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DYNAMIC FILTER TUNING

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## FM Soft Mute and Dynamic Filter Tuning

Associated Part Family: CYW4330

This application note is intended for engineers and designers who are using the CYW4330 device in their design and it explains the parameters available for tuning and provides recommendations on values that can be changed under specific circumstances. It is recommended that the parameters in this document be available in a hidden menu of a phone's user interface, where on-the-fly tuning of these parameters can be easily accomplished.

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### 1 Introduction

The Cypress CYW4330, a single-chip device, provides the highest level of integration for a mobile or handheld wireless system, with integrated IEEE 802.11 a/b/g and single-stream 802.11n (MAC/baseband/radio), Bluetooth® 4.0 + HS, and FM radio receiver and transmitter.

The CYW4330 FM tuner supports advanced muting and filtering, which makes the listening experience very comfortable and improves a user's experience when the radio is receiving a weak signal. The muting and filtering (high cut) parameters are highly programmable and can be reconfigured to fit different needs and preferences.

This application note explains the parameters available for tuning and provides recommendations on values that can be changed under specific circumstances. It is recommended that the parameters in this document be available in a hidden menu of a phone's user interface, where on-the-fly tuning of these parameters can be easily accomplished.

A system with Windows® XP operating system or above can be used to install and run the graphical tools described in this application note.

This application note is intended for engineers and designers who are using the CYW4330 device in their design.

#### 1.1 Cypress Part Numbering Scheme

Cypress is converting the acquired IoT part numbers from Broadcom to the Cypress part numbering scheme. Due to this conversion, there is no change in form, fit, or function as a result of offering the device with Cypress part number marking. The table provides Cypress ordering part number that matches an existing IoT part number.

Table 1. Mapping Table for Part Number between Broadcom and Cypress

Broadcom Part Number	Cypress Part Number
BCM4330	CYW4330

## 1.2 Acronyms and Abbreviations

In most cases, acronyms and abbreviations are defined on first use.

For a comprehensive list of acronyms and other terms used in Cypress documents, go to:

<http://www.cypress.com/glossary>

## 2 IoT Resources

Cypress provides a wealth of data at <http://www.cypress.com/internet-things-iot> to help you to select the right IoT device for your design, and quickly and effectively integrate the device into your design. Cypress provides customer access to a wide range of information, including technical documentation, schematic diagrams, product bill of materials, PCB layout information, and software updates. Customers can acquire technical documentation and software from the Cypress Support Community website (<http://community.cypress.com/>).

## 3 Overview

This section describes benefits of the soft mute and dynamic filter (high cut) algorithms as well as interaction of the two algorithms, along with the description of the signal-to-noise ratio (SNR) estimator.

### 3.1 Benefits of Soft Mute

As the reception strength of an FM signal declines, the audio output becomes noisier. At some point, the noise becomes louder than the desired audio content. At times, this noise can be so loud that it becomes uncomfortable for the listener.

In such situations, to improve the listening experience, the soft mute algorithm reduces the volume of the sound output as additional noise is detected. The soft mute algorithm keeps the amount of noise that a listener is exposed to below a certain limit.

### 3.2 Benefits of Dynamic Filter

The noise introduced by a weak FM signal is not always uniform. At certain frequencies this noise can be more bothersome than at other frequencies. In such situations, a dynamic audio filter can be applied to improve the listening experience. The dynamic filter removes the noise above a certain frequency, known as the roll-off point. The roll-off point is adjusted dynamically to the changing signal conditions. As the signal weakens, the roll-off point is reduced to eliminate additional noise.

### 3.3 Interaction Between the Two Algorithms

The two algorithms, soft mute and dynamic filter, work together to control the listening experience during the periods of weak signal strength. The dynamic filter removes the harsh edge from the noise, while the soft mute reduces the volume level to make it more comfortable.

The parameters of these algorithms are independent of one another. However, the two algorithms do affect the same audio output signal. To maximize the benefits, the settings for the two algorithms can be loosely coordinated as there is an interactive effect between the two algorithms even though they operate independently of one another. For example, the low-pass filtering removes certain frequencies from the audio signal, and this in turn causes an overall volume loss. Therefore, an extra soft mute effect is noticed as the low-pass filter roll-off applies. To compensate for this effect, the soft mute parameters can be tuned to apply less muting as the low-pass filter strength increases.

Overall, the interaction between the two algorithms is minor. So, to carefully coordinate the parameters of one algorithm with the other is not essential.

### 3.4 Signal-To-Noise Ratio Estimator

The FM receiver has a built-in SNR estimator. The estimator tracks the noisiness of the audio signal at the FM receiver output. Most of the parameters for soft mute and dynamic filter are applied based on the SNR estimator readings. This reading is lower for the noisier signals. Correspondingly, the soft mute or dynamic filter effect is stronger.

The SNR estimator is rounded to the nearest integer. The soft mute and dynamic filter algorithms base their operational 'steps' on this integer value. In this document, 1 step is considered as a 1 dB change in the SNR estimation.

## 4 Soft Mute Algorithm

This section presents details on the parameters, graphing tool, and programming new values, along with tuning tips for the soft mute algorithm.

### 4.1 Soft Mute Parameters

Table 2 lists the parameters of the soft mute algorithm.

**Note:** A 'Step' refers to a change of 1 dB SNR in the SNR estimator.

Table 2. Soft Mute Parameters

Parameter	Description
StartMuteSNR	This parameter defines the threshold where the soft muting starts. When the SNR falls below this threshold level, the soft muting starts to take effect.
MutePercentStep	This parameter defines the amount of volume that is reduced (in percent) for each SNR step below the StartMuteSNR. The default is 89%, which is about a 1 dB loss in volume for every 1 dB loss in SNR.
StartMuteAccelerateSNR	This parameter defines the threshold for an SNR value, and below that value the muting accelerates. This is useful near extremely low SNR values (0–5), where the signal is almost all noise. At that point, the signal has to be muted much faster than normal.
MuteAccelerateSteps	This parameter defines the volume reduction in accelerated steps. Once the signal drops below the StartMuteAccelerateSNR threshold, each additional loss of 1 dB SNR results in extra steps of volume reduction as specified by the MuteAccelerateSteps. Therefore, if MuteAccelerateSteps is 1, then the volume drop is 2 dB for every 1 dB of SNR loss (assuming MutePercentStep is 89%).
MaximumMuteSteps	This parameter defines the maximum number of steps that are allowed to be muted. If calculations fall below this value, the volume is held at this point even if the SNR degrades further. The recommended value is 14 (decimal). This corresponds to a maximum of 14 dB volume reduction.
SnrPoolThreshold	This parameter controls how quickly soft mute is released. A large SNR pool threshold value causes a slower but less fluctuating response time. A very low SNR pool value (0 is acceptable) causes a very quick response time that can be prone to volume fluctuations. The default value for the SnrPoolThreshold parameter is 0xF.

Table 3 provides the preloaded default values of the soft mute parameters.

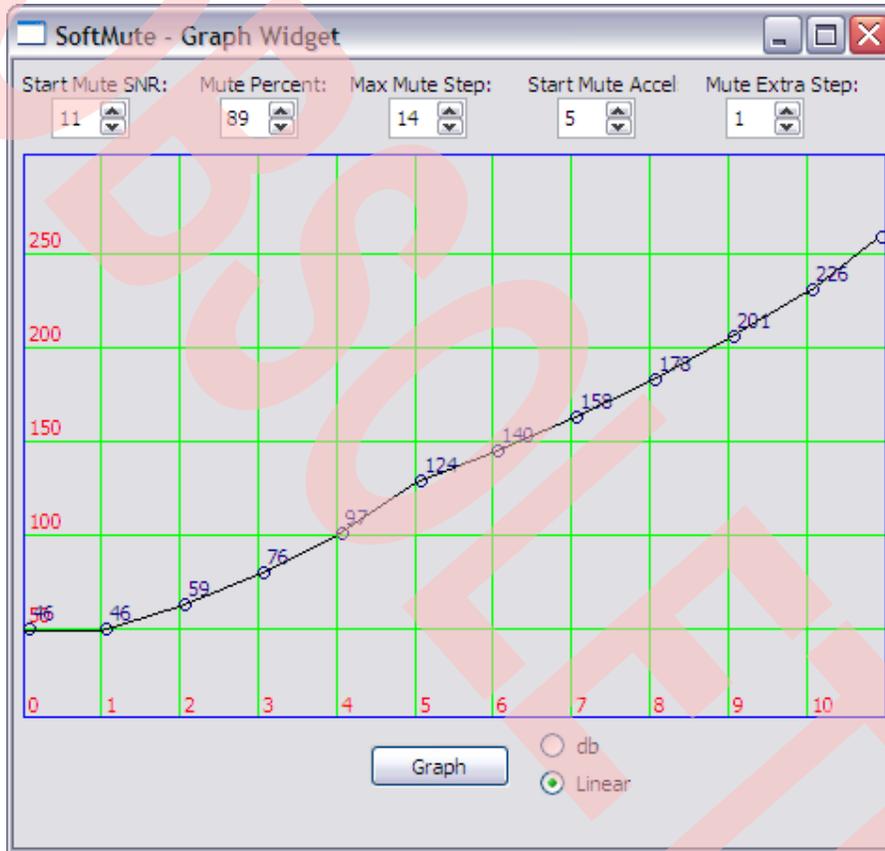
Table 3. Soft Mute Default Values

Parameter	Default Value
Start Mute SNR	11
Mute Percent	89
Max Mute Step	14
Start Mute Accel	5
Mute Extra Step	1

## 4.2 Soft Mute Graphing Tool

Cypress provides a soft mute graphing tool, which shows the different parameters that can affect a muting curve. Follow these steps to launch the soft mute graphing tool:

1. Open the 'SoftMute' folder included in this package.
2. Double-click the **SoftMute.exe** program inside this folder.  
The recommended default parameters (refer to [Table 3](#)) for reference boards are preloaded into this tool.
3. Enter the values that need to be adjusted into the following five options: Start Mute SNR, Mute Percent, Max Mute Step, Start Mute Accel, and Mute Extra Step.
4. Click the **Graph** button to see the mute curve that is created based on the parameters.



### Explanation of the Graph:

The horizontal axis (X-axis) represents the current SNR estimation of the FM receiver. The vertical axis (Y-axis) represents the linearly applied volume level (0–255) based on the SNR determined on the X-axis.

The default host-selectable FM volume level is assumed to be 255. If the FM volume is set lower than 255, then the muting curve is automatically adjusted to maintain the effective muting function. If the FM volume is set to an extremely low value (for example, under 25), then the soft muting curve does not perform optimally because there are not enough remaining volume steps to provide a smooth muting experience.

### 4.3 Programming New Values

After using the soft mute graphing tool to create the required muting curve, apply either of the following methods to implement the curve:

- The host can program the new values in real time using the FM\_RDS command for setting the soft mute parameter. This change takes an immediate effect. Refer to [Reference \[2\] on page 6](#).
- A Cypress engineer can apply the new muting values in the configuration file. The new parameters are automatically applied when the configuration file is loaded.

**Note:**

The `SnrPoolThreshold` parameter relies on the SNR changes to determine how quickly the volume tracks the muting curve. Since this parameter does not affect the muting curve directly, it is not included in the soft mute graphing tool.

### 4.4 Tuning Tips

This section explains the typical tuning strategy that can help solve the common tuning problems.

#### 4.4.1 General Concept

The amount of noise that is present in the audio signal is directly related to the SNR reading. As a general concept, the soft mute should be tuned to keep the noise below a certain level. To accomplish this task, soft mute should be typically configured to drop the volume by 1 dB for every 1 dB of additional noise that is detected. This is why the default mute percent value is 89 (~1 dB) per 1 dB SNR step. Muting in this manner provides the most transparent manipulation of the audio signal. The noise holds at a certain level, while the audio signal slowly 'fades' away.

The default parameters have already been tuned for the typical signal conditions. Therefore, in most cases, tuning the soft mute or the low-pass filter parameters may not be necessary. If the signal conditions are abnormal, then adjustment of the soft mute and dynamic filter can provide some benefits.

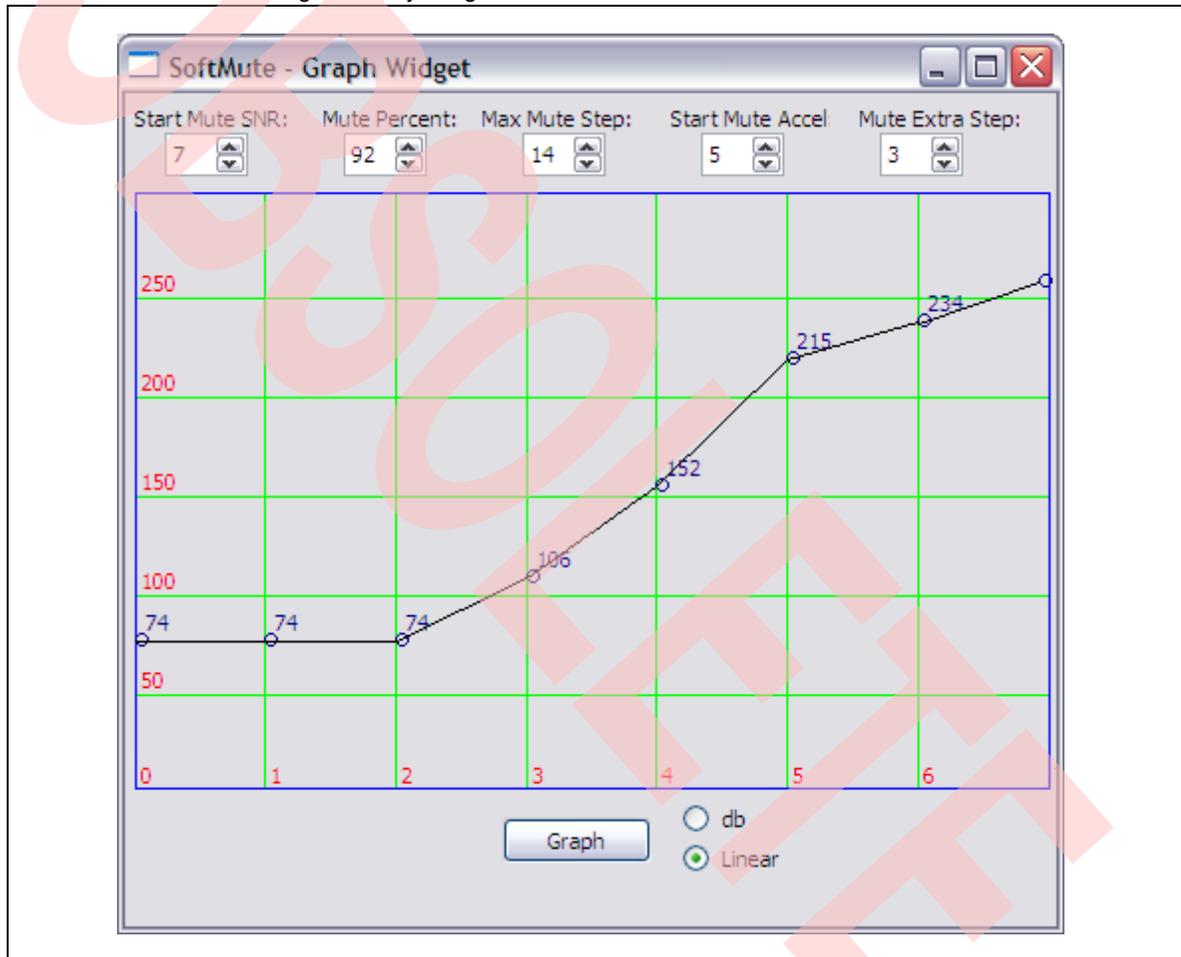
#### 4.4.2 Handling Lower Than Normal SNR

For a good FM radio listening experience, the SNR value should be above 11. This value is also the default threshold (refer to [Table 3 on page 4](#)) to enable the soft mute function.

In some cases, the signal conditions cause the SNR to be consistently lower than 11. In these cases, the soft mute algorithm can be active all the time. It is undesirable to have the volume levels adjust constantly, thus causing a fluctuating volume level. Lowering the 'Start Mute SNR' and increasing the 'Mute Extra Step' can help here. This causes the soft mute to activate at a lower threshold, but still provide a strong muting function near the noisier end of the signal strength. This allows the signal to be a bit more noisy before muting activates, thus trading off volume stability for noise.

An example of this configuration is shown in [Figure 1](#).

Figure 1. Adjusting Lower Than Normal SNR

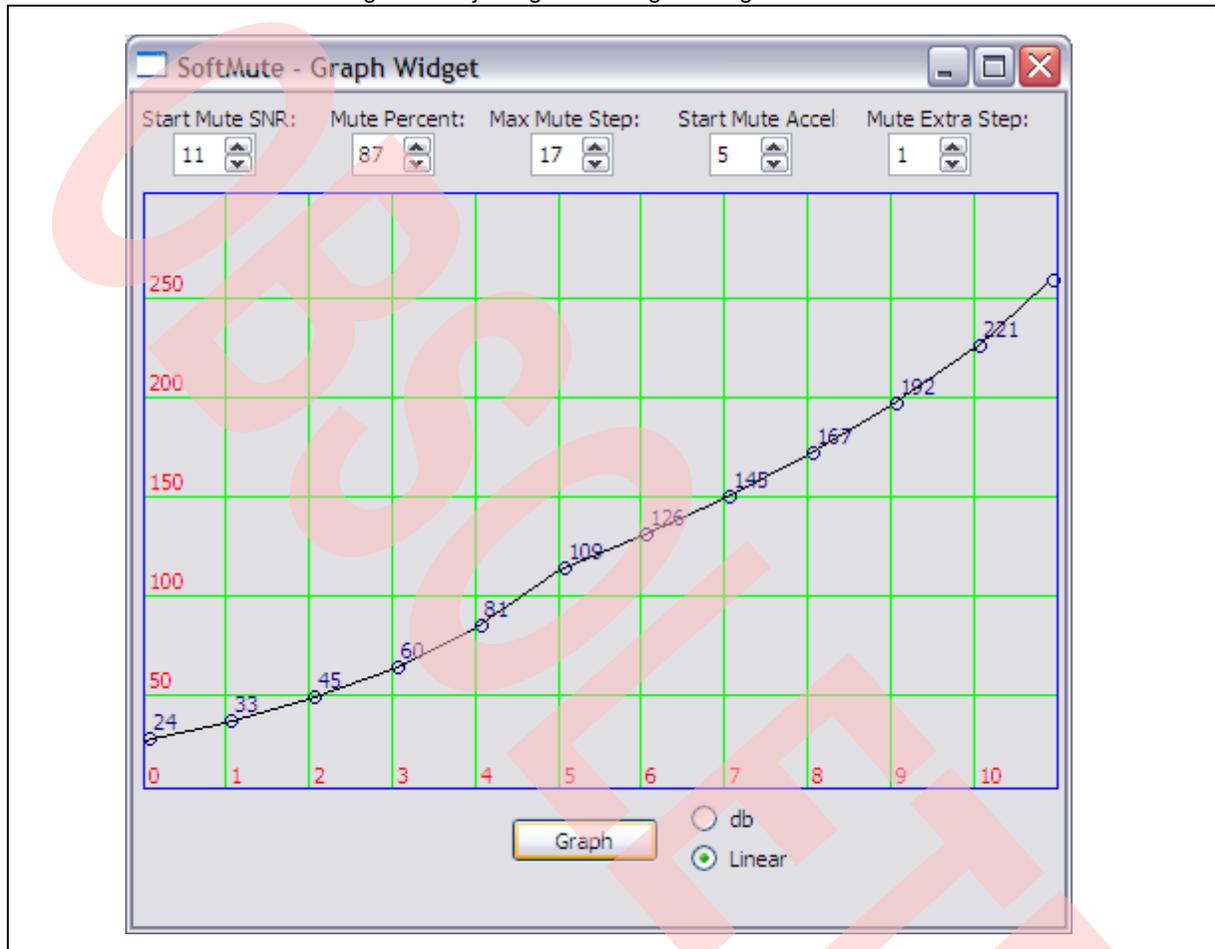


### 4.4.3 Not Enough Muting

Depending on the overall volume level of the system, there might not be enough muting applied at the maximum mute point. In this case, increasing the 'Max Mute Step' or decreasing the 'Mute Percent' value helps to add additional muting.

An example of this configuration is shown in [Figure 2](#).

Figure 2. Adjusting Not Enough Muting

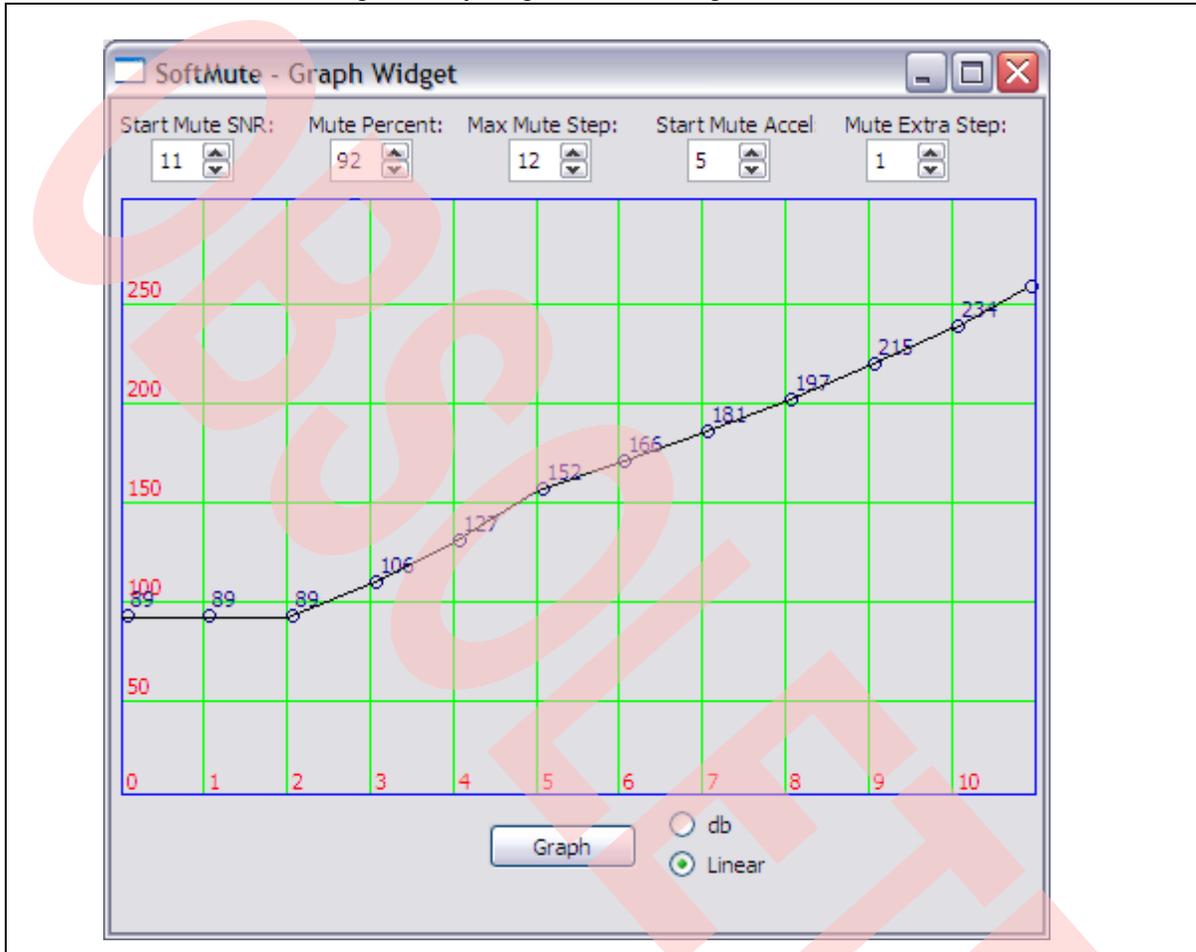


#### 4.4.4 Too Much Muting

Depending on the overall volume of the system, there might be too much muting applied either throughout the volume curve or at the maximum mute point. In this case, decreasing the 'Max Mute Step' or increasing the 'Mute Percent' value helps to reduce the muting effect.

An example of this configuration is shown in [Figure 3](#).

Figure 3. Adjusting Too Much Muting



#### 4.4.5 Volume Changing Too Quickly

Based on preferences, the speed at which the soft mute algorithm adapts can be adjusted. If the muting adjusts to signal conditions too quickly (that is, it is constantly 'chasing' a moving SNR value), then increase the value of the `SnrPoolThreshold` parameter (refer to the [Programming New Values on page 6](#)). This increase prevents momentary changes in the SNR value from affecting the volume; however, it induces a lag time to the change in signal strength.

**Note:** The graphical tools do not aid in the programming steps, they only aid in visualizing the parameters. All the programming of the values must be done using one of the two methods explained in the [Programming New Values on page 6](#).

If there is a big lag time from when the signal condition changes to when the soft mute adjusts the volume, then reduce the value of the `SnrPoolThreshold` parameter. This reduction causes the volume to track signal conditions much quickly. However, this can potentially cause the algorithm to 'chase' minor fluctuations in signal strength.

**Note:** The `SnrPoolThreshold` parameter relies on the SNR changes to determine how quickly the volume tracks the muting curve. Since this parameter does not affect the muting curve directly, it is not included in the soft mute graphing tool.

## 5 Dynamic Filter Algorithm

This section presents details on the parameters, dynamic low-pass filter tool, and programming new values, along with tuning tips for the dynamic filter algorithm.

### 5.1 Dynamic Low-Pass Filter Parameters

Table 4 lists the parameters of the dynamic low-pass filter algorithm.

Table 4. Dynamic Low-Pass Filter Parameters

Parameter	Description
LowPassFilter10kHzSNR	This parameter defines the SNR value below which the low-pass filter roll-off point is set to 10 kHz. It is recommended to place this value at the onset of hissing and crackling noise.
LowpassFilter40kHzSNR	This parameter defines the SNR value above which the low-pass filter returns to the 40 kHz roll-off point (that is, filtering is turned off).
StartLowpassFilterSNR	This parameter defines the SNR value below which a ramp of the low-pass filter cutoff point begins.
LowpassFilterStartFrequency	This parameter defines the frequency where the low-pass filter ramp starts once the StartLowpassFilterSNR is crossed.
LowpassFilterFrequencyStepSpeed	This parameter defines how quickly the low-pass filter drops based on the SNR value. If it is negative (for example, -2), then the roll-off drops 1 kHz for every two steps the SNR drops. If the value is positive (for example, +2), then the roll-off drops 2 kHz for every 1 step that the SNR drops. The recommended value is -2.

Table 5 provides the preloaded default values of the low-pass filter parameters.

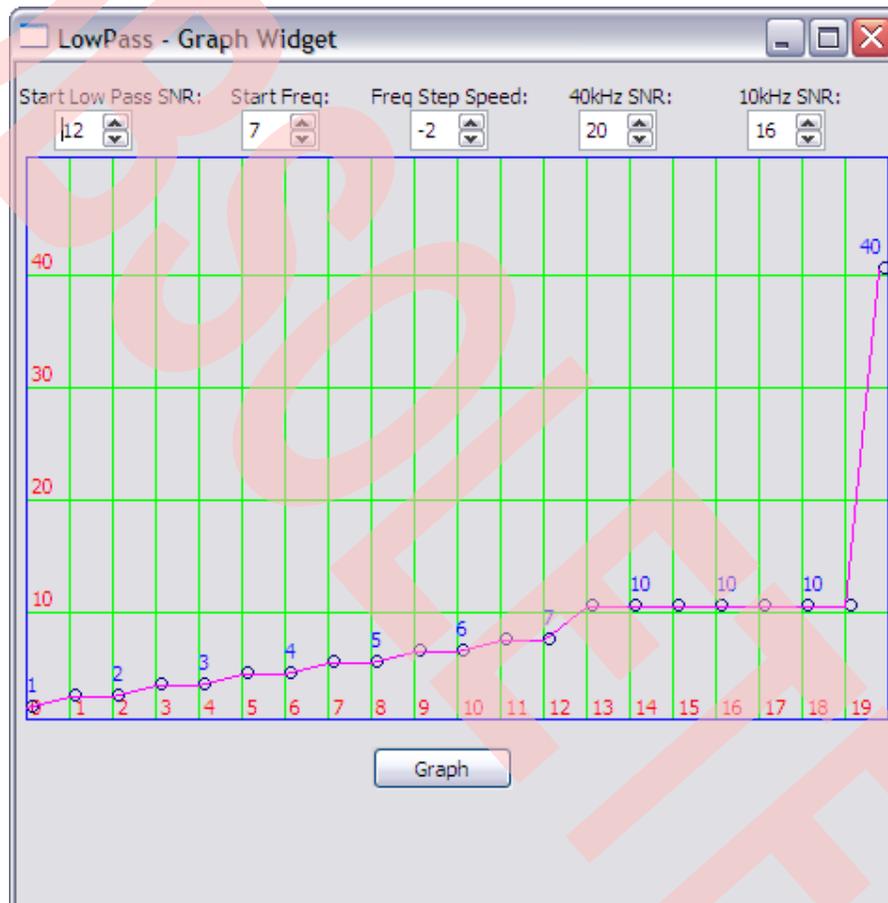
Table 5. Low-Pass Filter Default Values

Parameter	Default Value
Start Low Pass SNR	12
Start Freq	7
Freq Step Speed	-2
40kHz SNR	20
10kHz SNR	16

## 5.2 Dynamic Low-Pass Filter Tool

Cypress provides a tool to visualize how the parameters for the dynamic filtering work. The parameters are all referenced to the same SNR steps from the SNR estimator. Follow these steps to launch the dynamic low-pass filter tool:

1. Open the 'Low Pass' folder included in this package.
2. Double-click the **lowpass.exe** program inside this folder.  
The recommended default parameters (refer to [Table 5](#)) for reference boards are preloaded into this tool.
3. Enter the needed values into the following five options: Start Low Pass SNR, Start Freq, Freq Step Speed, 40 kHz SNR, and 10 kHz SNR.
4. Click the **Graph** button to see the mute curve that is created based on the parameters.



### Explanation of the Graph:

The horizontal axis (X-axis) represents the SNR step value from the SNR estimator. The vertical axis (Y-axis) represents the roll-off point of the low-pass filter for the given SNR value. The chart shows which roll-off value is selected for each SNR step from the SNR estimator.

There is a hysteresis zone between the 40 kHz SNR and 10 kHz SNR. This zone is not marked on the graph but is present in the algorithm. When the SNR drops below the 10 kHz SNR, the roll-off is set to 10 kHz. When the SNR goes above the 40 kHz SNR, the roll-off is set to 40 kHz. In-between these two values, the prior selected value remains until the other threshold is crossed.

### 5.3 Programming New Values

The same two methods are used to program the new dynamic filter values as the soft mute. Refer to the [Programming New Values on page 6](#).

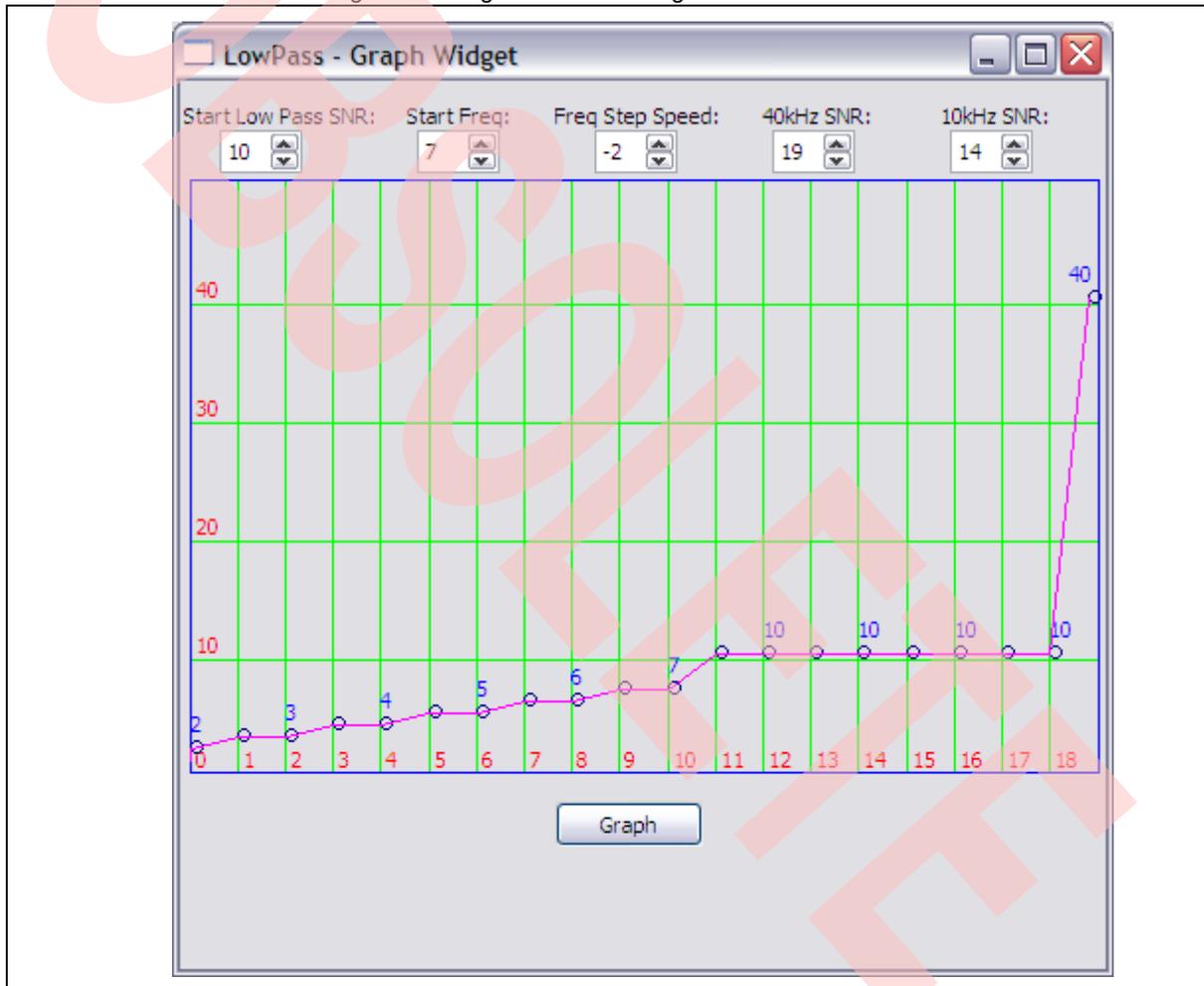
### 5.4 Tuning Tips

#### 5.4.1 Muffled Sounding Audio

If the dynamic audio filter is applied too early, then the audio can sound muffled even when there is little to no noise present in the audio signal. In this case, reducing the 'Start Low Pass SNR' value activates the algorithm later. Additionally, reducing the '10 kHz SNR' value can also help in delaying the activation of the low-pass filter.

An example of this configuration is shown in [Figure 4](#).

Figure 4. Fixing Muffled Sounding Audio

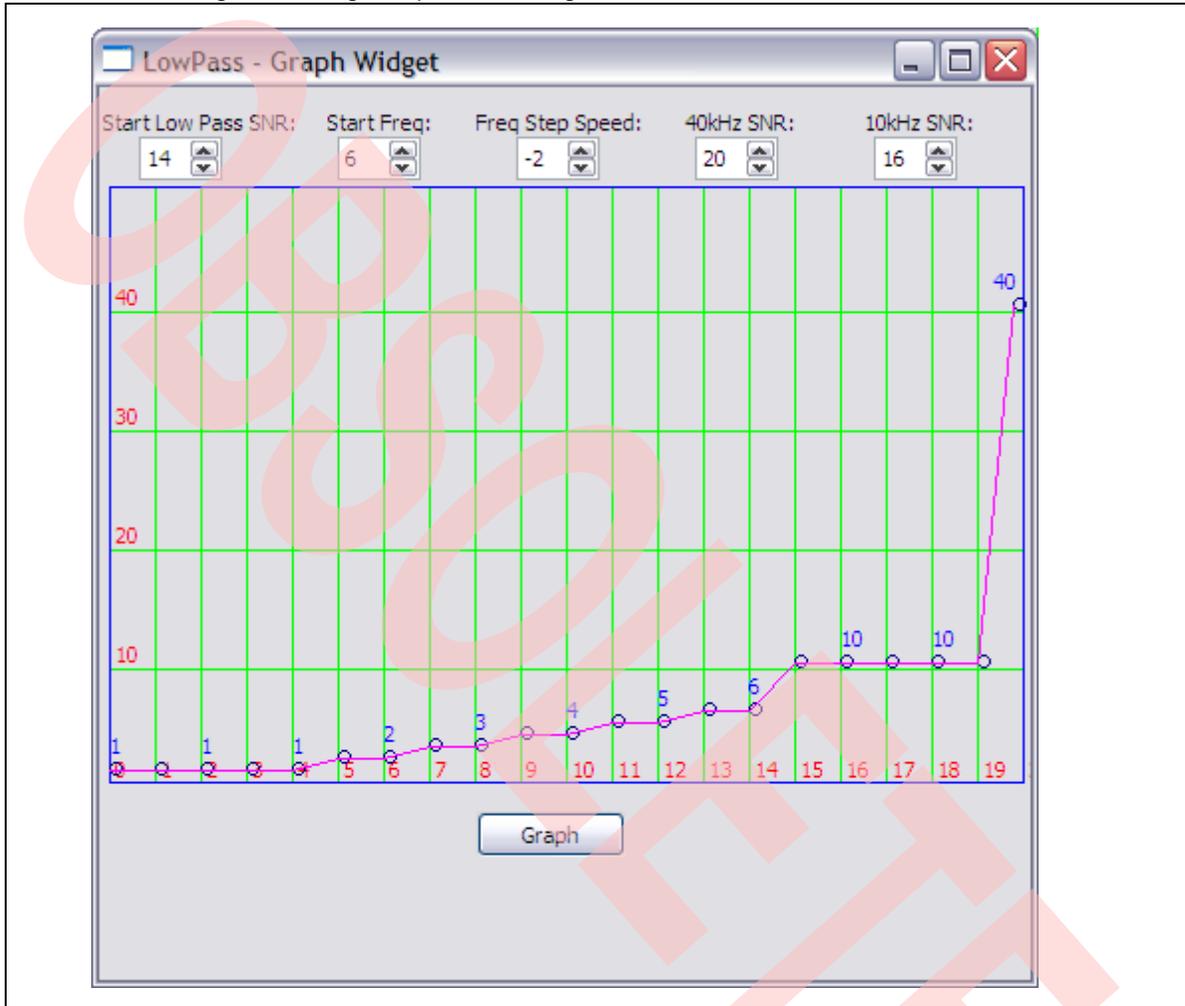


### 5.4.2 Noise/Static Sounds Too Sharp or Distracting

The dynamic audio filter is designed to reduce the sharp distracting noise in the audio signal. Therefore, select a roll-off point that increases in strength as the noise level becomes more distracting. If the static/noise is too sharp in timbre, then raise the 'Start Low Pass SNR' value or reduce the 'Start Freq' value.

An example of this configuration is shown in [Figure 5](#).

Figure 5. Fixing Sharp or Distracting Noise and Static Sounds



#### Explanation of the Graph:

This graph forces the low-pass filter to activate much sooner, and it also reaches its lowest possible value (1 kHz) much sooner. Therefore, it eliminates a lot of high-frequency noise very quickly, but the original audio can sound muffled when the filter activates.

## 5.5 References

The references in this section may be used in conjunction with this document.

**Note:** Cypress provides customer access to technical documentation and software through its Customer Support Portal (CSP) and Downloads & Support site (see [IoT Resources](#)).

For Cypress documents, replace the “xx” in the document number with the largest number available in the repository to ensure that you have the most current version of the document.

Document (or Item) Name	Number	Cypress Number	Source
[1] Single-Chip IEEE 802.11™ a/b/g/n MAC/Baseband/Radio with Integrated Bluetooth® 4.0 + HS and FM Transceiver, CYW4330 Data Sheet	4330-DS2xx-R	002-14938	<a href="http://community.cypress.com">community.cypress.com</a>
[2] CYW4329 FM/RDS Command and Event Specification, Technical Information Manual	4329-TI10x-R	-	<a href="http://community.cypress.com">community.cypress.com</a>
[3] FM Command and Control Specification, Technical Information Manual	2049-TI10x-R	-	<a href="http://community.cypress.com">community.cypress.com</a>

## Document History

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Rev.	ECN No.	Orig. of Change	Submission Date	Description of Change
**	-	-	11/07/2011	4330-AN800-R Initial release
*A	5466340	UTSV	10/07/2016	Updated to Cypress template
*B	5879843	AESATMP8	09/11/2017	Updated logo and Copyright.
*C	6352268	SELE	10/16/2018	Obsoleted

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