AN86

RINGING/RINGTRIP OPERATION AND ARCHITECTURE ON THE Si3220/Si3225

Introduction

The Dual ProSLIC (Si3220/Si3225) offers a wide variety of ringing options to match any application. The Si3220 supplies a ringing waveform produced by its internal oscillator and allows software programmability of the amplitude, frequency, and dc offset. The Si3225 requires an external ringing source and switches between the ringing source and its own TIP/RING line driver as necessary. This document describes the ringing architecture and operation of both products.

Internal Balanced Ringing

Internal balanced ringing via the Si3220 is accomplished through its internal oscillator using frequency and amplitude parameters. The waveform is comprised of the output of the oscillator and an optional voltage offset. Two waveforms of half the total amplitude are generated, one on TIP and one on RING, 180° out-of-phase with each other as shown in Figure 1. This produces a differential waveform of double the peak amplitude on the loop.

Using the equations in Table 1, an Si3220 application can generate a ringing sinusoidal or trapezoidal wave between the frequencies of 4 and 100 Hz and up to 160.8 V_{PK}. If using the Si3200, the ringing amplitude is limited to 95 V_{PK}. A dc offset can be added to the ringing waveform also using the equations in Table 1.

Trapezoidal ringing is generally used when a greater power to peak voltage ratio is needed and harmonic distortion is not a cause of concern. The Si3220 can generate trapezoidal waveforms of variable frequency, amplitude, and crest factor according to the equations in Table 1. An example waveform is shown in Figure 2. The rise time is related to the crest factor by Equation 1:

$$t_{RISE} = \frac{3}{4f}\left(1 - \frac{1}{CF^2}\right)$$

where f is the Ringing Frequency

and CF is the Crest Factor of the waveform

Equation 1.

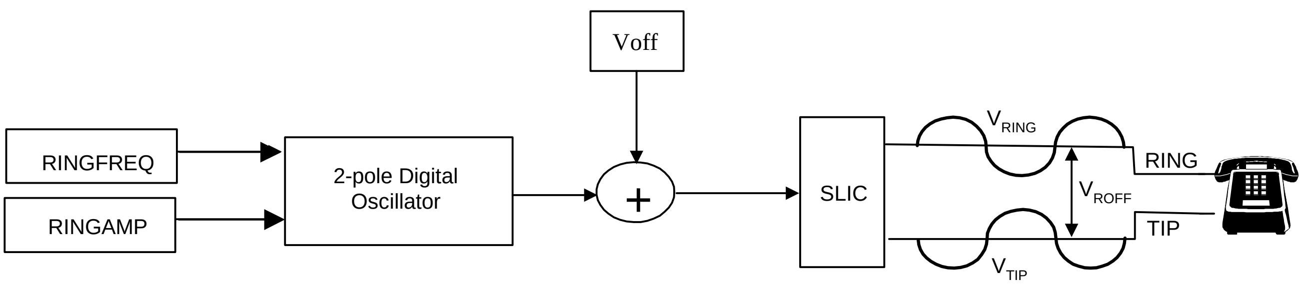

Figure 1. Internal Ringing Generation

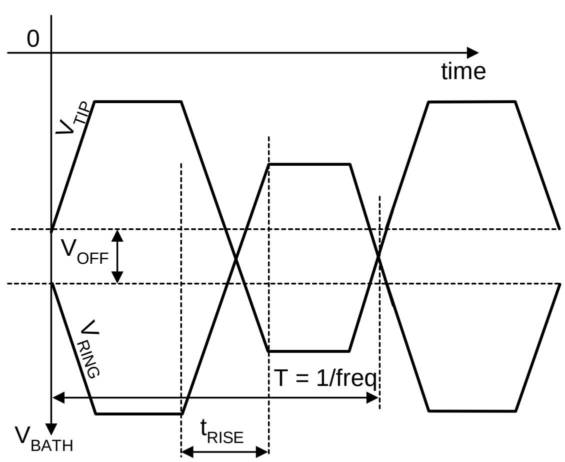

Figure 2. Trapezoidal Waveform

Table 1. Equations for Si3220 Ringing Parameters

Register/RAM	Sinusoidal	Trapezoidal
RINGAMP	$\frac{1}{4} \times \sqrt{\frac{1 - \cos\left(\frac{2\pi f}{1000}\right)}{1 + \cos\left(\frac{2\pi f}{1000}\right)}} \times (2^{15}) \times \frac{V_{AMP}}{160.173V}$	$\frac{V_{AMP}}{160.8} \times (2^{15})$
RINGFREQ	$\cos\left(\frac{2\pi f}{1000}\right) \times (2^{23})$	$\frac{2 \times RINGAMP}{t_{RISE} \times 8000}$
RINGFRHI	$\frac{\text{RINGFREQ \& 0xFFF000}}{2^9}$	(RINGFREQ & 0xFF)
RINGFRLO	(RINGFREQ & 0xFFF) x 2^3	Unused
RINGPHAS	Unused.	$4 \times \frac{1}{f} \times 8000$
RINGOF	$\frac{V_{OFF}}{160.801} \times (2^{15})$ (2s complement)	$\frac{V_{OFF}}{160.801} \times (2^{15})$ (2s complement)
RINGCON: [TRAP]	0	1
RINGTA	$\frac{t_{active}}{125 \times 10^{-6}}$	$\frac{t_{active}}{125 \times 10^{-6}}$
RINGTAHI	$\frac{\text{RINGTA \& 0xFF00}}{2^8}$	$\frac{\text{RINGTA \& 0xFF00}}{2^8}$
RINGTALO	RINGTA & 0xFF	RINGTA & 0xFF
RINGTI	$\frac{t_{inactive}}{125 \times 10^{-6}}$	$\frac{t_{inactive}}{125 \times 10^{-6}}$
RINGTIHI	$\frac{\text{RINGTI \& 0xFF00}}{2^8}$	$\frac{\text{RINGTI \& 0xFF00}}{2^8}$
RINGTILO	RINGTI & 0xFF	RINGTI & 0xFF

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It is important to remember that the ringing waveform cannot go out of range of the maximum allowable voltage. As shown in Figure 3, Equation 2 must hold true:

$$|-V_{BATH}| > V_{PK} + V_{CM} + |V_{OFF}| + V_{OVRING}$$

Equation 2.

V_{PK} and V_{OFF} are the peak amplitude and offset ringing voltage respectively. V_{CM} is the common mode voltage to give head room from ground, typically 3 V. V_{OVRING} is the headroom from V_{BATH}. Because of the inherent ringing source impedance, Silicon Laboratories recommends 0 V for V_{OVRING}. The voltages can be controlled by the corresponding registers. See the data sheet for more information. It is possible to have a V_{OFF} value of 0 if the loop length is short; this is discussed in more detail in "Ringtrip" on page 7. If the ring signal goes out of ringing range of the battery, the Si3220 digitally limits the ringing signal to prevent the voltage source from saturating.

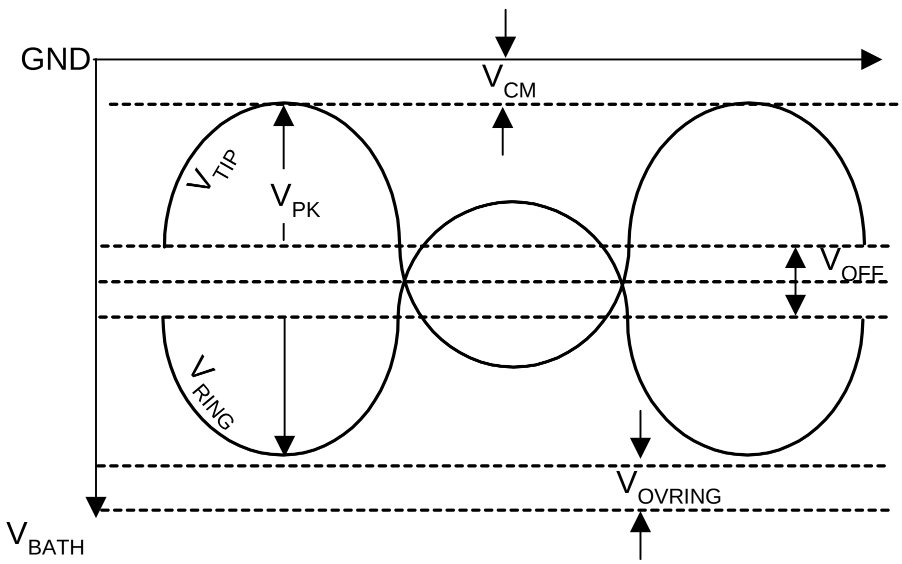

Figure 3. Ringing Voltages

Internal Unbalanced Ringing

Unbalanced Ringing is an available option on the Si3220. To enable unbalanced ringing, set the RINGUNB bit (bit 5) of the RINGCON register. When the Linefeed register is set to 0x04 (ringing mode) in unbalanced ringing mode, the TIP lead will stay at its current voltage (V_{CM}) and the RING lead will oscillate around –80 V. The RINGOF register is used in unbalanced ringing to move the position of the center of oscillation on the ring lead, as shown in Figure 4. (RINGOF is a 2s complement number. For example, if it is desired that the voltage oscillate around –50, a –30 V offset, which corresponds to a value of 0xe81e, is required. However, if a –110 V offset is desired, the RINGOF value is 0x17e1.) Therefore, a differential offset, shown in Equation 3, exists between TIP and RING.

$$(-80 - Voff) - |Vcm|$$

Equation 3.

It is necessary to make sure a sufficient ringing battery exists for the ring oscillation as shown in Figure 5. The following equation must hold true:

$$|-V_{batH}| > V_{PK} + (-80 - V_{OFF}) + V_{ovRING}$$

Equation 4.

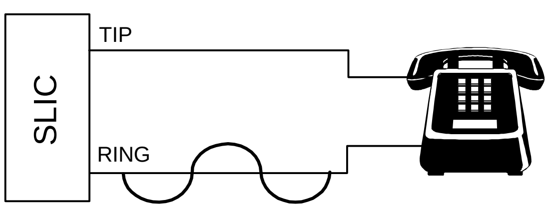

Figure 4. Unbalanced Ringing Application

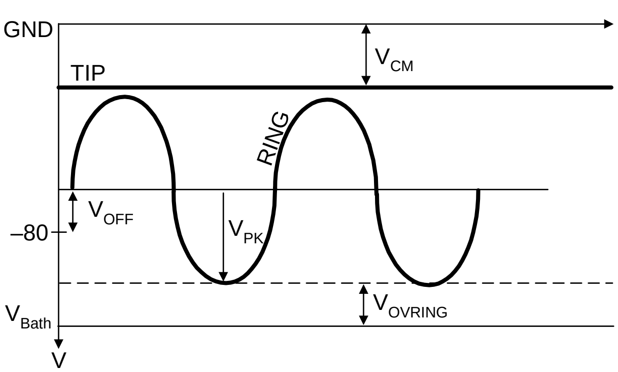

Figure 5. Unbalanced Ringing

It is possible to reverse the polarity of the loop and have tip oscillate while ring stays stagnant using the UNBPOLR bit (bit 1) of the RINGCON register.

Note: The polarity of V_{OFF} must also be reversed when using polarity reversal in unbalanced ringing.

The ringing amplitude and frequency is set according to the equations in Table 1 on page 2.

Ringing Cadence

Ringing cadencing is the act of alternating between periods of a dc-only state and ringing bursts. On the Si3220, ringing cadence can be accomplished both manually or automatically.

Manual Cadencing

Cadencing can be performed manually by changing the state in the Linefeed register between ringing (LINEFEED=0x04) to either a forward active (LINEFEED = 0x01) or forward on-hook transmission (LINEFEED=0x02) in between ringing bursts. Forward on-hook transmission is used for transmitting data during an active on-hook period (i.e., FSK caller-id information). Forward active keeps the SLIC in low power mode when on-hook while providing power to the phone.

Automatic Cadencing

The active and inactive timer registers (RINGTI and RINGTA) are used to perform cadencing automatically.

The former should be programmed with the amount of time that a ringing burst should last and the later should contain the amount of time in between ringing bursts. Both registers have a resolution of 125 µs. When ringing is first initiated (LINEFEED = 0x04), the active timer counts the amount of time in RINGTA. When it expires, the Linefeed Shadow register changes to active (LINEFEED = 0x24) for the period of time that the inactive timer is set for as shown in Figure 6. When the inactive timer expires, the Linefeed Shadow register changes back to the ringing state (LINEFEED = 0x44) and the active timer again starts counting down. These two timers together toggle the ringer enable bit in RINGCON (RING_EN). Consult Table 1 on how to program these timer registers.

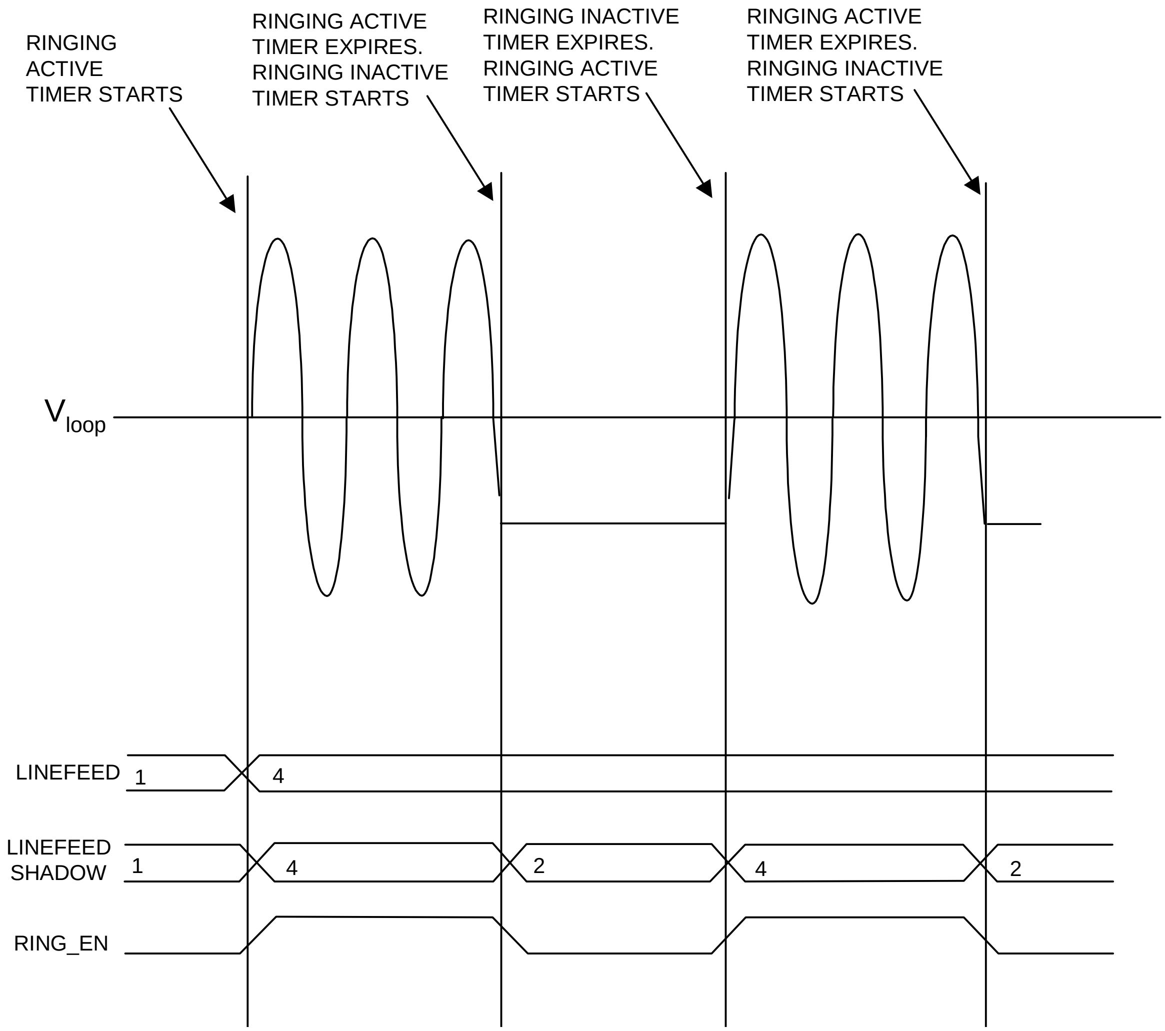

Figure 6. Automatic Cadencing

State Transitions

Whether cadencing is performed automatically or manually, the state change and Linefeed Shadow register do not update immediately. Going from ringing to the silent dc-only state, the ProSLIC waits for the ringing to be at the same voltage as the on-hook voltage before switching states. (See Figure 7). Likewise, at the end of a ringburst the Si3220 waits for the TIP-RING voltage to equal V_{OC} before switching from the ringing state to the active state. This is to provide the smoothest possible transition between states and minimize TIP-RING voltage transients.

Note: For ringing to begin correctly, the peak-to-peak ringing voltage must be greater than the programmed open circuit voltage, V_{OC}.

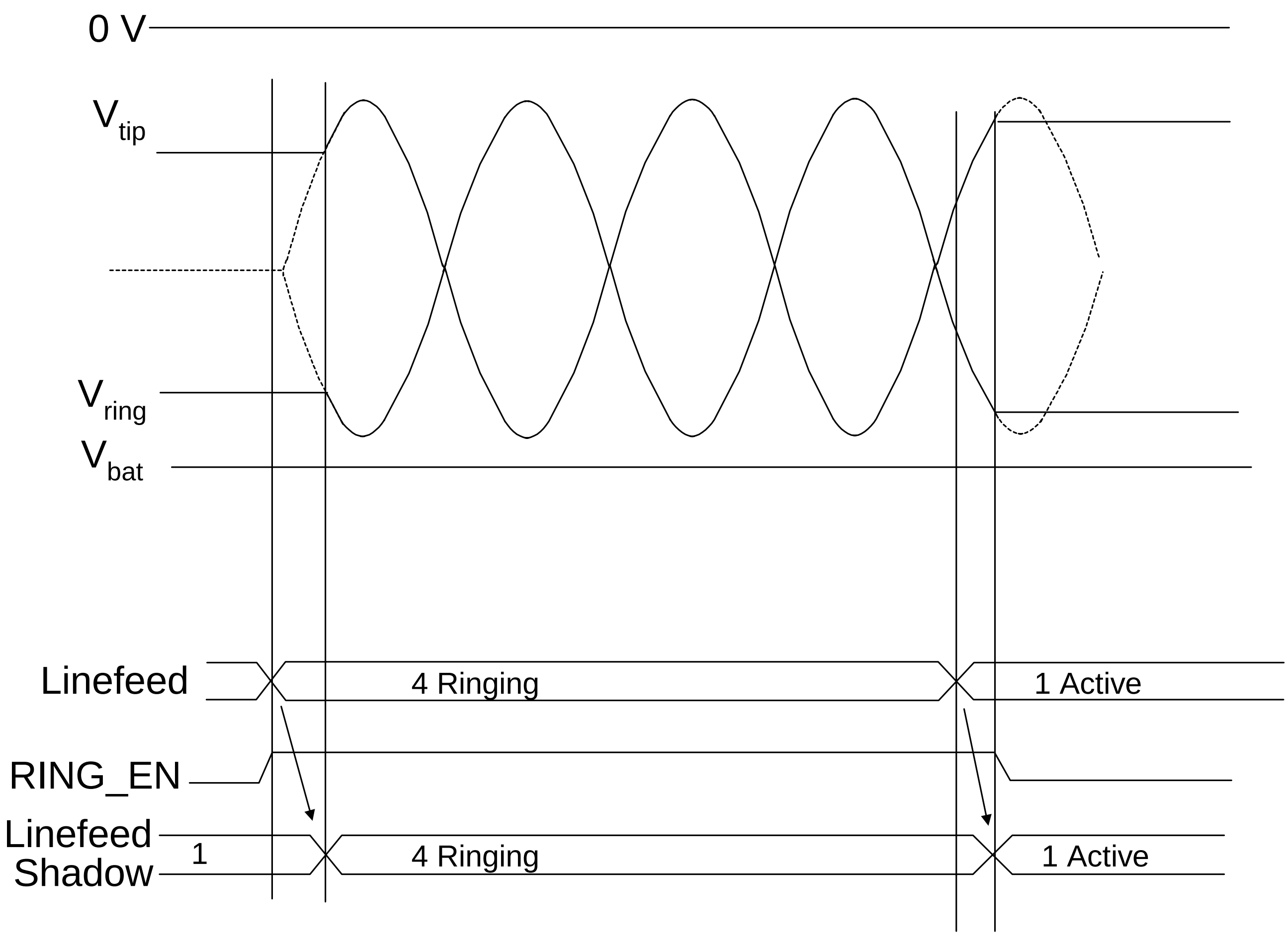

Figure 7. Switching Between the Active State and the Ringing State

Ringtrip

The Si3220 determines an off-hook condition during a ringburst by sensing the metallic current through the loop. For internal ring, the ac and dc metallic loop current are sensed. Ringtrip works off a programmed threshold placed in RTACTH and RTDCTH and can be based on ac or dc loop current. When the current in the loop is above that threshold, a ringtrip is detected. If the Si3220 ringtrip signal is obtained for a set debounce period, then the ringtrip flag goes high and an interrupt is generated. Figure 8 shows a block diagram of the ringtrip algorithm.

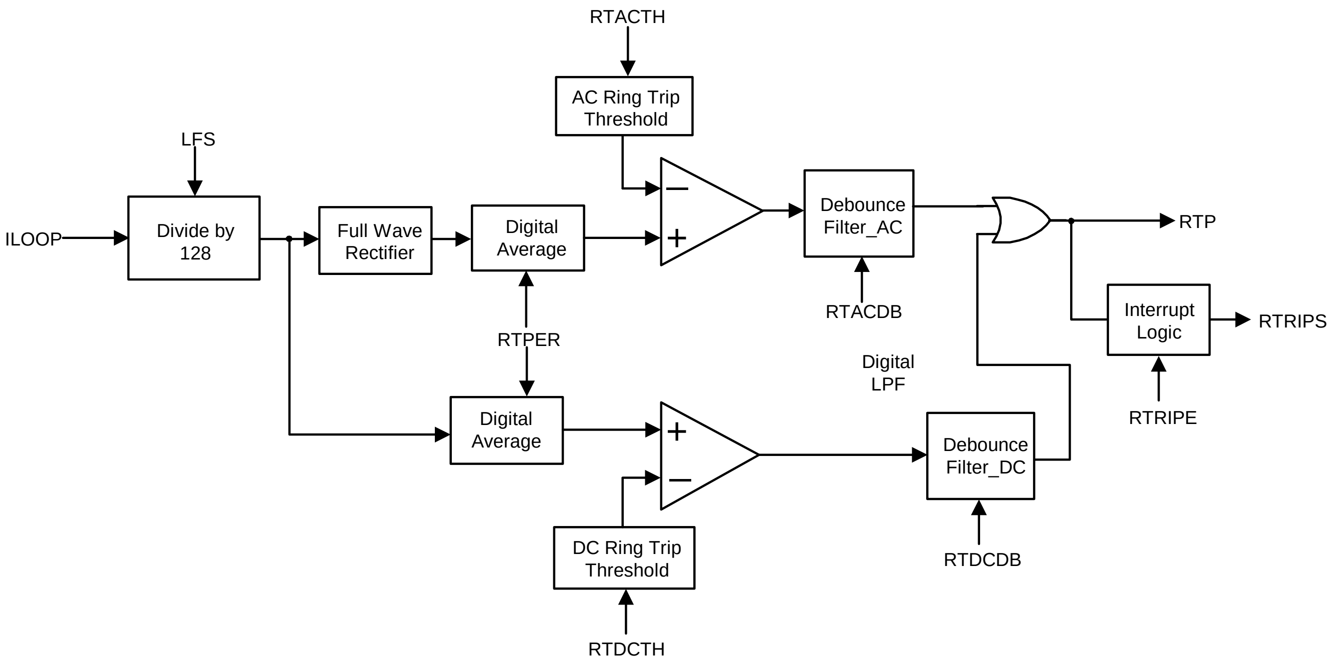

Figure 8. Ringtrip Algorithm Block Diagram

AC Current Ringtrip

The internal DSP obtains loop current samples at a rate of 800 Hz. AC ringtrip takes the absolute value of the loop current samples and sums the values taken over a sample period specified by RTPER. RTPER is the RAM location that specifies the number of samples summed for further computation. (See Figure 9). The sum is divided by a constant 128 in the input signal processor to allow it to fit in a 16-bit register. After a sum is calculated over a period, RTPER, the Si3220 compares it to the threshold specified in RTACTH. If the current value is greater than the threshold, a ringtrip is detected.

The equation for RTPER is as shown in Equation 5:

$$RTPER = \frac{800}{f} \text{ for } f < 32$$

$$= 2 \times \left(\frac{800}{f}\right) \text{ for } f > 32$$

where f is the ringing frequency

Equation 5.

The Si3220 has two counters summing current values simultaneously, each resetting half a sample period apart from one another. Every time a ringtrip is detected from either counter, the Si3220 subtracts 1 from the debounce counter specified in RTACDB. Since there are two counters running half a phase apart, the debounce counter runs at a rate twice the sample time specified in RTPER. Therefore, an LSB of the debounce counter can be calculated as shown in Equation 6:

$$LSB\_RTxCDB = \frac{800 \times 2}{RTPER}$$

Equation 6.

Once the debounce counter hits 0, the ringtrip flag is set, and if the interrupt is enabled, an interrupt is generated. If the ac loop current is below the threshold, the debounce counter is reset to its programmed value.

Therefore, the equation for ac ringtrip is as shown in Equation 7.

$$RTACTH = I_{PK} \times \left(\frac{1}{\Lambda}\right) \times \beta \times \left(\frac{RTPER}{128}\right)$$

where I_{PK} is the peak threshold current to ringtrip.

$\Lambda = 3.1 \times 10^{-6}$ A (the scaling factor)

and β is the average of the current wafeform

$\beta = \left(\frac{2}{\pi}\right)$ for a sinusoidal wafeform, and

$\beta = \left(1 - \frac{t_{RISE}}{T}\right)$ for a trapezoidal waveform

Equation 7.

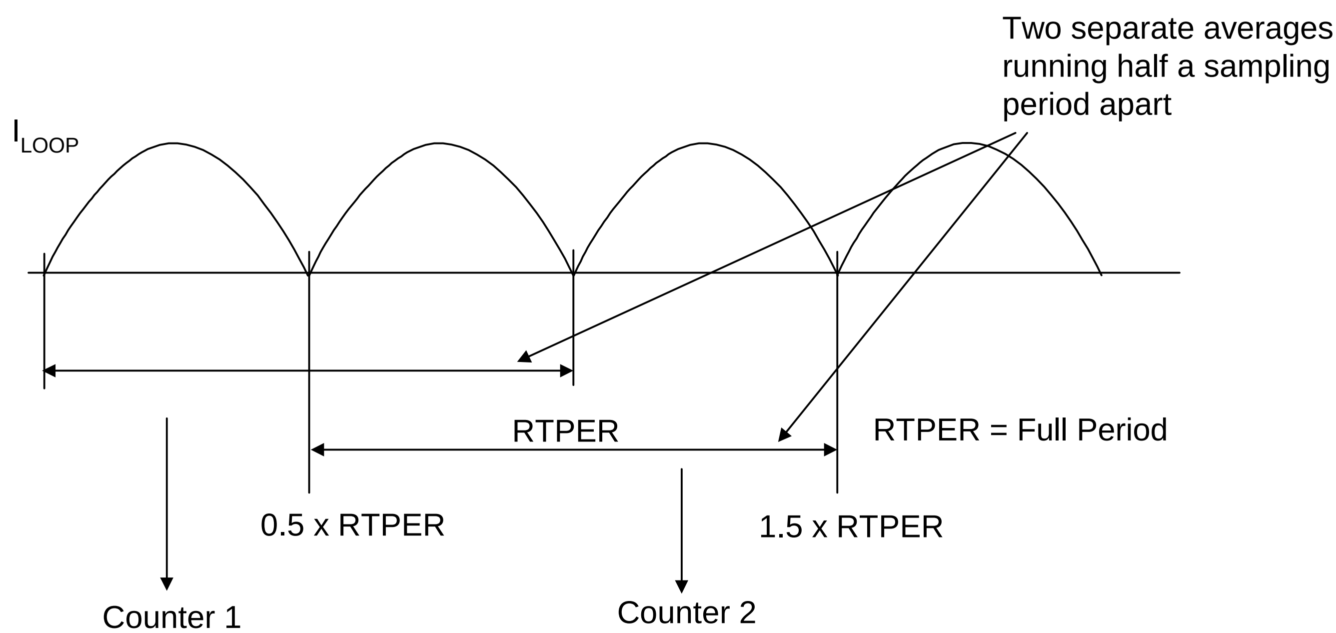

Figure 9. AC Current Sampling

Inside the internal signal processor, the current is summed over a constant 128; therefore, in the threshold, multiply by the number of samples (RTPER) and divide by 128 to align the scaling of the measured loop current with that of the threshold.

If ac ringtrip is desired, threshold values should be generated by the average of two impedance extremes, maximum off-hook impedance at maximum loop vs. minimum on-hook impedance at 0 loop. A simplified circuit is seen in Figure 10.

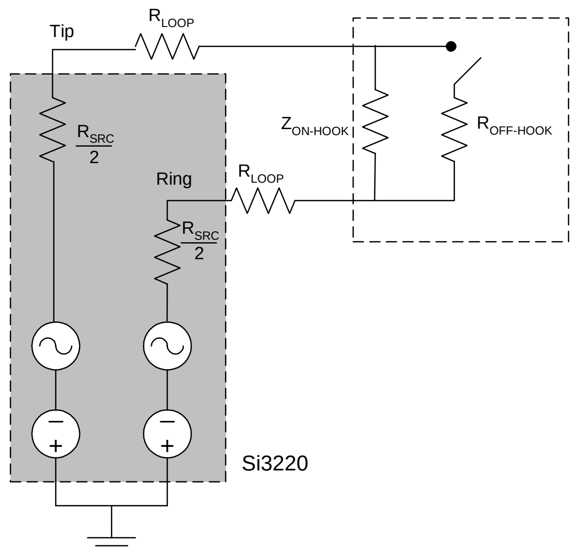

Figure 10. Example Ringing Circuit

In the ac case, the minimum on-hook impedance is based on the impedance of the maximum number of ringers in parallel in series with the source impedance, as shown in Figure 11 or Equation 8:

$$Z_{MINon-hook} = Z_{MAXREN} + Z_{SRC}$$

Equation 8.

REN impedance is determined by Equation 9:

$$Z_{MAXREN} = \sqrt{\left(\frac{6800}{MAXren}\right)^2 + \left(\frac{1}{2 \times \pi \times f \times 8e-6 \times MAXren}\right)^2}$$

where MAXren is the maximum REN on an application and f is the ringing frequency

Equation 9.

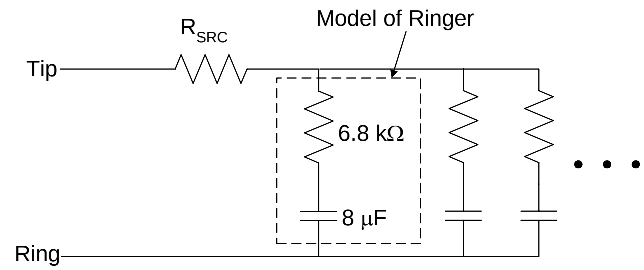

Figure 11. REN Line Model

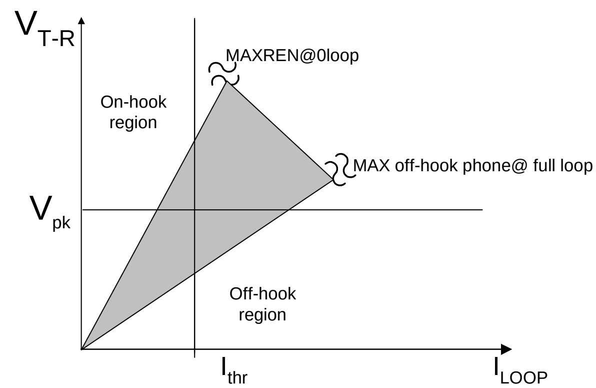

Figure 12. V,I Graph of ac Ringtrip

The maximum off-hook impedance is based on maximum impedance of one off-hook phone in series with the impedance of the maximum loop length in series with the source impedance or Equation 10:

$$Z_{MAXoff-hook} = Z_{MAXphone} + Z_{MAXloop} + Z_{SRC}$$

For the Si3220, $Z_{SRC} = 320\Omega$

Equation 10.

Figure 12 shows a V,I graph. The gray area is where the threshold should lie. For a particular V_{PK}, the current threshold should be a value between the two extremes.

In the case of Figure 13, where the maximum off-hook impedance is greater than the minimum on-hook impedance, a valid ac ringtrip threshold cannot be obtained. Therefore, dc ringtrip must be used.

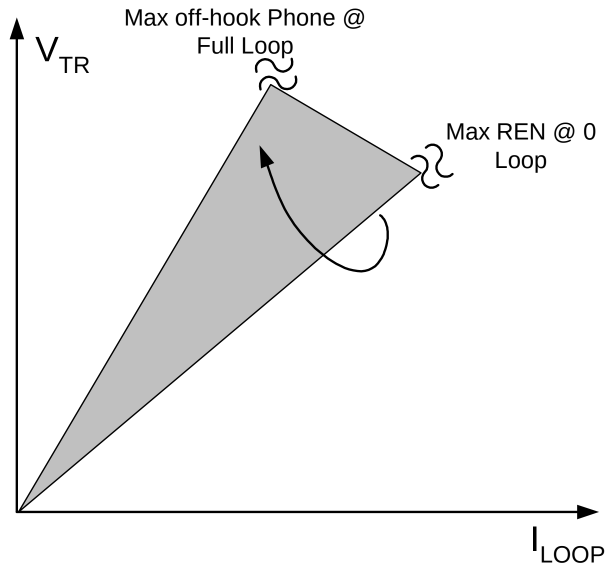

Figure 13. V,I Graph of ac Ringtrip Error Case

DC Current Ringtrip

Like ac ringtrip, dc ringtrip uses two separate counters that are half a period apart. The dc ringtrip algorithm averages an RTPER number of samples of the current. Therefore, when RTPER is set to a multiple of 800/T (where T is the time period of the ringing waveform), the ac component of loop current is averaged out and only the dc current is left as shown in Figure 14. As with ac ringtrip, the absolute value of the dc current is compared to a threshold specified in RTDCTH. Therefore, a dc offset specified in RINGOF is necessary for dc ringtrip. After a ringtrip is detected, it decrements the debounce counter, specified in RTDCDB, and once the counter hits 0, the ringtrip flag is set and the interrupt logic generates an interrupt.

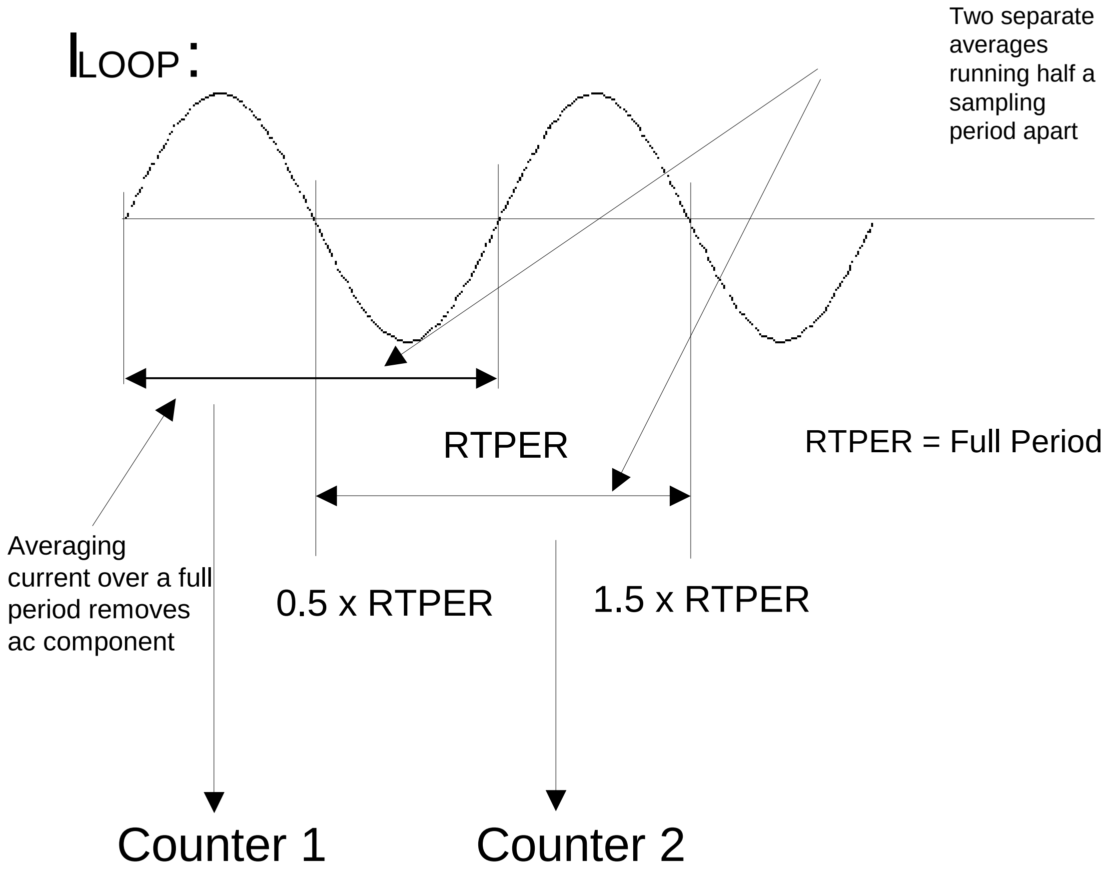

Figure 14. DC Ringtrip Sampling

RTDCTH should also be chosen based upon the maximum off-hook resistance vs. the minimum on-hook resistance. In most cases, dc current does not flow through an on-hook case due to the ringer capacitance on the line. However, telecom standards specify a minimum on-hook impedance at 10 kΩ. Therefore, the dc VI graph looks like the one shown in Figure 15. The gray region is the impedance range between minimum on-hook and maximum off-hook. As in the ac case, dc threshold can be set by finding a value in the gray area between the points where the offset voltage line crosses the gray area. DC thresholds are generally set very conservatively due to very small on-hook current.

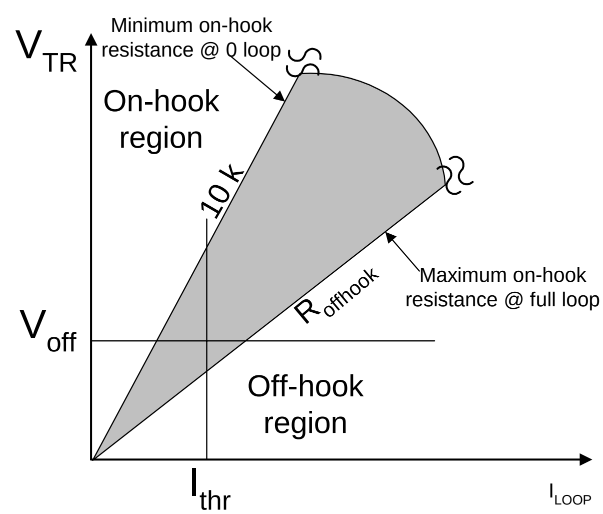

Figure 15. VI Graph of DC Ringtrip

The dc threshold is calculated with Equation 11:

$$RTDCTH = I_{DC} \times \left(\frac{1}{\Lambda}\right) \times \left(\frac{RTPER}{128}\right)$$

I_{DC} is the dc threshold current for ringtrip

$\Lambda = 3.1 \times 10^{-6}$ µA

Equation 11.

RTPER is the RAM location that contains the number of samples summed for further computation.

Clipping

The current driver of the Si3220 is limited to 100 mA. In the event that a loop is so short that the loop current peak is above 100 mA, the Si3220 will not recognize this as a ringtrip due to the fact that the ac current is averaging the total current down as shown in Figure 16. In order to solve this situation, ac ringtrip must also be used when using a dc offset. The ac threshold value, RTACTH, should be set to detect a square wave of around 85 mA. Therefore the equation for RTACTH is as shown in Equation 12:

$$RTACTH = 85mA \times \frac{1}{\Delta} \times \frac{RTPER}{128}$$

$\Delta = 3.1 \times 10^{-6}$

Equation 12.

Watchdog Timeout

The Si3220 waits for the ringing signal to be equal in voltage to the nominal V_{OC} voltage before switching states. This is to provide the smoothest possible transition. In the event that the loop voltage never crosses V_{OC}, the Si3220 incorporates a watchdog timer that will force a ringtrip as soon as it expires. The watchdog register is programmed through the RTCOUNT direct register with the Equation 13:

$$RTCOUNT = \frac{t_{WATCH}}{.000125}$$

Equation 13.

RTCOUNT will operate upon a manual change away from ringing, a ringtrip, or an expiration of the ringing active timer. A typical value for RTCOUNT is 0x310 (120 ms).

Loop Closure Mask

The Si3220 also has a register that causes a certain delay between ringing active and ringing inactive to prevent a loop closure detection during transient currents. This delay is programmed through LCRMSK by Equation 14:

$$LCRMSK = \frac{t_{DELAY}}{.000125}$$

Equation 14.

A typical value for LCRMSK is 0x60 (12 ms).

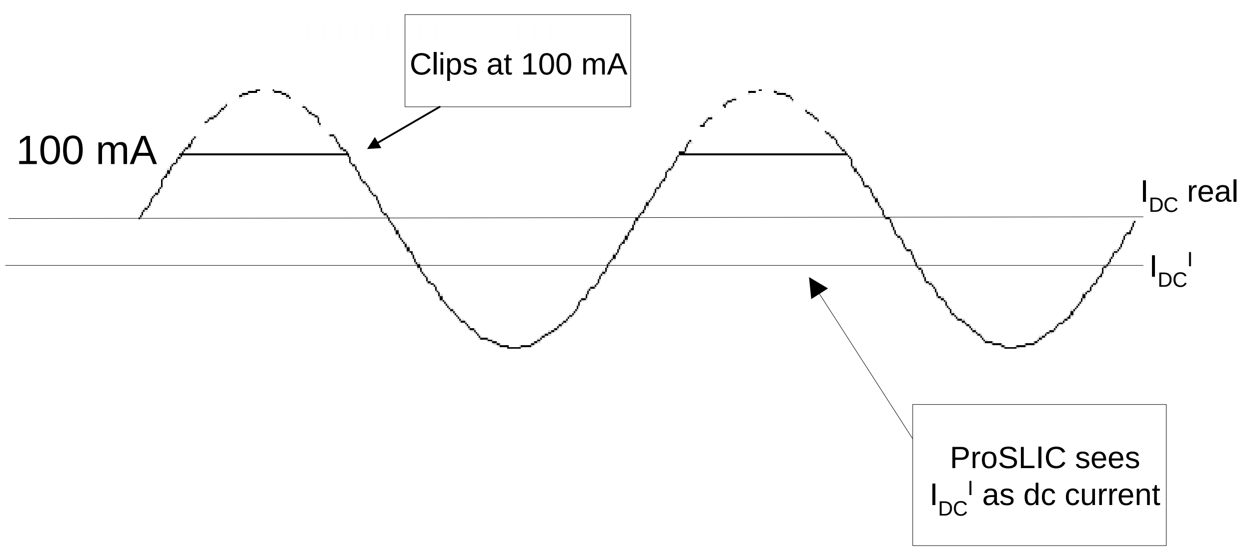

Figure 16. Ringing Current Clipping on the Si3220

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Design Example

Following current Telecom Specs, applications have to meet the following criteria:

- GR 909: must not ringtrip using the circuit shown in Figure 17 and must not ringtrip when 200 Ω is connected for less than 12 ms. Must ringtrip within 200 ms:
- GR 57: must not ringtrip using the circuit shown in Figure 18:
- IEC60950 must ringtrip when current is greater than 100 mA within 200 ms.

The following is an example to calculate ringtrip coefficients for a 20 Hz, 45 V_{rms} (across the ringer) internal ringing signal with 50 Ω of loop length designed to meet the above criteria. Equation 15 assumes an off-hook impedance of 600 Ω:

$$\text{RTPER} = \frac{800\text{ Hz}}{20\text{ Hz}} = 40$$

Equation 15.

A value of 40 samples one full ringing period. For higher frequencies, it is recommended that two ringing periods be sampled:

$$\text{RTPER} = 2 \times \left(\frac{800}{f}\right)$$

Equation 16.

Where f = Ringing frequency. (Any number of ringing periods can be used; it will just add extra time between ringtrip computations.)

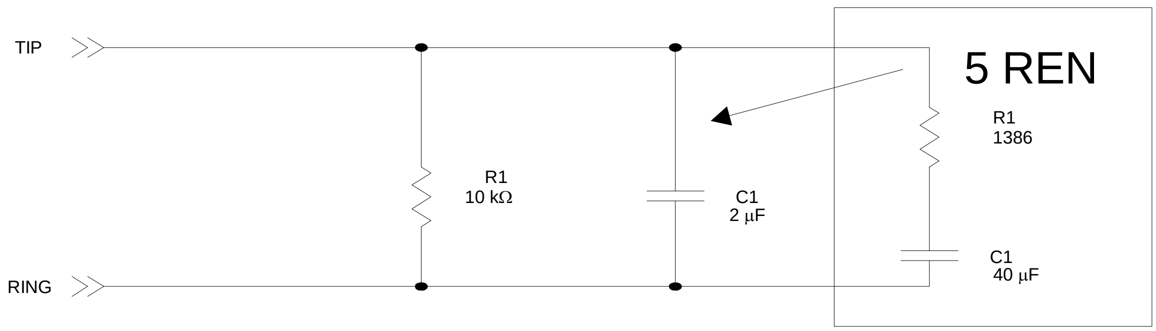


Figure 17. GR 909 Test Case

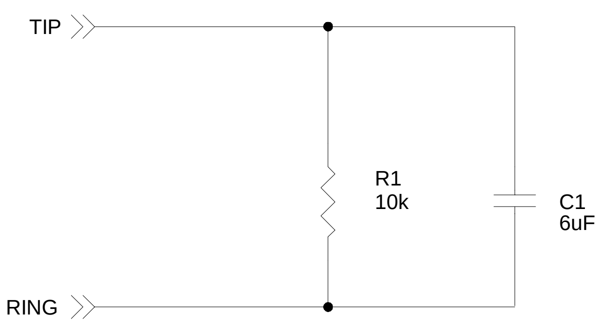


Figure 18. GR 57 Test Case

To find ac impedances:

$$|Z_{GR} - 909| = \frac{166667}{\sqrt{(\omega^2 + 277.778)}}\Omega$$

Equation 17.

$$|Z_{GR} - 57| = \frac{500000(\omega^2 + 325.352 \times \sqrt{\omega^6 + 182381\omega^4 + 6.00454 \times 10^7 \times \omega^2 + 2.64635 \times 10^8})}{\omega^6 + 182381\omega^4 + 6.00454 \times 10^7 \times \omega^2 + 2.64635 \times 10^8}\Omega$$

where $\omega = 2 \times \pi \times$ Ringing Frequency

Equation 18.

At 20 Hz, we find:

From Equation 17 and Equation 18:

Z_{GR} – 909 = 1315 Ω

Z_{GR} – 57 = 1135 Ω

Therefore, the minimum on-hook impedance is as follows:

$Z_{MIN\_On\text{-}hook}$ = 1135 + 320 = 1455 Ω

In Equation 19, the maximum off-hook impedance is found by using Equation 10:

$$Z_{MAX\_Off\text{-}hook} = \frac{V_{PK}}{.1} + 2 \times 50 + 320\Omega = 1056\Omega$$

Equation 19.

Because:

Zmax_off-hook < Zmin_on-hook, it is justified to use ac ringtrip. (It is good practice to not use ac ringtrip if the two impedances are within 100 Ω.)

Using $I_{rms} = V_{rms}/Z$, we find an average current value to be 36 mA.

In Equation 20, the ac threshold is found by using Equation 7:

$$RTACTH = I_{RMS} \times \sqrt{2} \times \frac{1}{\Delta} \times \left(\frac{2}{\pi}\right) \times \frac{RTPER}{128} =$$

$$3267 = 0xCC3$$

Equation 20.

To find the debounce coefficient:

$$200ms > RTACDB > 12ms$$

Using Equation 6, we find that a value of 0x01 corresponds to 25 ms. The number in RTACDB is equal to the number of times before a flag is set that the Si3220 checked for a ringtrip. Therefore, this value should be sufficient to ensure that a ringtrip did not occur due to transient currents. Silicon Laboratories recommends a value of 3 or greater. See Equation 21:

$$RTACDB = 75ms \times \left(\frac{1600}{RTPER}\right) = 3$$

Equation 21.

Since only ac ringtrip is being used, dc ringtrip may be turned off by setting RTDCTH to 0x7FFF.

Design Example 2

In Example 1, if the loop resistance was 300 Ω instead, Equation 22 applies:

$$Z_{MAX\_Off\text{-}hook} = \frac{V_{PK}}{.1} + 2 \times 300 + 320\Omega = 1556\Omega$$

Equation 22.

In this case, Zmax_off-hook > Zmin_on-hook; therefore, ac ringtrip cannot be used, and dc ringtrip must be used. If a 30 V offset is required, find the current threshold by using the following equations:

$$R_{MIN\_On\text{-}hook} = 10000 + 320 = 10320\Omega$$

Equation 23.

$$R_{MAX\_Off\text{-}hook} = 1500 + 2 \times 300 + 320\Omega = 2420\Omega$$

Equation 24.

A conservative estimate of the trip current is 9 mA.

Therefore, using Equation 11, the dc threshold is as shown in Equation 25:

$$RTDCTH = 9mA \times \frac{1}{\Delta} \times \frac{RTPER}{128} = 908 = 0x38C$$

Equation 25.

The ac threshold shown in Equation 26 is also required and can be found with Equation 12:

$$RTACTH = .09 \times \left(\frac{1}{\Delta}\right) \times \frac{RTPER}{128} = 9072 = 0x2370$$

Equation 26.

The debounce coefficients are found the same way as the ac case:

RTACDB = RTDCDB = 3

Dissipated Power During Ringing

The power dissipated during ringing can be higher than in any other mode of operation. An equivalent circuit of the ringing system inside the Si3220/3200 is shown in Figure 19.

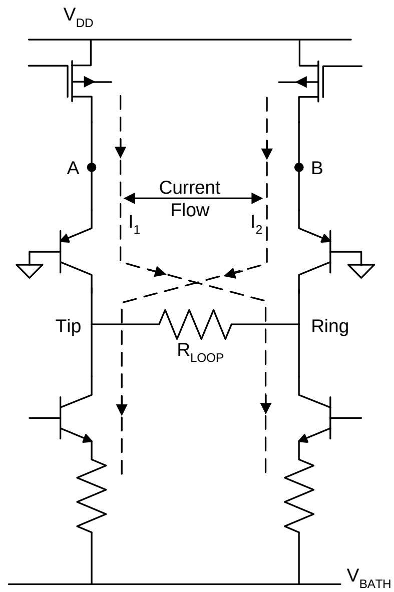


Figure 19. Equivalent Circuit of Ringing Architecture

The total current through the loop first needs to be found with the following equation:

$$I_{Loop\_pk} = \frac{V_{ring\_pk}}{|Z_{loop}|}$$

Equation 27.

The current waveform is a rectified sine wave with the peak value equal to I_{Loop_pk}.

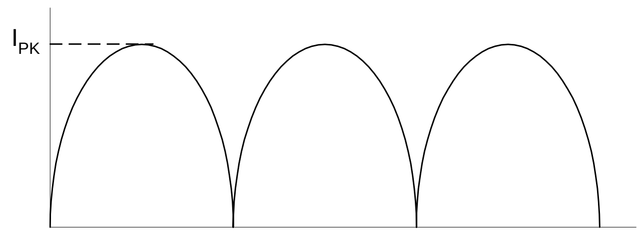


Figure 20.

where the average current is as shown in Equation 28:

$$I_{avg} = \left(\frac{2}{\pi}\right) I_{pk} \times 1.02$$

Equation 28.

Therefore, the average power is as shown in Equation 29:

$$P_{avg} = P_{VBat} + P_{VDDD}$$
$$= I_{avg} \times |V_{bath}| + I_{avg} \times |V_{DD}| + 60\text{ mW}$$

Equation 29.

External Ringing

Ringing on the Si3225 requires an external ringing source. As shown in Figure 21, the external ringing signal is sensed across a source resistance (R_{SRC}). Silicon Laboratories recommends 510 Ω, 2 W resistors for that resistance. The internal DSP uses these measurements to calculate the current through the loop. A relay driven by RRD switches the relay between the ringing signal and the tip/ring signals supplied by the Si3200. (See Figure 21.) The BLKRING pin monitors the voltage across the ringing source and the RTRP pin senses the voltage across R_{SRC}.

To use external ringing, RDOE bit (bit 3) of RLYCON must be set during initialization. Additionally, external ringing/ringtrip is very susceptible to offsets; therefore, MADC calibration must be performed during initialization. The Si3225 switches its RRD pin in order to drive the relay when the LINEFEED is put in the ringing state. Refer to the data sheet on the necessary hardware to accomplish this. The Si3225 will toggle the pin as necessary.

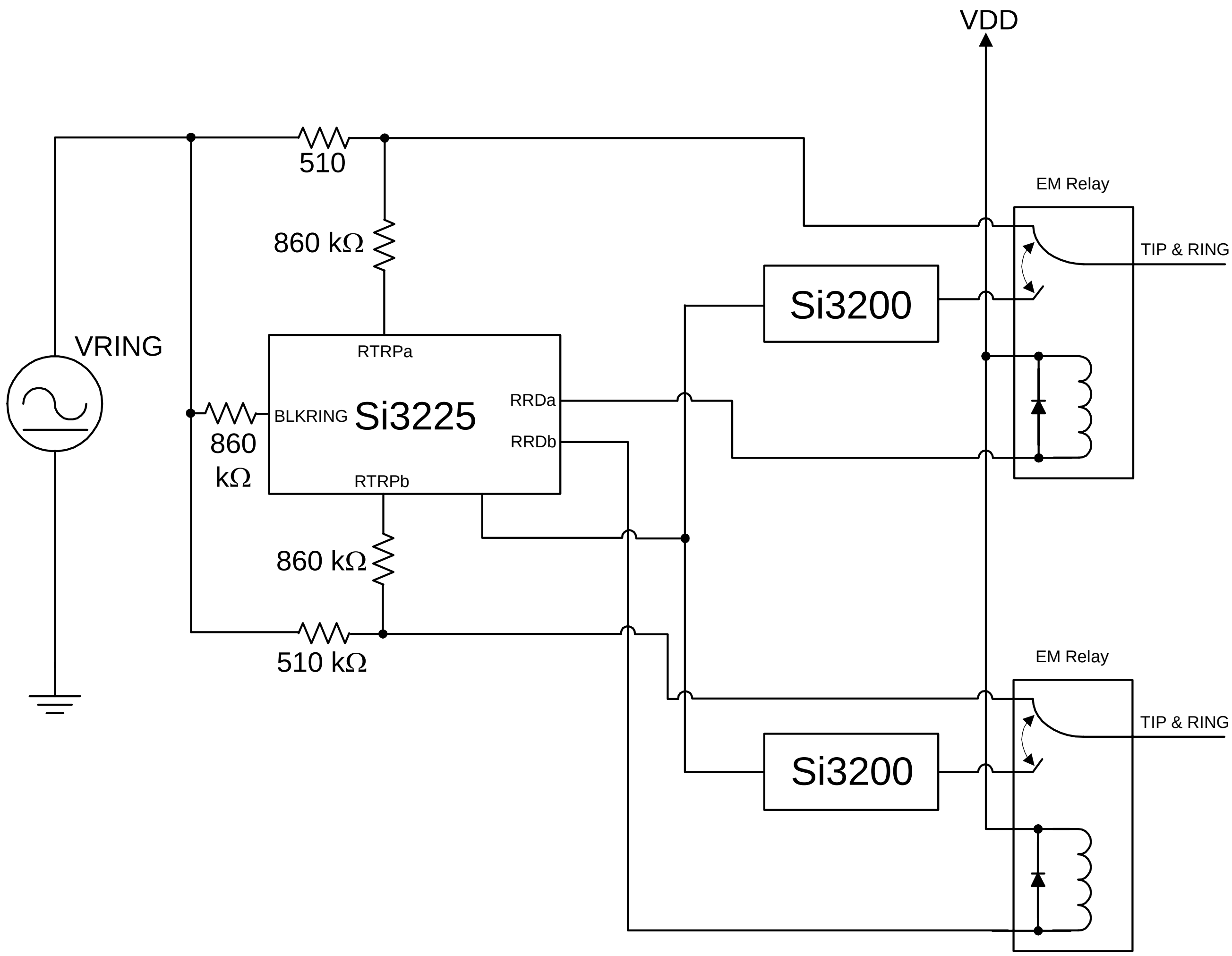


Figure 21. External Ringing Circuit

External Ringing Cadencing

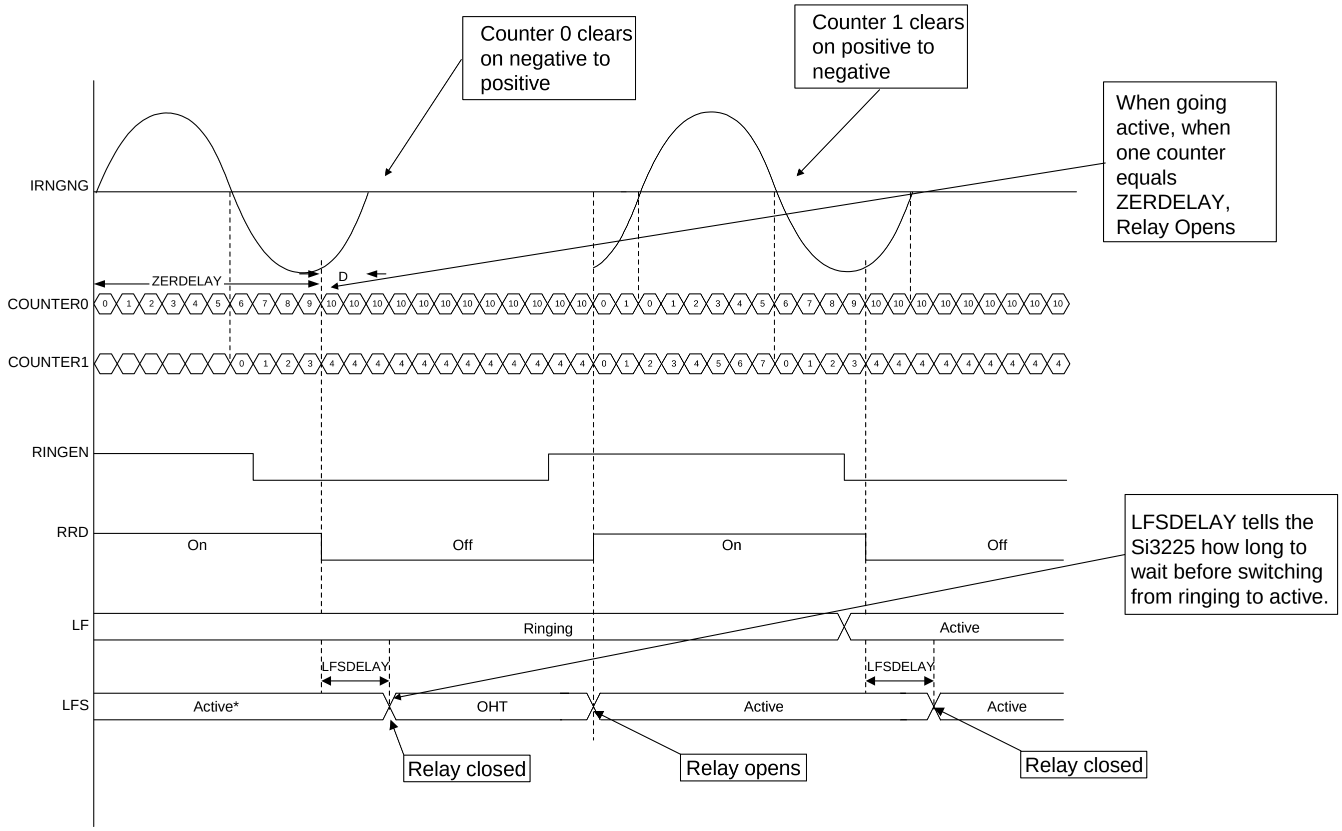
The external ringer cadence timers work similar to the ones of internal ringing. As shown in Figure 22, the Si3225 opens and closes the relay according to Ringing Active and Inactive timers. (Refer to Table 2.)

At the end of a ringburst, whether it is cadencing, end of ringing, or ringtrip, the Si3225 attempts to open the relay at a zero current crossing to provide the smoothest possible transition. However, because of the delay in the amount of time it takes for a relay to switch, by the time the relay actually switches, the current could be significant. Therefore, a programmable register tells the Si3225 when to switch the relay. In Figure 22, D is the delay of the switching relay. The Si3225 is programmed with the amount of time from when a waveform begins to a switching point. Two separate counters exist, one for negative-to-positive zero crossing and one for positive-to-negative zero crossing.

Once the end of the ringing burst is signaled, the next counter to reach the amount programmed causes a state change. Direct Register ZERDELAY is the program time from the last zero crossing to the time the relay opens. When a ringtrip is detected, the next timer (regardless of where it started) to reach the ZERDELAY value causes the relay to open. The delay for the electromechanical relay on the Silicon Labs evaluation board is on average 1.8 ms. Therefore, following the equation in Table 2, the value for ZERDELAY is 0x181.

LFSDELAY is the amount of time to wait after a ringing burst before the Si3225 goes from open to active. Ideally, this should be sufficient to allow the relay to stop bouncing and for the current to settle.

Likewise, at the onset of a ringing burst, the Si3225 attempts to switch the relay at a time when the ringing voltage is equal to the current V_{OC} (open loop) voltage currently on TIP and RING.



*Note: While the relay is open and the external ringer is connected to the line, the SLIC reports active in the Linefeed Shadow register. The Linefeed register would still report a 0x04 to indicate the ringing.

Figure 22. External Ringing Timing Diagram

Table 2. Equations for External Ringing Parameters

Register/RAM	
ZERDELAY	$$ZERDELAY = \frac{\frac{1}{f} - t_{DELAY}}{0.000125}$$
LFSDELAY	$$LFSDELAY = \frac{t_{DELAY}}{.000125}$$
RINGFRLO	Unused
RINGPHAS	Used for hysteresis current, see below
RINGOF	Unused
RLYCON: [RDOE]	1
RINGTA	$$\frac{t_{active}}{125 \times 10^{-6}}$$
RINGTAHI	$$\frac{RINGTA \ \& \ 0xFF00}{2^8}$$
RINGTALO	RINGTA & 0xFF
RINGTI	$$\frac{t_{inactive}}{125 \times 10^{-6}}$$
RINGTIHI	$$\frac{RINGTI \ \& \ 0xFF00}{2^8}$$
RINGTILO	RINGTI & 0xFF

External Ringtrip

External ringtrip is more complicated than the internal ringtrip case. When the Si3225 detects a ringtrip, it switches a relay from connecting the ringing signal from TIP and RING to the TIP and RING of the Si3200. External ringtrip works similarly to the internal dc ringtrip case. Two existing counters constantly monitor the loop current.

In the case where the current may never cross zero following a RINGTRIP, the RTCOUNT register is a watchdog timer that, when the programmed time is reached, whether or not a zero crossing has been found, a ringtrip automatically occurs. Equation 30 sets RTCOUNT:

$$\text{RTCOUNT} = \frac{t_{WATCH}}{.000125}$$

Equation 30.

In the external case, only dc ringtrip is used. Threshold values are obtained similarly to the dc ringtrip case for internal ringing. The Si3225 dc threshold is calculated by Equation 31:

$$\text{RTDCTH} = I_{DC} \times \left(\frac{R_{SRC}}{.010356}\right) \times \left(\frac{\text{RTPER}}{128}\right)$$

Equation 31.

I_{DC} is the dc threshold current for ringtrip.

R_{SRC} is the source resistance of the ringing generator. (Silicon Laboratories recommends 510 Ω.)

The debounce registers are found the same way in the internal case. Nominally, RTDCDB is set to 0x03. AC ringtrip is turned off by setting RTACTH to 0x7FFF. ZERDELAY and LFSDELAY, and RTCOUNT will affect the ringtrip time.

The RINGPHAS register serves a different purpose in external ringing than in internal ringing. This register provides a hysteresis current offset for zero-crossing detection. This register prevents noise from causing an inadvertent zero-crossing detect. At a negative to positive zero crossing, it adds this amount to the loop current, and, for the positive to negative crossing, subtracts this amount from the loop current. Silicon Laboratories recommends a value of 0x01 for RINGPHAS. RINGPHAS should not contain a 0 as a value; the minimum value is 0x01. However, for smaller loop current, a higher value causes more accurate zero crossing detection. Like the ring trip threshold, RINGPHAS resolution depends on the source resistance. See Equation 32:

$$\text{RINGPHAS} = I_{HY} \times \left(\frac{R_{SRC}}{.010356}\right)$$

Equation 32.

Conclusion

The Si3220 and Si3225 have highly-programmable ringing structures that can be made to fit any application. The ringtrip interrupt is reported for system developers' convenience only, but a user should wait for a loop closure event for the operational state machine. Table 3 contains the necessary registers to set to initialize ringing. The LINC software has a calculator to help obtain values for these registers. Consult "AN58: Si3220/Si3225 Programmer's Guide" for detailed information about these register.

Table 3. Register/RAM differences between the Si3220 and Si3225

Register/RAM	Si3220[bits]	Si3225[bits]
Register:5	RLYCON	RLYCON
Register:6	LINEFEED	LINEFEED
Register:23	RINGCON	RINGCON
Register:24/25	RINGTALO/RINGTAHI	RINGTALO/RINGTAHI
Register:26/27	RINGTILO/RINGTIHI	RINGTILO/RINGTIHI
RAM: 4	VCM	Unused (in ringing architecture)
RAM: 6	VOVRING	Unused
RAM: 26	LCRMSK	Unused
RAM: 56	RINGOF[15:0]	Unused
RAM: 57	RINGFRHI[13:3]	LFSDELAY[15:0]
RAM: 58	RINGFRLO[14:3]	Unused
RAM: 59	RINGAMP	ZERDELAY[15:0]
RAM: 60	RINGPHAS	RINGPHAS
RAM: 61	RTCOUNT	RTCOUNT
RAM: 62	RTDCTH	RTDCTH
RAM: 63	RTPER	RTPER
RAM: 64	RTACTH	RTACTH
Note: See AN58 for register bit definitions.		

Document Change List

Revision 0.1 to Revision 0.2

- Corrected RTPER equation.
- Corrected Power equation.
- Corrected Figure 22.
- Added cadencing equations to Tables 1 and 2.

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