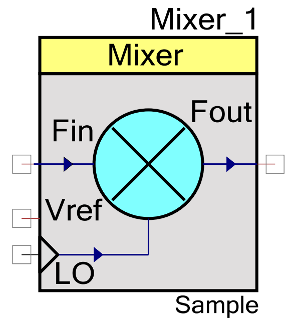
Mixer

1.60



Features

- Single-ended mixer
- Continuous time up mixing:
  - Input frequencies up to 500 kHz
  - Sample clock up to 1 MHz
- Discrete time, sample & hold down mixing:
  - Input frequencies up to 14 MHz
  - Sample clock up to 4 MHz
- Adjustable power settings
- Selectable reference voltage

General Description

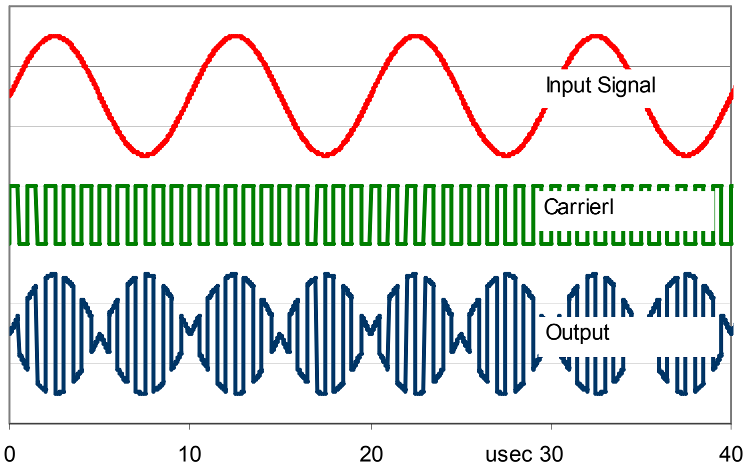
The Mixer component provides a single-ended modulator. The Mixer component can be used for frequency conversion of an input signal using a fixed Local Oscillator (LO) signal as the sampling clock. The manipulations of signal frequencies performed by a mixer can be used to move signals between frequency bands or to encode and decode signals. A Mixer can be used to convert signal power at one frequency into power at another frequency to make signal processing easier, typically shifting higher frequencies to base-band. The mixer output is best used by filtering the desired signal harmonics using an off-chip filter or the output can be used to drive an on-chip ADC through internal routing. The component offers two configurations:

- Up mixer, continuous time balance mixer, operates as a switching multiplier
- Down mixer, discrete time, sample and hold mixer

The component accepts as inputs two signals at different frequencies and presents at the output a mixture of signals at multiple frequencies, including the sum and difference of the input signal and the local oscillator signal. Typically, the undesired frequency components in the output signal are removed by filtering. A few examples illustrate the operation of the mixer in different modes.

Up Mixer: LO frequency greater than signal frequency

Shown with 100 kHz sine wave input , modulated by a 1.0 MHz Local Oscillator

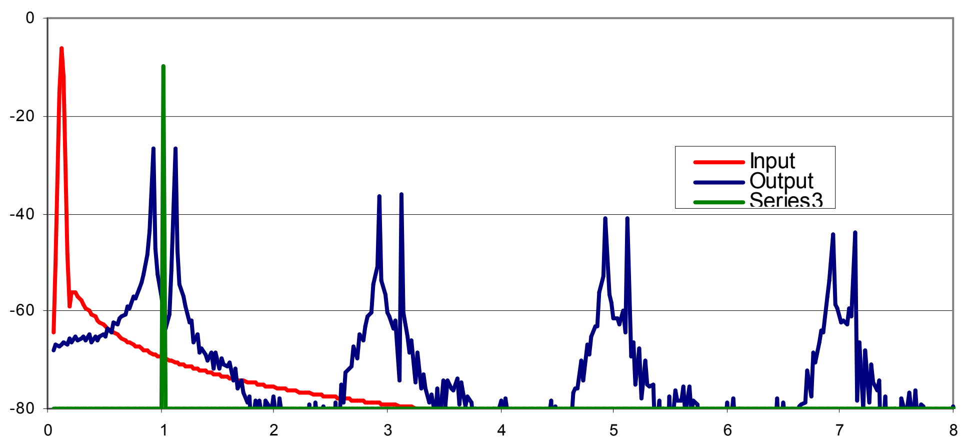


The Up mixer is a multiplier. For signal frequency at f_{SIG} and clock at f_{LO} it generates a modulated signal that is the product of the input and the LO. Since the LO is a square wave, with all of its expected harmonics, the output has the form

$$f_{MOD}(t) = \sin(2\pi f_{SIG}) \sum_{n=odd} \frac{1}{n} \sin(2\pi f_{LO} t)$$

$$f_{MOD}(t) = \frac{1}{2} \sum \left[\cos(2\pi(nf_{LO} - f_{SIG})) - \cos(2\pi(nf_{LO} + f_{SIG})) \right]$$

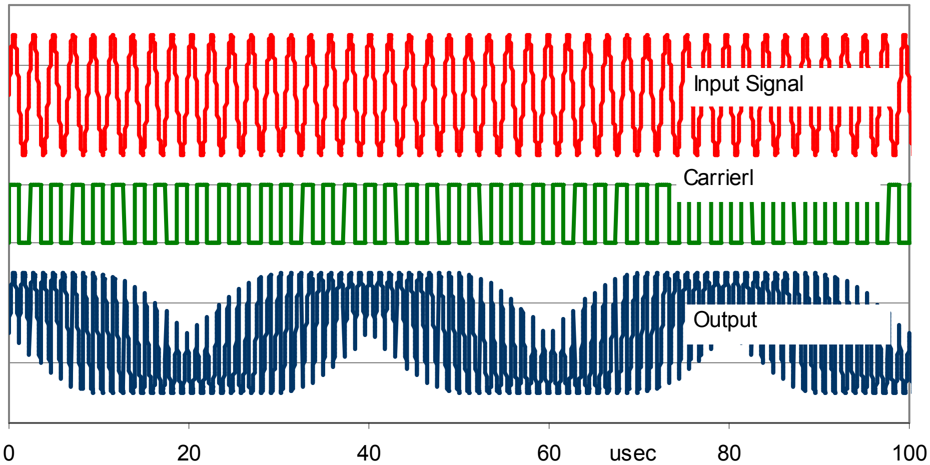
In this case the intended output is at $f_{LO}+f_{SIG}$ and $f_{LO}-f_{SIG}$, as shown in the FFT below.



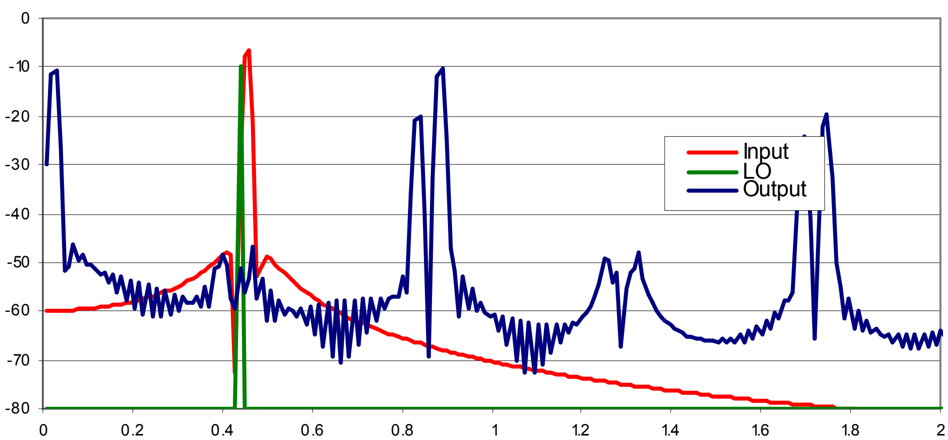
If a specific sideband, e.g., $f_{LO}+f_{SIG}$, is required, the unwanted sideband can be filtered out with active RC filters using the on-board opamps or with the Filter component after digitizing the Mixer output waveform.

Up Mixer: LO frequency less than signal frequency

Shown with input frequency of 455 kHz and LO of 430 kHz to yield a nominal output at 25 kHz. The underlying sine wave at 25 kHz is apparent, but not obvious because the sum of 455 and 430 kHz appears at the same level.

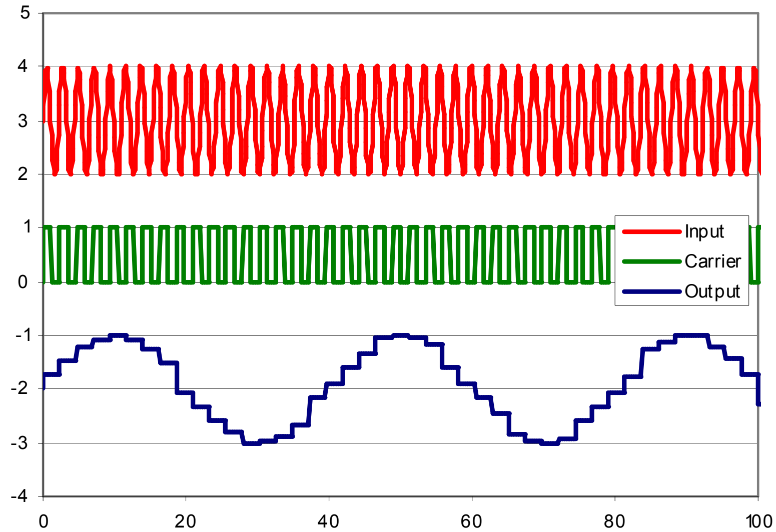


The FFT for these waveforms clearly shows the input at 455 kHz, the output difference frequency at the intended 25 kHz and the sum output of the signal and first LO harmonic at 885 kHz. Just below the first harmonic's sum output is a term at $3*f_{LO}-f_{SIG}$ or 835 kHz. The pattern repeats with the term at $5*f_{LO}-f_{SIG}$ just below $3*f_{LO}+f_{SIG}$. The miscellaneous "stuff" between these well known spectral lines is a function of the FFT, the windowing calculation process, and the sin(x)/x nature of the sampling process. The look of these signals may change depending on the type of spectrum analyzer used (swept spectrum vs FFT).



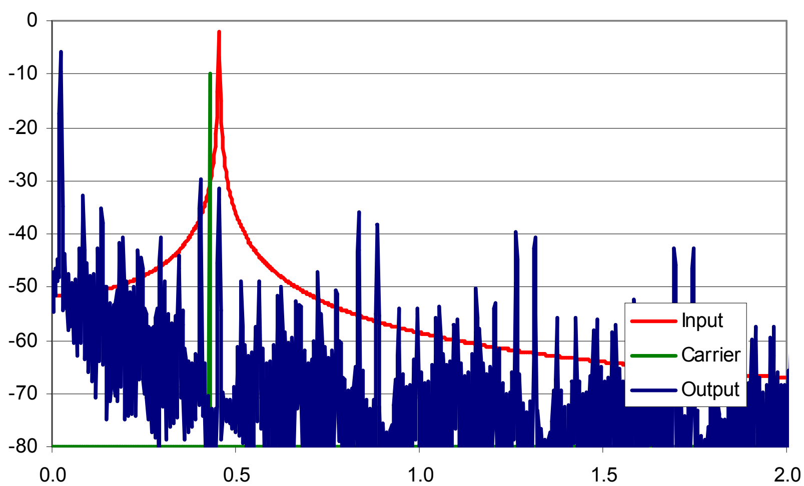
Down Mixer: LO near f_{SIGNAL}

When the LO frequency is near the signal frequency, a sampling mixer offers advantages over a multiplying mixer. The time domain plot shows less higher-frequency content for harmonics of the mixer. The steps at the sampling rate of the LO are readily apparent. The LO can be either above or below the signal frequency, but the frequency distribution for LO > f_{SIG} will be inverted compared to the frequency distribution for LO < f_{SIG}.



The mixing products are sin(x)/x related, so that when the sampling frequency (LO) is close to the signal frequency, 'x' is close to π and these terms are quite different from the 1/n harmonic characteristic of the multiplying mixer. The harmonic content generated is substantially lower, which means that higher order terms are more easily filtered and eliminated.

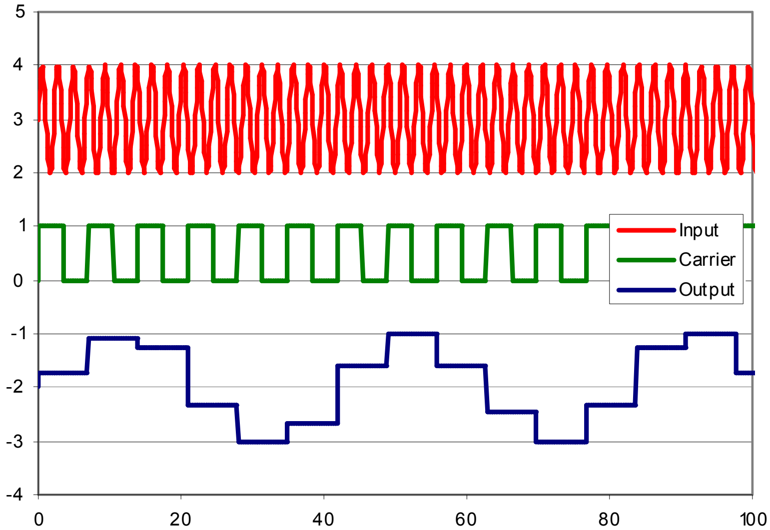
The difference frequency between the signal and LO shows clearly in the FFT. Mix products near the signal frequency are somewhat higher than the multiplying mixer, but all higher order harmonic terms are substantially.



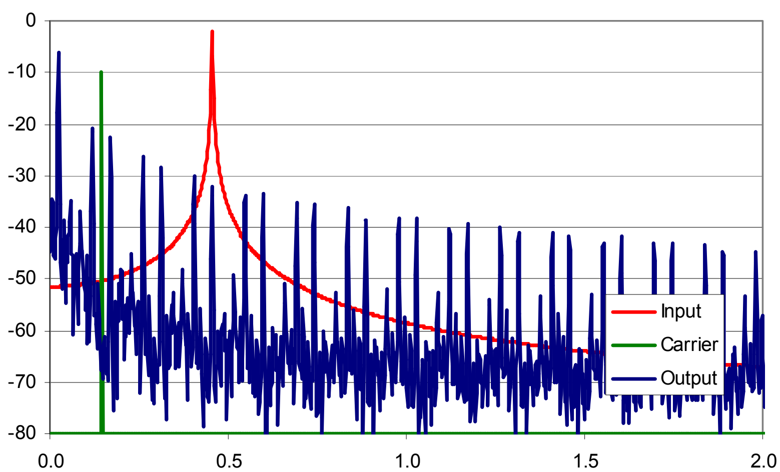
When the LO frequency is above $f_{SIG}/2$ or below $f_{SIG}*1.5$, substantial mix products appear and the mixer loses its utility, it hardly separates the desired difference frequency from the mix products.

Down Mixer: LO frequency less than $f_{SIGNAL}/2$

This is referred to as a sub-sampling mixer. When the LO frequency is less than half of the signal frequency, the primary output is at f_{SIG}-n*f_{LO} where 'n' is the largest integer such that n*f_{LO} is less than f_{SIG}. The waveforms for f_{SIG} = 455 kHz and f_{LO} = 143.3 kHz (=430 kHz/3) show that the primary output frequency is 25 kHz. The waveform is "coarser" than one with a higher frequency LO, but the output frequency is the same as if the signal was sampled at a higher rate.



The advantage of the sub-sampling mixer is in the range of the allowed input signal frequency. It is common to sub-sample by a factor of 4, so that a 13.57 MHz can be sampled at 3.2 MHz to yield a primary output frequency of 770 kHz.



Over sampling mixers (e.g., fSIG = 455 kHz and LO = 820 kHz result in mixer products similar to those of the multiplying mixer. These products may be more difficult to filter out of the desired waveform.

Input/Output Connections

This section describes the input and output connections for the Mixer component. An asterisk (*) in the list of I/Os indicates that the I/O may be hidden on the symbol under the conditions listed in the description of that I/O.

Fin – Analog

F_{in} is the input signal terminal. The F_{in} signal is mixed with the local oscillator clock signal to generate the F_{out} signal. F_{in} frequency is limited as follows:

- Multiply (Up) Mixer Fin < 500 kHz
- Sample (Down) Mixer Fin < 14 MHz

LO – Digital

LO is the local oscillator signal terminal. This signal serves as the sampling clock for the mixer. The LO signal is mixed with the F_{in} signal to generate the F_{out} signal. For the Multiply Mixer mode, the LO clock signal must have a duty cycle of 50%.

LO frequency is limited as follows:

- Multiply (Up) Mixer LO < 1 MHz
- Sample (Down) Mixer LO < 4 MHz

Vref – Analog

Vref is the input terminal for a reference voltage. The reference voltage may be one of the PSoC internal reference sources, an internal VDAC value, or an external signal.

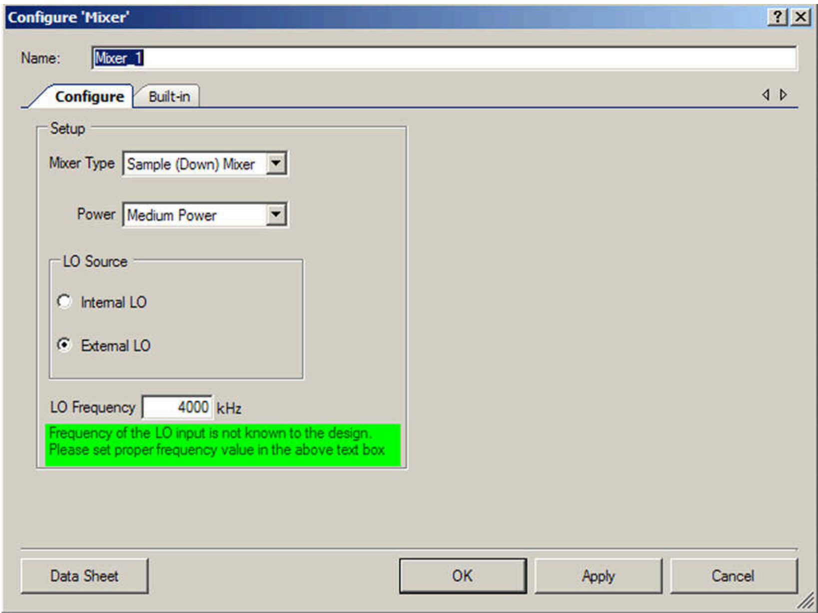
Fout – Analog

F_{out} is the output signal terminal. The F_{out} signal is the resultant signal of the mixing operation of the F_{in} and LO signals.

Component Parameters

Drag a Mixer component onto your design and double-click it to open the Configure dialog.

Figure 1: Configure Mixer Dialog



Mixer_Type

This parameter determines the configured mode of the mixer SC/CT block. The component supports two mixer modes: Multiply (Up) Mixer and Sample (Down) Mixer.

LO_Source

The Mixer may be connected to a clock source external to the component (External) or may configure its own clock (Internal). If the LO is External, it is the user's responsibility to supply a 50% duty cycle for UP Mixers (DOWN Mixers do not have this requirement). If the LO is Internal then the component derives the desired clock frequency with a 50% duty cycle for to UP Mixers. This impacts the clock divider calculation. When changing a Mixer from Up to Down, or vice versa, it may be necessary to change the clock parameters to maintain proper operation of the Mixer in the Up mode.

LO_Frequency

This parameter sets the clock frequency when LO_Source is internal. In the UP mode, the terminating resistances in the mixer have values that are switched depending on operating frequency in order to optimize performance. Lower LO_Frequency values allow using higher internal resistance values resulting in slightly better modulator performance.

When LO Source is set to External LO, the users sets the frequency in his external clock (whether clock resource or digital block source).

Power

This sets the initial drive power of the mixer. The power determines the speed with which the mixer reacts to changes in the input signal. There are four power settings; Minimum, Low, Medium (default), and High. A Low Power setting results in the slowest response time and a High Power setting results in the fastest response time.

Placement

There are no placement specific options.

Resources

Analog Blocks	Digital Blocks					API Memory (Bytes)		Pins (per External I/O)
	Datapaths	Macro cells	Status Registers	Control Registers	Counter7	Flash	RAM	
1 Fixed SC/CT block	N/A	N/A	N/A	N/A	N/A	297	2	4

The mixer uses one SC/CT block.

Application Programming Interface

Application Programming Interface (API) routines allow you to configure the component using software. The following table lists each routine and provides a brief functional description. The subsequent sections cover each function in more detail.

By default, PSoC Creator assigns the instance name "Mixer_1" to the first instance of the component in a given design. You can rename it to any unique value that follows the syntactic rules for identifiers. The instance name becomes the prefix of every global function name, variable, and constant symbol associated with the component. For readability, the instance name used in the following table is "Mixer".

Function	Description
void Mixer_Start(void)	Power up the Mixer.
void Mixer_Stop(void)	Power down the Mixer.
void Mixer_SetPower(uint8 power)	Set drive power to one of four levels.

Function	Description
void Mixer_Sleep(void)	Stops and saves the user configuration.
void Mixer_Wakeup(void)	Restores and enables the user configuration.
void Mixer_Init(void)	Initializes or restores default Mixer configuration.
void Mixer_Enable(void)	Enables the Mixer.
void Mixer_SaveConfig(void)	Empty function. Provided for future usage.
void Mixer_RestoreConfig(void)	Empty function. Provided for future usage.

Global Variables

Variable	Description
Mixer_initVar	Indicates whether the Mixer has been initialized. The variable is initialized to 0 and set to 1 the first time Mixer_Start() is called. This allows the component to restart without reinitialization after the first call to the Mixer_Start() routine. If reinitialization of the component is required, then the Mixer_Init() function can be called before the Mixer_Start() or Mixer_Enable() function.

void Mixer_Start(void)

Description: Performs all of the required initialization for the component and enables power to the block. The first time the routine is executed, the input and feedback resistance values are configured for the operating mode selected in the design. When called to restart the mixer following a Mixer_Stop() call, the current component parameter settings are retained.

Parameters: None

Return Value: None

Side Effects: None

void Mixer_Stop(void)

Description: Turns off the Mixer block.

Parameters: None

Return Value: None

Side Effects: Does not affect mixer type or power settings

void Mixer_SetPower(uint8 power)

Description: Sets the drive power to one of four settings; minimum, low, medium, or high.

Parameters: (uint8) power: See the following table for valid power settings.

Power Setting	Notes
Mixer_MINPOWER	Lowest active power and slowest reaction time.
Mixer_LOWPOWER	Low power and speed.
Mixer_MEDPOWER	Medium power and speed.
Mixer_HIGHPOWER	Highest active power and fastest reaction time.

Return Value: None

Side Effects: None

void Mixer_Sleep(void)

Description: This is the preferred API to prepare the component for sleep. The Mixer_Sleep() API saves the current component state. Then it calls the Mixer_Stop() function and calls Mixer_SaveConfig() to save the hardware configuration.
Call the Mixer_Sleep() function before calling the CyPmSleep() or the CyPmHibernate() function. Refer to the PSoC Creator *System Reference Guide* for more information about power management functions.

Parameters: None

Return Value: None

Side Effects: None

void Mixer_Wakeup(void)

Description: This is the preferred API to restore the component to the state when Mixer_Sleep() was called. The Mixer_Wakeup() function calls the Mixer_RestoreConfig() function to restore the configuration. If the component was enabled before the Mixer_Sleep() function was called, the Mixer_Wakeup() function will also re-enable the component.

Parameters: None

Return Value: None

Side Effects: Calling the Mixer_Wakeup() function without first calling the Mixer_Sleep() or Mixer_SaveConfig() function may produce unexpected behavior.

void Mixer_Init(void)

Description: Initializes or restores the component according to the customizer Configure dialog settings. It is not necessary to call Mixer_Init() because the Mixer_Start() API calls this function and is the preferred method to begin component operation.

Parameters: None

Return Value: None

Side Effects: All registers will be set to values according to the customizer Configure dialog.

void Mixer_Enable(void)

Description: Activates the hardware and begins component operation. It is not necessary to call Mixer_Enable() because the Mixer_Start() API calls this function, which is the preferred method to begin component operation.

Parameters: None

Return Value: None

Side Effects: None

void Mixer_SaveConfig(void)

Description: Empty function. Provided for future usage.

Parameters: None

Return Value: None

Side Effects: None

void Mixer_RestoreConfig(void)

Description: Empty function. Provided for future usage.

Parameters: None

Return Value: None

Side Effects: None

Sample Firmware Source Code

PSoC Creator provides numerous example projects that include schematics and example code in the Find Example Project dialog. For component-specific examples, open the dialog from the Component Catalog or an instance of the component in a schematic. For general examples, open the dialog from the Start Page or **File** menu. As needed, use the **Filter Options** in the dialog to narrow the list of projects available to select.

Refer to the "Find Example Project" topic in the PSoC Creator Help for more information.

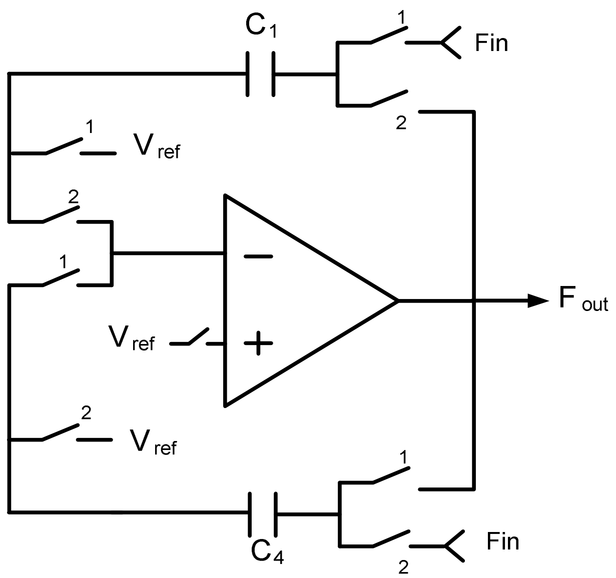
Functional Description

Mixer functionality is implemented using the PSoC SC/CT block. The discrete time down mixer is implemented using the switched capacitor mode. The multiplying (up) mixer uses the continuous time block mode.

Discrete Time Down Mixer

The schematic for the internal configuration of the discrete time mixer is shown in the following figure:

Figure 2 Discrete Time Sample & Hold Mixer Schematic



The non-return-to-zero sample and hold is achieved by switching the integrating capacitor between two capacitors. In Figure 2 above, either C1 or C4 can always be sampling the input signal while the other is being integrated across the amplifier. The F_{in} signal is sampled at a rate less than the F_{in} signal frequency. The mixer component is configured such that F_{out} is integrated with a new value on the rising edge of the input clock.

For LO sample clock frequencies greater than half of the F_{in} signal frequency, the output is the difference between the input and LO frequencies plus aliasing components. When the sample clock frequency is less than half of the F_{in} signal frequency, the output is the difference between the input and the largest integer multiple of the LO frequency that is less than the F_{in} signal frequency.

For a given input carrier frequency, F_{in}, a sample LO clock frequency, F_{clk}, can be chosen to provide the desired output frequency, F_{out}, for the system.

Provided that F_{clk} is less than 4MHz, and F_{in} is less than 14MHz:

If $\frac{2N-1}{2}F_{clk} < F_{in} < N \cdot F_{clk}$, **then** $F_{out} = N \cdot F_{clk} - F_{in}$ **Equation 1**

If $N \cdot F_{clk} < F_{in} < \frac{2N+1}{2}F_{clk}$, **then** $F_{out} = F_{in} - N \cdot F_{clk}$ **Equation 2**

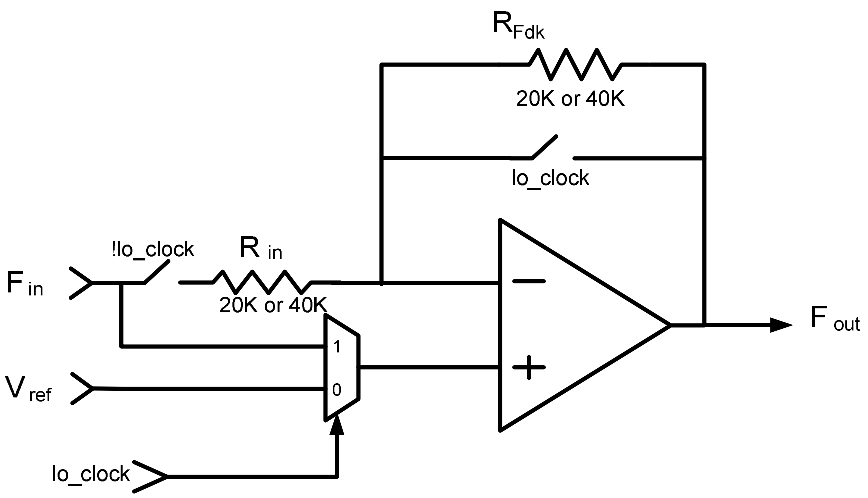
Equation 1 and Equation 2 can be summarized as:

$F_{out} = abs(N * F_{clk} - F_{in})$ **Equation 3**

Continuous Time Up Mixer

The schematic for the internal configuration of the continuous time mixer is shown below:

Figure 3: Continuous Time Mixer Configuration Schematic



In this mode the op-amp is configured as a PGA that uses the LO input signal to toggle between an inverting PGA gain of 1 and a non-inverting unity gain buffer. The output signal includes frequency components at $F_{clk} \pm F_{in}$ plus terms at odd harmonics of the LO frequency plus and minus the input signal frequency: $3*F_{clk} \pm F_{in}$, $5*F_{clk} \pm F_{in}$, $7*F_{clk} \pm F_{in}$ etc.

$F_{out} = N * F_{clk} \pm F_{in}$ **with N holding odd values** **Equation 4**

Frequency Planning

Note that proper frequency planning is required to achieve the desired F_{out}. The clocks must be carefully controlled in the design wide resources.

DC and AC Electrical Characteristics

The following values are indicative of expected performance and based on initial characterization data. Unless otherwise specified in the tables below, all T_A = 25°C, V_{dd} = 5.0 V, Power HIGH, Opamp bias LOW, output referenced to 1.024 V.

Mixer DC Specifications

Parameter	Description	Conditions	Min	Typ	Max	Units
V_{OS}	Input offset voltage		–	–	10	mV
	Quiescent current		–	0.9	2	mA

Mixer AC Specifications

Parameter	Description	Conditions	Min	Typ	Max	Units
f_{LO}	Local oscillator frequency	Down mixer mode	–	–	4	MHz
f_{in}	Input signal frequency	Down mixer mode	–	–	14	MHz
f_{LO}	Local oscillator frequency	Up mixer mode	–	–	1	MHz
f_{in}	Input signal frequency	Up mixer mode	–	–	1	MHz
SR	Slew rate		–	–	–	V/µs

Component Changes

This section lists the major changes in the component from the previous version.

Version	Description of Changes	Reason for Changes / Impact
1.60	Removed VDDA parameter from component customizer	VDDA setting in the component is redundant and unnecessary for multiple components. The parameter was removed and the component queries the global setting for minimum VDDA in the DWR and automatically enables the pump when necessary.
	Added a GUI Configuration Editor	Previous configuration window did not provide enough information for ease of use.
	LO - local oscillator is enabled correctly	The local oscillator was not being enabled correctly in previous versions of the component.
	Added characterization data to datasheet	
	Minor datasheet edits and updates	

1.50	Added Sleep/Wakeup and Init/Enable APIs.	To support low power modes, as well as to provide common interfaces to separate control of initialization and enabling of most components.
	Updated Symbol and Configure dialog.	To comply with corporate standards.

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