |
| 0x4        | DPA Offset    | R / W  | DPA_OS0-5  | 0-5  | 0           | Dynamic Phase Aligner Offset<br>Bit 5, 4, 3, 2, 1, 0 = (MUST be < total # of DPA elements)                                                   | 8    |
|            |               |        | Reserved   | 6    | 0           | Reserved                                                                                                                                     |      |
|            |               |        | Fil_Sel    | 7    | 0           | Loop Filter Select (0=External, 1=Internal)                                                                                                  | 6    |
| 0x5        | DPA Control   | R / W  | DPA_Res0-1 | 0-1  | 3           | DPA Resolution, Total # of delay elements<br>Bit 1, 0 = (00 = 16, 01 = 32, 10 = Reserved, 11 = 64)                                           | 2, 8 |
|            |               |        | Metal_Rev  | 2-7  | 0           | Metal Mask Revision Number                                                                                                                   |      |

Note 1: Double-buffered register. Working registers are loaded during software PLL reset. See 0x8.

Note 2: Double-buffered register. Working registers are loaded during software DPA reset. See 0x8.

Notes 3~8: See [Section 5, "Register Set Details"](#)



## 4.1 Register Set Summary (continued)

| Reg. Index | Name           | Access | Bit Name    | Bit # | Reset Value | Description                                                                                                                         | Notes |
|------------|----------------|--------|-------------|-------|-------------|-------------------------------------------------------------------------------------------------------------------------------------|-------|
| 0x6        | Output Enables | R / W  | OE_Pck      | 0     | 0           | Output Enable for PECL CLK (Pins 20, 21)<br>0=High Z, 1=Enabled                                                                     |       |
|            |                |        | OE_Tck      | 1     | 0           | Output Enable for STTL_3 CLK (Pin 17)<br>0=High Z, 1=Enabled                                                                        |       |
|            |                |        | OE_P2       | 2     | 0           | Output Enable for PECL CLK/2 (Pins 22, 23)<br>0=High Z, 1=Enabled                                                                   |       |
|            |                |        | OE_T2       | 3     | 0           | Output Enable for STTL_3 CLK/2 (Pin 16)<br>0=High Z, 1=Enabled                                                                      |       |
|            |                |        | OE_F        | 4     | 0           | Output Enable for STTL_3 FUNC Output (Pin15)<br>0=High Z, 1=Enabled                                                                 |       |
|            |                |        | Ck2_Inv     | 5     | 0           | CLK/2 Invert (0=Not Inverted, 1= Inverted)                                                                                          |       |
|            |                |        | Out_Scl     | 6-7   | 0           | CLK Scaler (pin 17)<br>Bit 7, 6 = (00 = ÷ 1, 01 = ÷ 2, 10 = ÷ 4, 11 = ÷ 8)<br>See <a href="#">Section 5, "Register Set Details"</a> |       |
| 0x7        | Osc_Div        | R / W  | Osc_Div 0-6 | 0-6   | 0           | Osc Divider modulus<br>See <a href="#">Section 6, "OSC Divider and REF"</a>                                                         |       |
|            |                |        | In-Sel      | 7     | 1           | Input Select<br>0=HSYNC Input, 1=Osc Divider                                                                                        |       |
| 0x8        | Reset          | Write  | DPA         | 0-3   | x           | Writing xAh resets DPA and loads working 0x5                                                                                        |       |
|            |                |        | PLL         | 4-7   | x           | Writing 5xh resets PLL and loads working 0x1- 0x3                                                                                   |       |
| 0x10       | Chip Ver       | Read   | Chip Ver    | 0-7   | 17          | Chip Version 23 Dec (17h) as in 1523                                                                                                |       |
| 0x11       | Chip Rev       | Read   | Chip Rev    | 0-7   | 01          | Initial value 01h. Value Increments with each all-layer change.                                                                     |       |
| 0x12       | Rd_Reg         | Read   | Reserved    | 0     | N/A         | Reserved                                                                                                                            |       |
|            |                |        | PLL_Lock    | 1     | N/A         | PLL Lock Status<br>0=Unlocked, 1=Locked                                                                                             |       |
|            |                |        | Reserved    | 2-7   | 0           | Reserved                                                                                                                            |       |



## Section 5 Register Set Details

### Register Conventions

0xY:Z = Register Index Y(hex), bit Z

0xY:Z~Q = Register Index Y(hex), bit Z to Q

### Note 3- COAST - Charge Pump Enable/Disable

| CP_Pol         | CPen |                                  |
|----------------|------|----------------------------------|
| <b>0x0:1~0</b> |      | <b>Charge Pump Enabled If...</b> |
| 0 0            |      | COAST (Pin 5) = 1                |
| x 1            |      | Always Enabled (Default)         |
| 1 0            |      | COAST (Pin 5) = 0                |

The COAST input can be used to disable the charge pump during the vertical blanking interval if the input HSYNC input changes frequency during this time. The charge pump is asynchronously disabled and synchronously re-enabled on the second input HSYNC after the disable signal goes invalid. This pin can be connected to VSYNC or pulled to either rail if unused.

### Note 4 - LOCK/REF Function

| EnPLS      | -              | IN_SEL           |                                                        |
|------------|----------------|------------------|--------------------------------------------------------|
| <b>0x0</b> | <b>bit 7~6</b> | <b>0x7:bit 7</b> | <b>LOCK/REF Output</b>                                 |
| 0 0        |                | -                | 0                                                      |
| 0 1        |                | -                | PLL locked = 1 else 0                                  |
| 1 0        |                | -                | RESERVED                                               |
| 1 1        |                | 0                | Post Schmitt trigger HSYNC (pin 7) XOR REF_Pol (0x0:2) |
| 1 1        |                | 1                | F <sub>OSC</sub> / (OSC_DIV +2)                        |

### Note 5- CLK Output Divider

| <b>0x6 bit 7,6</b> | <b>CLK Divider</b> |
|--------------------|--------------------|
| 0 0                | 1 (default)        |
| 0 1                | 2                  |
| 1 0                | 4                  |
| 1 1                | 8                  |

SSTL\_3 CLK Freq. = Output Freq. / CLK Divider

### Note 6 - ICP - Charge Pump Current

| <b>0x1</b>     | <b>Charge Pump Current (μA)</b>   |
|----------------|-----------------------------------|
| <b>Bit 2~0</b> |                                   |
| 0 0 0          | 1                                 |
| 0 0 1          | 2                                 |
| 0 1 0          | 4                                 |
| 0 1 1          | 8 (Typical Internal Filter Value) |
| 1 0 0          | 16                                |
| 1 0 1          | 32                                |
| 1 1 0          | 64                                |
| 1 1 1          | Reserved                          |

Increasing the charge pump current makes the loop respond faster, raising the loop bandwidth. The typical value when using the internal loop filter is 011.

### Note 7 - VCO Divider

| <b>0x1:bit 5,4</b> | <b>VCO Divider</b> |
|--------------------|--------------------|
| 0 0                | 2 (default)        |
| 0 1                | 4                  |
| 1 0                | 8                  |
| 1 1                | 16                 |

This is used to keep the VCO running at faster speeds even when the output frequency is low.

VCO speed = Output Frequency \* VCO Scaler

### Note 8 - DPA Offset Ranges

| 0x5<br>bit 1-0 | # of DPA Delay<br>Elements (d) | 0x4<br>bit 5-0<br>Max. (h) | Clock Range (MHz) |     |
|----------------|--------------------------------|----------------------------|-------------------|-----|
|                |                                |                            | Min               | Max |
| 0 0            | 16                             | 0F                         | 48                | 160 |
| 0 1            | 32                             | 1F                         | 24                | 80  |
| 1 0            | Reserved                       |                            |                   |     |
| 1 1            | 64                             | 3F                         | 12                | 40  |

Using the DPA above 160 MHz is not recommended. Set DPA\_OS = 0 for speeds in excess of 160 MHz to bypass the DPA.



The DPA Resolution Select register (0x5:0~1) is double-buffered. Working registers are loaded only after a DPA software reset (0x8=xA)

For more details, See [Figure 11.2](#)

## Section 6 OSC Divider and REF

The ICS1523 accepts a single-ended clock on pin 12, the OSC input. The period of this input signal becomes the high time of the REF signal and the low time is controlled by 0x7:0~6.

The resulting REF signal can be used as an input to the PLL's phase detector to allow the ICS1523 to synthesize frequencies without an HSYNC input when 0x7:7=1.

This REF signal may also be output on the LOCK/REF pin (14) when 0x0:6-7 = 11

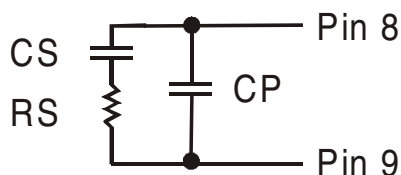
Table 6-1 REF Functionality

| Parameter            | Value                                    |
|----------------------|------------------------------------------|
| REF Frequency        | (Input Osc Frequency) * [(0x7: 6~0) + 2] |
| REF High Time        | Input OSC Period                         |
| REF Low Time         | [(0x7: 6~0) + 1] * Input OSC Period      |
| Minimum OSC Divider  | 3 (0x7:6~0 = 000001)                     |
| Maximum OSC Divider  | 129 (0x7:6~0 = 111111)                   |
| RESERVED OSC Divider | 0 (0x7:6~0 = 000000)                     |

## Section 7 Loop Filter

The ICS1523 contains an internal loop filter, but also supports the use of an external loop filter configured as in [Figure 7-1](#). Selection between these two filters is controlled by 0x4:7. The external filter is selected when 4:7=0; internal filter is selected with a 1.

Figure 7-1 External Loop Filter



While the internal loop filter works well for most applications, ICS still recommends the implementation of an external filter network on all designs.

Implementing the external loop filter gives the system engineer flexibility to add external filter functionality if without having to alter the PCB.

### 7.1 External Filter Recommendations

ICS recommends the following as a general purpose external loop filter:

$$CS = 3300 \text{ pF}$$

$$RS = 6.8 \text{ k}\Omega$$

$$CP = 33 \text{ pF}$$

Special considerations must be made in selecting loop capacitors CS and CP. These recommendations can be found at:

<http://www.icst.com/appnotes/loopfilter.pdf>

## Section 8 PLL Parameter Settings

Settings for all standard VESA video modes are provided by ICS as a starting point for the systems engineer. These files are in human readable text files (\*.ics files) and come bundled within the ICS1523 Register Editor Tool.

This tool directly drives the ICS1523EB Evaluation Board and can be downloaded from:

<http://www.icst.com/icscs/PartSummary.aspx?id=d28dbe26-195c-46a4-8ac7-fc756463febf&name=ICS1523&mode=short>



## Section 9 Output Termination

### 9.1 PECL Description

The ICS1523 PECL outputs consist of open-drain, current-source, pull-down transistors. An external resistor network permits complete flexibility of logic levels and source impedance. This section describes the design procedure to select the resistor values and the pull-down current for these devices.

### 9.2 PECL Output Structure

The output stage and external circuitry are shown below in [Figure 9-1](#). The output devices are open-drain pull-downs. The two output transistors switch differentially, steering the current source (programmable via RSET) from one output to the other.

For the high logic level, the output transistor is off, so the logic level is set by the ratio of R1 and R2 and the voltage VAA. Generally, VAA will be equal to VDD.

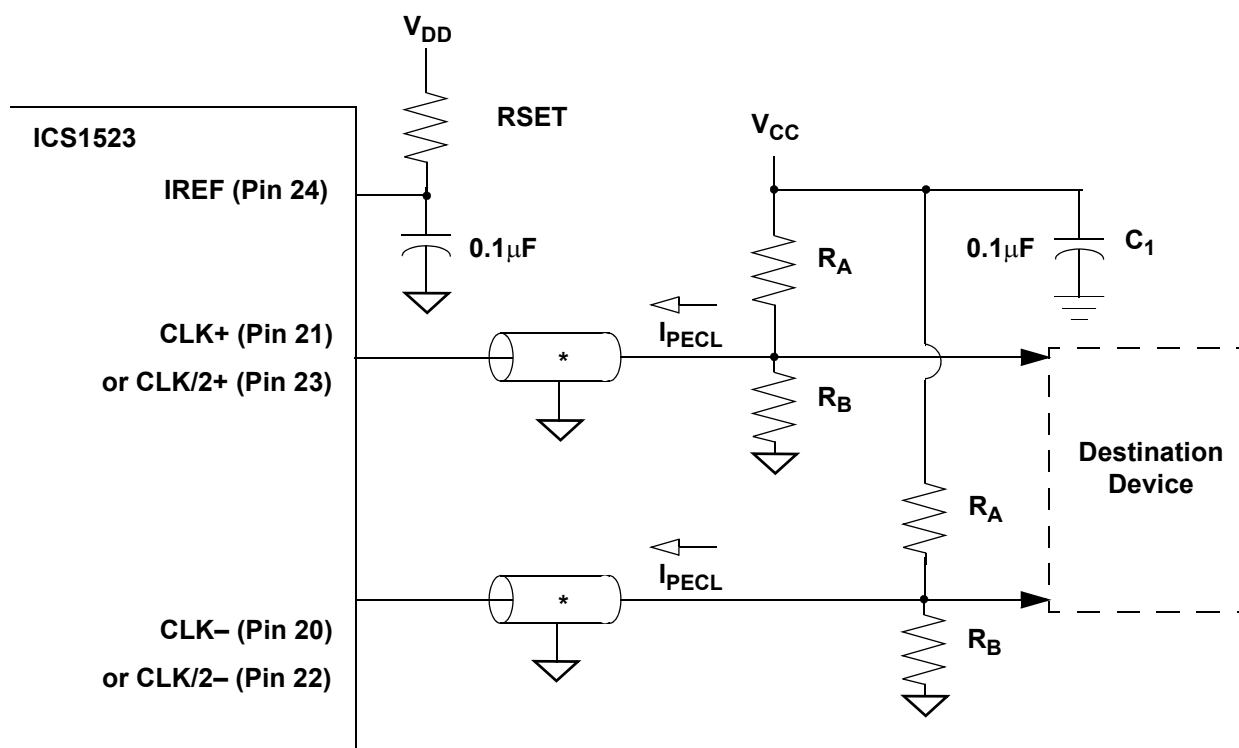
For logic low, the pull-down transistor turns on, pulling the output voltage down to the low logic level. Decoupling capacitor C1 should be a 0.01μF high-frequency ceramic unit, and all power pins on the ICS1523 should also be decoupled with similar capacitors.

### 9.3 PECL Design Assumptions

All referenced voltages in this application note are positive and referenced to the GND pin of the chip. However, negative logic levels can be generated by level shifting, i.e. connecting the VDD pin of the device to system ground and the GND pin to a negative voltage.

All logic levels must be between GND and the lesser of VAA and VDD. Then, nodal equations are written, with resistances transformed into conductances.

Figure 9-1 PECL Termination Network



\* Coaxial cable, microstrip, or stripline, with  $Z_0 = R_L$ . Typically, coaxial cable, microstrip, or stripline is not required if the distance from the ICS1523 to the PECL load is short (that is, < 3 cm).



## 9.4 PECL Example

Determine  $V_{OL}$  and  $V_{OH}$  for target device, as follows (see also Figure 9-1):

1. Choose  $Z_O$
2.  $RA = (VCC * Z_O) / V_{OH}$
3.  $RB = (Z_O * RA) / (RA - Z_O)$
4.  $RSET = \frac{(16.661E-3 * -(VCC/RA) + (VOL/RA) + (VOL/RB))}{2.4E-6}$

For more detailed equations regarding PECL termination, please see the following application note on the ICS web site at:

<http://www.icst.com/appnotes/man09.pdf>

## Section 10 SSTL\_3 Outputs

The ICS1523 incorporates SSTL\_3 outputs on FUNC (pin 15), CLK/2 (pin 16), and CLK (pin 17).

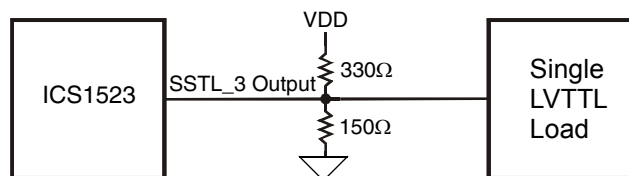
### 10.1 Unterminated Outputs

In the ICS1523, unterminated SSTL\_3 output pins display exponential transitions similar to those of rectangular pulses presented to RC loads. The 10 to 90% rise time is typically 1.6 ns, and the corresponding fall time is typically 700 ps. This asymmetry and external capacitive loading contribute to duty cycle distortion at higher output frequencies. Typically, no termination is required for either the LOCK/REF, FUNC, and CLK/2 outputs. The CLK output works up to approximately 135 MHz, and normally requires no termination.

### 10.2 Terminated Outputs

SSTL\_3 outputs are intended to be terminated into low impedances to reduce the effect of external circuit capacitance. Use of transmission line techniques enables use of longer traces between source and driver without increasing ringing due to reflections. Where external capacitance is minimal and substantial voltage swing is required to meet LVTTTL  $V_{IH}$  and  $V_{OL}$  requirements, the intrinsic rise and fall times of ICS1523 SSTL\_3 outputs are only slightly improved by termination in a low impedance.

Figure 10-1 SSTL\_3 Outputs



The ICS1523s SSTL\_3 output source impedance is typically less than 60Ω. Termination impedance of 100Ω reduces output swing by less than 30% which is more than enough to drive a single LVTTTL load.

### 10.3 Using SSTL\_3 Outputs with CMOS or LVTTTL Inputs

Per EIA/JESD8-8, SSTL\_3 outputs are intended to provide a moderate voltage swing across a low-impedance load at the end of a transmission line. However, if an SSTL\_3 output is connected directly to a destination LVTTTL-compatible input, it can provide nearly rail-to-rail swings (from 0 to 3.3 V). The equivalent source impedance of these outputs is typically 30 to 50Ω. The FUNC and LOCK/REF signals are both at the input HSYNC frequency rate. As a result, if these signals are directly connected to a destination LVTTTL-compatible input, this direct connection does not typically result in signal degradation.

The CLK and CLK/2 signals operate at much higher frequency rates, and if they are directly connected to a destination LVTTTL-compatible input, they can exhibit distortion. For example, their waveforms can appear as though some shunt capacitance is present across the output load. This equivalent RC effect limits the highest frequency at which the SSTL\_3 outputs can be used. For these applications, the PECL outputs must be used instead.

ICS recommends traces less than 3 cm for all high-frequency signals.



## Section 11 Programming

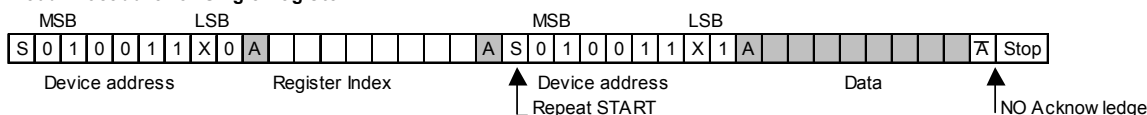
### 11.1 Industry-Standard I<sup>2</sup>C Serial Bus: Data Format

Figure 11-1 ICS1523 Data Format for I<sup>2</sup>C 2-Wire Serial Bus

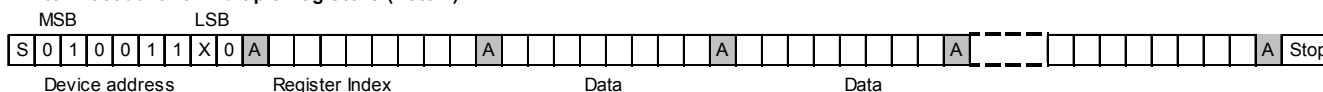
#### Write Procedure for Single Register



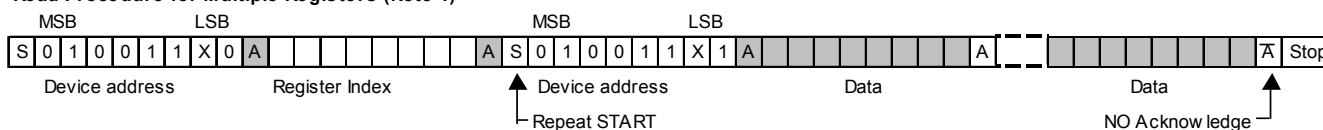
#### Read Procedure for Single Register



#### Write Procedure for Multiple Registers (Note 1)



#### Read Procedure for Multiple Registers (Note 1)



#### Legend

All values are sent with the most-significant bit (MSB) first and least-significant bit (LSB) last.

S = Start (SDA goes low when SCL was high, then SCL goes low too)

A = ACK = Acknowledge = 0

A-bar =  $\overline{\text{ACK}}$  = No Acknowledge = 1

X = Bit value that equals logic state of SBADR pin.

--- = (Dashed Line) Multiple transactions

□ Bus Master drives signal to ICS1523

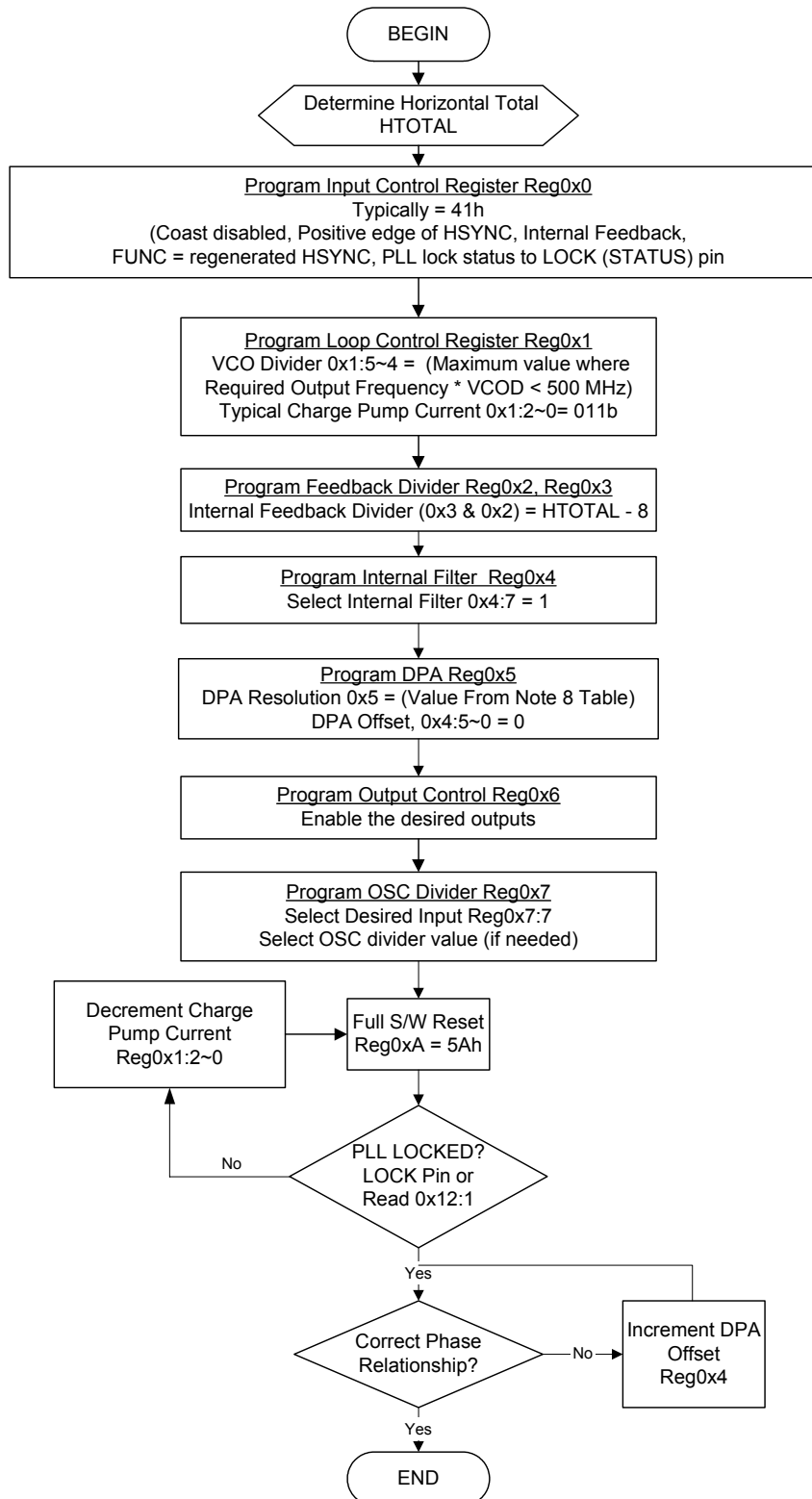
■ ICS1523 (Slave Device) drives signal to Bus Master

Note:

- 1 - Lower nibble of the I<sup>2</sup>C register automatically increments after each successive data byte is written to or read from the ICS1523.
- 2 - Upper nibble of the I<sup>2</sup>C register does not automatically increment, and the software must explicitly re-address the ICS1523. The software:
  - Must NOT just index 0 and then do all the I/O as one-byte transactions.
  - Must break the transactions into at least two separate bus transactions:  
(1) 00 to 08 (2) 10 to 12



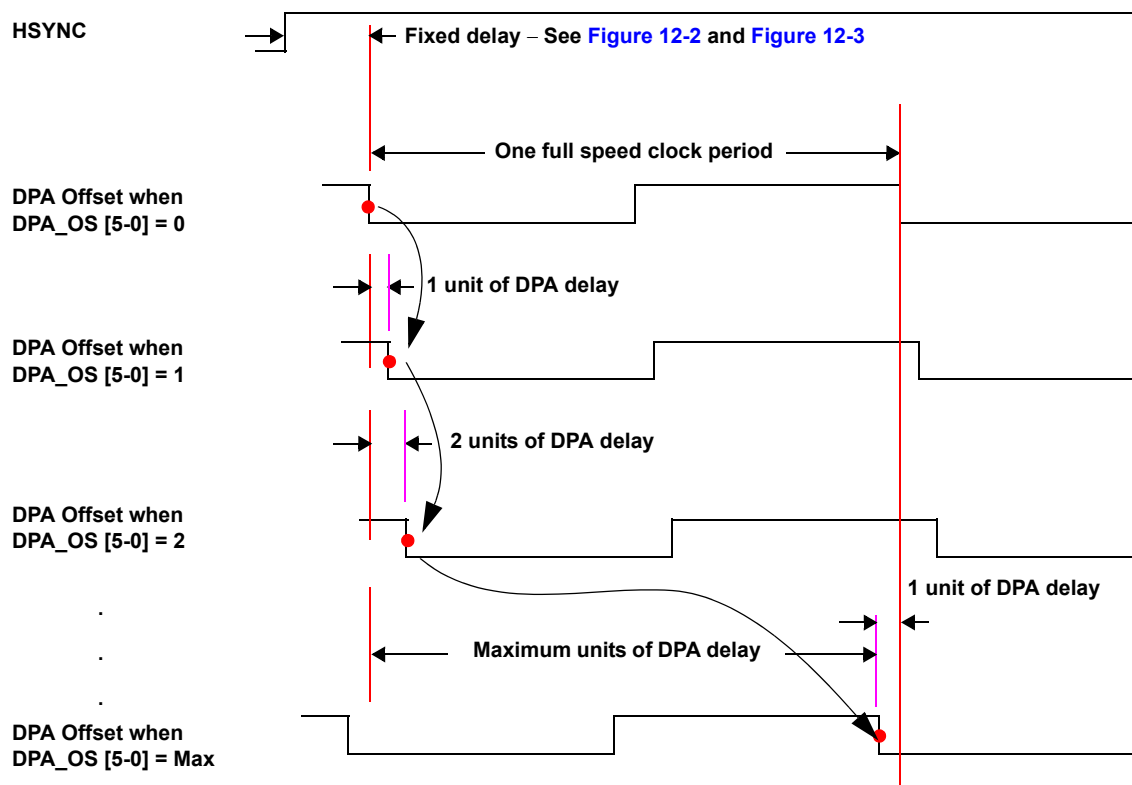
## 11.2 Programming Flow for Modifying PLL and DPA Settings





## Section 12 Timing Diagrams

Figure 12-1 DPA Operation



$$\text{DPA Offset} = \frac{\text{CLK Period} * (\# \text{ of DPA Elements Selected } [0x4:4\sim0])}{(\# \text{ of DPA Elements Available})[0x5:1\sim0]}$$

Table 12-1 DPA Offset Ranges

| Register 5 |                            | 0x4:5-0<br>Maximum               | DPA Clock Range in MHz |     |
|------------|----------------------------|----------------------------------|------------------------|-----|
| 1~0        | Total # of DPA<br>Elements | Selected #<br>of DPA<br>Elements | Min                    | Max |
| 00         | 16                         | 0F                               | 48                     | 160 |
| 01         | 32                         | 1F                               | 24                     | 80  |
| 11         | 64                         | 3F                               | 12                     | 40  |

Using the DPA above 160 MHz is not recommended. Set DPA\_OS = 0 for speeds in excess of 160 MHz to bypass the DPA. The DPA Resolution Select register (0x5:0~1) is double-buffered. Working registers are loaded only after a DPA Software reset (0x8=xA)



## 12.1 Timing for 0x0:2=0

Figure 12-2 0x0:2=0 Timing Diagram

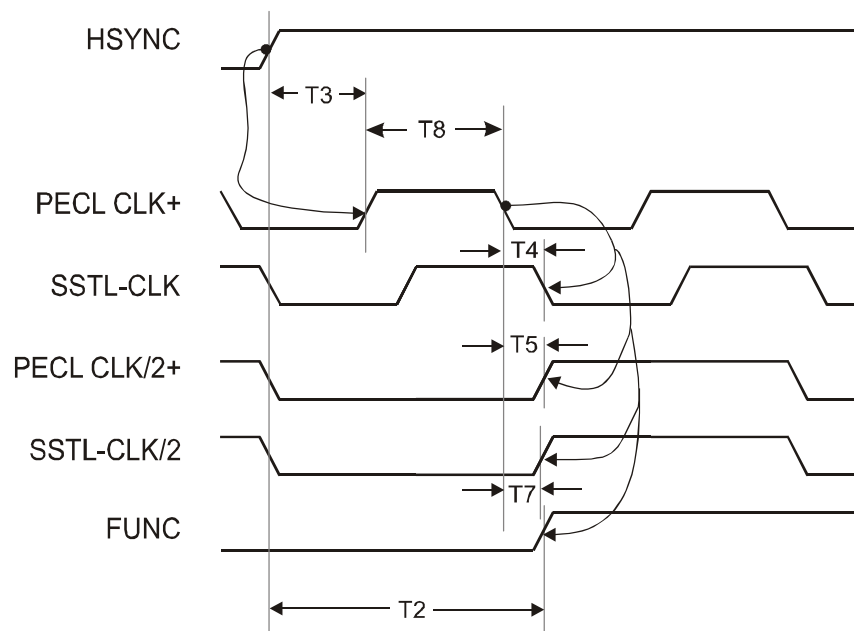


Table 12-2 0x0:2=0 Timing Values

| Symbol | Parameter                                        | Minimum | Typical | Maximum | Units |
|--------|--------------------------------------------------|---------|---------|---------|-------|
| T2     | HSYNC High to FUNC High<br>(DPA Offset = 0)      | T8 + T3 |         |         | ns    |
| T3     | HSYNC High to PECL CLK+ High<br>(DPA Offset = 0) | -       | 7       | -       | ns    |
| T4     | PECL Clock Low to SSTL_3 Clock Low<br>Delay      | 0       | 0.2     | 0.6     | ns    |
| T5     | PECL Clock Low to FUNC High Delay                | 0.6     | 1.0     | 1.6     | ns    |
| T6     | PECL Clock Low to PECL/2 High Clock              | 0.6     | 1.0     | 1.6     | ns    |
| T7     | PECL Clock Low to SSTL_3 CLK/2 Delay             | 0.4     | 0.9     | 1.2     | ns    |
| T8     | PECL Clock High Time                             | -       | 0.5     | -       | UI    |



## 12.2 Timing for 0x0:2=1

Figure 12-3 0x0:2=1 Timing Diagram

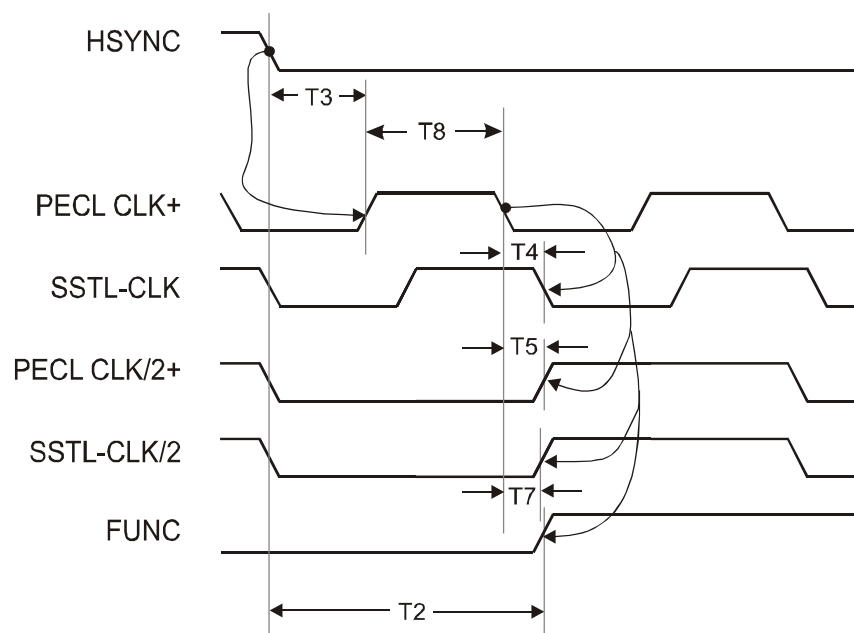


Table 12-3 0x0:2=1 Timing Values

| Symbol | Parameter                                          | Minimum | Typical | Maximum | Units |
|--------|----------------------------------------------------|---------|---------|---------|-------|
| T2     | HSYNC Low to FUNC High Delay                       | T8 + T3 |         |         | ns    |
| T3     | HSYNC Low to PECL CLK+ High Delay (DPA Offset = 0) | -       | 10      | -       | ns    |
| T4     | PECL Clock to SSTL_3 Clock Delay                   | 0       | 0.2     | 0.6     | ns    |
| T5     | PECL Clock to FUNC Delay                           | 0.6     | 1.0     | 1.6     | ns    |
| T6     | PECL Clock to PECL/2 Clock                         | 0.6     | 1.0     | 1.6     | ns    |
| T7     | PECL Clock to SSTL_3 CLK/2 Delay                   | 0.4     | 0.9     | 1.2     | ns    |
| T8     | PECL Clock High Time                               | -       | 0.5     | -       | UI    |



## 12.3 HSYNC to REF Timing

Figure 12-4 HSYNC to REF Timing Diagram

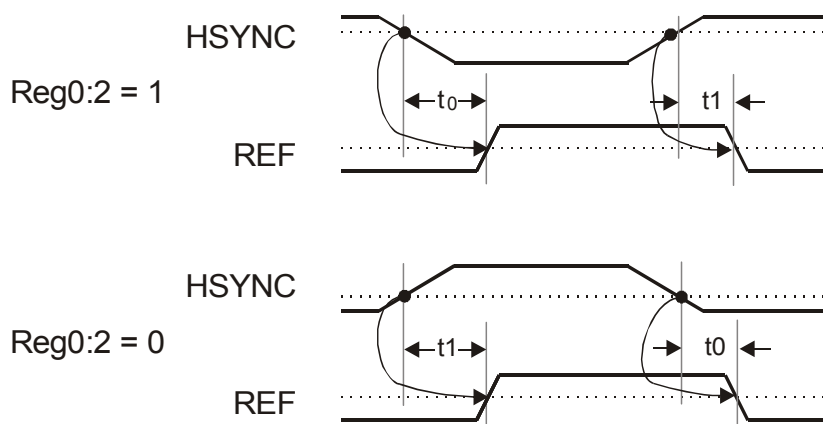


Table 12-4 HSYNC to REF Timing Diagram

| Symbol | Parameter               | Minimum | Typical | Maximum | Units |
|--------|-------------------------|---------|---------|---------|-------|
| $T_0$  | HSYNC Low to REF Delay  | 6       | 7.5     | 8.5     | ns    |
| $T_1$  | HSYNC High to REF Delay | 3.5     | 4.3     | 6       | ns    |

## 12.4 CLK/2 Timing for Odd and Even Feedback Divider

Figure 12-5 CLK/2: Even versus Odd



For simplicity, the waveforms drawn show only the identical PECL CLK/2+ and the SSTL\_3 CLK/2 signals. CLK/2- is the complement of the CLK/2+ signal.

Note that regardless of the CLK/2 phase at the assertion of FUNC, the clocks always have the same phase at the fall of FUNC, regardless of 0x2



## Section 13 AC/DC Operating Conditions

### 13.1 Absolute Maximum Ratings

Table 13-1 lists absolute maximum ratings for the ICS1523. Stresses above these ratings can cause permanent damage to the device. These ratings, which are standard values for ICS commercially rated parts, are stress ratings only. Functional operation of the ICS1523 at these or any other conditions above those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods can affect product reliability. Electrical parameters are guaranteed only over the recommended operating temperature range.

Table 13-1 ICS1523 Absolute Maximum Ratings

| Item                              | Rating                     |
|-----------------------------------|----------------------------|
| VDD, VDDA, VDDQ (measured to VSS) | 4.3 V                      |
| Digital Inputs                    | VSS –0.3 V to 5.5 V        |
| Analog Outputs                    | VSSA –0.3 V to VDDA +0.3 V |
| Digital Outputs                   | VSSQ –0.3 V to VDDQ +0.3 V |
| Storage Temperature               | –65°C to +150°C            |
| Junction Temperature              | 125°C                      |
| Soldering Temperature             | 260°C                      |
| ESD Susceptibility*               | > 2 KV                     |

(\*Electrostatic-sensitive devices. Do not open or handle except in a static-free workstation.)

**Note:** Measured with respect to VSS. During normal operations, the VDD supply voltage for the ICS1523 must remain within the recommended operating conditions.

Table 13-2 Environmental Conditions

| Parameter                     | Min. | Typ. | Max. | Units |
|-------------------------------|------|------|------|-------|
| Ambient Operating Temperature | 0    | –    | +70  | °C    |
| Power Supply Voltage          | +3.0 | +3.3 | +3.6 | V     |

Table 13-3 DC Characteristics

| Parameter                    | Symbol | Conditions                      | Min. | Max. | UNITS |
|------------------------------|--------|---------------------------------|------|------|-------|
| Digital Supply Current       | IDDD   | VDDD=3.6V                       | –    | 25   | mA    |
| Output Driver Supply Current | IDDQ   | VDDD=3.6V<br>No drivers enabled | –    | 6    | mA    |
| Analog Supply Current        | IDDA   | VDDA=3.6V                       | –    | 5    | mA    |

Table 13-4 AC Characteristics

| Parameter              | Symbol             | Min.   | Max.   | Units | Notes   |
|------------------------|--------------------|--------|--------|-------|---------|
| <b>AC Inputs</b>       |                    |        |        |       |         |
| HSYNC Input Frequency  | f <sub>HSYNC</sub> | 15.734 | 10,000 | kHz   | 0x7:7=1 |
| OSC Input Frequency    | f <sub>OSC</sub>   | 0.05   | 100    | MHz   | 0x7:7=0 |
| PDEN Input Frequency   | f <sub>PDEN</sub>  | 30     | 120    | Hz    |         |
| Internal VCO Frequency | f <sub>VCO</sub>   | 100    | 500    | MHz   |         |
| Typical Lock Time      | t <sub>LOCK</sub>  | 20     |        | ms    |         |



| Parameter                                                        | Symbol             | Min.      | Max. | Units | Notes                                |
|------------------------------------------------------------------|--------------------|-----------|------|-------|--------------------------------------|
| <b>Analog Input (HSYNC)</b>                                      |                    |           |      |       |                                      |
| Input High Voltage                                               | V <sub>IH</sub>    | 1.7       | 5.5  | V     |                                      |
| Input Low Voltage                                                | V <sub>IL</sub>    | VSS - 0.3 | 1.1  | V     |                                      |
| <b>Digital Inputs (SDA, SCL, EXTFB, OSC, I<sup>2</sup>CADDR)</b> |                    |           |      |       |                                      |
| Input High Voltage                                               | V <sub>IH</sub>    | 2         | 5.5  | V     |                                      |
| Input Low Voltage                                                | V <sub>IL</sub>    | VSS - 0.3 | 0.8  | V     |                                      |
| Input Hysteresis                                                 | -                  | 0.2       | 0.6  | V     |                                      |
| POR Threshold                                                    | -                  | VSS       | 1.8  | V     | Voltage that resets register values  |
| <b>SDA Digital Output</b>                                        |                    |           |      |       |                                      |
| SDA Output Low Voltage                                           | V <sub>OL</sub>    |           | 0.4  | V     | IOUT = 3ma                           |
| SDA Output High Voltage                                          | V <sub>OH</sub>    |           | 6.0  | V     | Determined by external Rset resistor |
| <b>PECL Outputs (CLK+, CLK-, CLK/2+, CLK/2-)</b>                 |                    |           |      |       |                                      |
| Output High Voltage                                              | V <sub>OH</sub>    | -         | VDD  | V     | IOUT=0                               |
| Maximum Output Frequency                                         | F <sub>P</sub> MAX | -         | 250  | MHz   | VDDD = 3.3 V                         |
| Output Low Voltage *                                             | V <sub>OL</sub>    | 1.0       | -    | V     | IOUT =<br>Programmed Value<br>1      |
| Duty Cycle                                                       | P <sub>DC</sub>    | 45        | 55   | %     | 2                                    |
| Transition Time - Rise                                           | T <sub>PR</sub>    | -         | 1.0  | ns    | 2                                    |
| Transition Time - Fall                                           | T <sub>PF</sub>    | -         | 1.2  | ns    | 2                                    |
| <b>SSTL_3 Outputs (CLK, CLK/2, FUNC, LOCK/REF)</b>               |                    |           |      |       |                                      |
| Output Resistance                                                | R <sub>O</sub>     | -         | 80   | Ω     | 1 V < V <sub>O</sub> < 2 V           |
| Maximum Output Frequency                                         | F <sub>S</sub> MAX | -         | 150  | MHz   | VDDD = 3.3 V                         |
| Duty Cycle                                                       | S <sub>DC</sub>    | 45        | 55   | %     | 3                                    |
| Clock and FUNC<br>Transition Time - Rise                         | T <sub>CR</sub>    | -         | 1.6  | ns    | 3                                    |
| Clock and FUNC<br>Transition Time - Fall                         | T <sub>CF</sub>    | -         | 1.0  | ns    | 3                                    |
| LOCK/REF Transition Time -<br>Rise                               | T <sub>LR</sub>    | -         | 3.0  | ns    | 3                                    |
| LOCK/REF Transition Time - Fall                                  | T <sub>LF</sub>    | -         | 2.0  | ns    | 3                                    |

Note 1- V<sub>OL</sub> must not fall below the level given so that the correct value for IOUT can be maintained.

Note 2- Measured at 135MHz, 3.6 VDC, 0°C, 20 pF, with 75 Ω Termination

Note 3- Measured at 135MHz, 3.6 VDC, 0°C, 20 pF, Unterminated

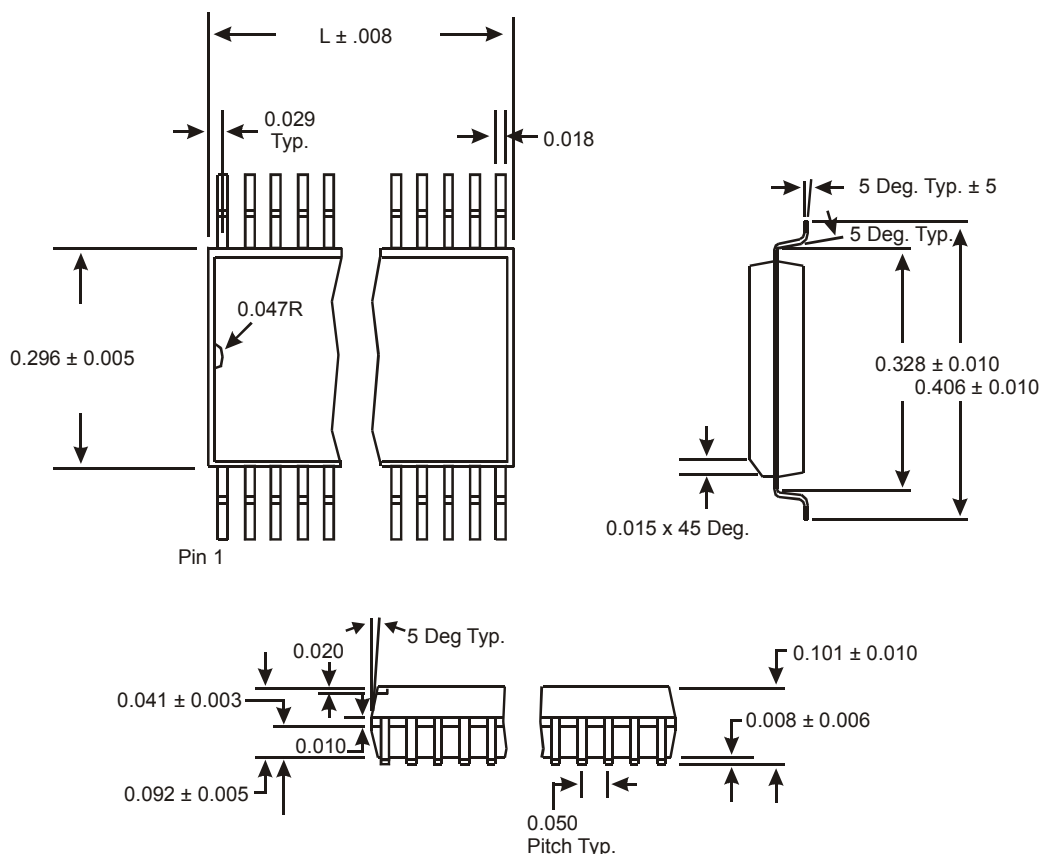
**Table 13-5** Thermal Characteristics

| Parameter                              | Symbol        | Conditions     | Min. | Typ. | Max. | Units |
|----------------------------------------|---------------|----------------|------|------|------|-------|
| Thermal Resistance Junction to Ambient | $\theta_{JA}$ | Still Air      |      | 67   |      | °C/W  |
|                                        | $\theta_{JA}$ | 1 m/s air flow |      | 56   |      | °C/W  |
|                                        | $\theta_{JA}$ | 3 m/s air flow |      | 51   |      | °C/W  |
| Thermal Resistance Junction to Case    | $\theta_{JC}$ |                |      | 25   |      | °C/W  |



## Section 14 Package Dimensions

Figure 14-1 Physical Dimensions for ICS1523



24-pin SOIC (300 Mil Wide Body)

## Section 15 Ordering Information

| Part / Order Number | Marking    | Package     | Shipping Package | Temperature |
|---------------------|------------|-------------|------------------|-------------|
| ICS1523M            | ICS1523M   | 24-pin SOIC | Tubes            | 0 to 70°C   |
| ICS1523MT           | ICS1523M   | 24-pin SOIC | Tape and Reel    | 0 to 70°C   |
| ICS1523MLF          | ICS1523MLF | 24-pin SOIC | Tubes            | 0 to 70°C   |
| ICS1523MLFT         | ICS1523MLF | 24-pin SOIC | Tape and Reel    | 0 to 70°C   |

Note: "LF" denotes Pb (lead) free package.

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