MX•COM, INC.
COMMUNICATION ICs

APPLICATION NOTE

CMX808A

FRS Group Calling and Tone Cloning™

1. Introduction

The CMX808A Family Radio Service CTCSS Processor IC contains unique and innovative functions to support significant new end product features for the FRS two-way radio market. This document describes the end product features and the CMX808A functions that support them.

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2.1 User scenarios

2.1.1 Selective Calling Background

Family Radio Service (FRS) and similar consumer oriented walkie-talkies (radios) share RF channels among multiple groups of users. This is done to greatly increase the number of users supported by the few allocated radio channels (14 total RF channels for FRS in the U.S.). A tradeoff of this 'spectrum sharing' approach is that unrelated user groups that happen to tune their radios to the same RF channel will hear both the desired communications of their own group as well as the undesired communications of other groups.

To spare radio users from hearing received transmissions that are not intended for them, transmissions can be 'marked' with a special, hidden, call signal that a radio receiver uses to decide whether to open the squelch (turn on) the receiving loudspeaker. In this scheme a radio receiver only opens its squelch when the received 'marker' signal is correct so its user does not hear the transmissions of unrelated user groups that use the same RF frequency but different hidden transmission markers. This technique is called 'selective calling'.

In the large U.S. FRS market, the far most popular selective calling technique uses a subaudio (lower frequency than voice) continuous tone signal, simultaneous with voice, that is called CTCSS (Continuous Tone Controlled Selective Squelch or Continuous Tone Controlled Squelch System). CTCSS it is very well established in industrial and commercial two-way radio markets.

2.1.2 TIA/EIA-603 Standard

TIA/EIA-603, *Land Mobile FM or PM Communications Equipment Measurement and Performance Standards*, (including its addendum, TIA/EIA-603-1) is a strongly supported telecommunications industry standard that defines commonly used CTCSS tone frequencies ranging from 67.0Hz up to 250.3Hz. In part, the standard specifies this particular tone set to help maintain the best distinction between adjacent tone frequencies and so reduce the probability of false tone detection.

TIA/EIA-603 also specifies required CTCSS performance levels and some non-CTCSS functions such as preemphasis and deemphasis response curves.

Although TIA/EIA-603 was created for industrial/commercial two-way radios (e.g. taxi dispatchers, mobile repair service teams, etc.), CTCSS-based FRS radio designs can also use and benefit from TIA/EIA-603 techniques. Perhaps, for this reason, most FRS radios use CTCSS signaling and support nearly the same subaudio tone set (38 supported out of the 39) specified in TIA/EIA-603. (Low performance FRS radios do not support CTCSS selective calling and other attractive features such as maximum permitted RF power output and support for all 14 permitted RF channels.) Some FRS models support CTCSS tones that are not defined in TIA/EIA-603 but that fall within the TIA/EIA-603 defined CTCSS tone range.

2.1.3 Differences Between FRS and Industrial/Commercial Two-Way Radio Applications

FRS and industrial/commercial two-way radios are based on similar technology but they are different in some important ways.

2.1.3.1 Licensed vs. Unlicensed Operation

In the U.S., CTCSS-based industrial/commercial two-way radios are regulated by the FCC (Federal Communications Commission) that requires a license to be obtained for radio operation. These industrial/commercial licenses restrict each user's geographic region of use and choice of RF frequency so that different groups of users do not interfere with each other or hear each other's communications. In these applications, CTCSS tone selections are relatively fixed so users may not conveniently or quickly change them. In some non-U.S. countries, CTCSS tones are assigned by the licensing body and so may never be changed by users.

FRS radios may be purchased and operated by consumers nearly any place in the U.S. without a need to obtain a license. In addition, FRS users are free to select any CTCSS tone frequency and any of 14 standard RF frequencies at any time. This unlicensed arrangement increases the probability that multiple groups of FRS users will select the same RF channel and, therefore, benefit from the use of CTCSS selective calling.

2.1.3.2 Ease of Use

Industrial/Commercial users often use a variety of special tools in their work. Their two-way radios are considered a special tool for which they receive special operating instructions.

Average consumers use FRS radios without the benefit of specialized instructions. This can lead to user confusion and dissatisfaction because:

- As described in section 2.1.3.1, FRS users are faced with more radio configuration choices than are industrial/commercial radio users e.g. which of the 38 or more selective calling codes should be configured?
- FRS radios fail to properly transmit or receive when their selective calling code (tone) is incorrectly configured.
- Some FRS radios and their instruction manuals display and describe calling codes in unfamiliar technical terminology such as actual CTCSS tone frequencies e.g. “118.8Hz” or “71.9Hz”.
- The same CTCSS selective calling codes (tones) are described differently in different FRS radio models and brands e.g. “67.0Hz” or code “A” or code “F” so it is virtually impossible for a user to configure these different radio models to work together, even when they are compatible.

2.1.4 FRS User Scenarios

Differences in FRS and industrial/commercial radio applications lead to unique FRS user needs.

2.1.4.1 Group Calling

FRS radios are likely to be used by groups that contain some smaller subgroups. For example, a family of two parents and two children would likely use FRS radios when visiting a park and so they would wish to have their four FRS radios configured for the same CTCSS selective calling group. In addition, it would be convenient for the parents to arrange to be a second group (a subgroup of the family) by configuring their radios to support two simultaneous groups: (1) the ‘family’ CTCSS selective calling group and (2) the ‘parent’ CTCSS selective calling group. Similarly, it may be useful for the two children to add a ‘children’ CTCSS selective calling group (a second subgroup) to their radios. This will allow parent-to-parent, child-to-child, parent-to-family, and child-to-family communications to be conveniently made.

2.1.4.2 Tone Cloning™

As described in sections, 2.1.1, 2.1.3.2 and 2.1.4.1, CTCSS selective calling is very helpful but confusion can occur in the configuration process. Incorrect configuration dissatisfies users because it makes their FRS radios stop operating as expected. Selective calling configuration can be automated to make it very simple and easy for users to successfully operate FRS radios and enjoy the benefits of selective calling.

Automatic selective calling configuration is done using an innovative technique called ‘tone cloning™’. An FRS radio that supports ‘tone cloning™’ can copy (clone) the CTCSS selective calling configuration used by another radio. This greatly simplifies and reduces the configuration process for a group of radios into two steps:

1. Configure a ‘first’ radio with a desired CTCSS selective calling code (tone).
2. Use the ‘tone clone™’ feature of the other radios so they clone (copy) the hidden code in the ‘first’ radio’s transmissions.

The tone cloning™ feature makes selective calling easy to use by eliminating the problems of mismatched radio configurations.

An FRS radio with ‘tone cloning™’ can also clone other CTCSS-based FRS radios that otherwise would not be compatible due to differences in the display and naming of their selective calling codes e.g. that present “67.0Hz” or code “A” or code “F” for the same CTCSS tone frequency. In this way, FRS radios with the tone cloning™ feature can be nearly universally compatible with other CTCSS-based radio models and so save the cost of having to purchase the same FRS radio model for each member of a group. (Two families can join together and combine their FRS radios into one large group whereas, without tone cloning™, their radios might not be successfully configured to work together.)

3. CMX808A CTCSS Engine – Required Functions

The benefits of group calling and tone cloning™ innovations require novel CTCSS signal processing features that are provided by the CMX808A Family Radio Service CTCSS Processor IC.

3.1 Group CTCSS encoding

To support group calling an FRS radio must be able to quickly transmit any one of multiple CTCSS tones (one for each group supported). The CMX808A can quickly generate (encode) virtually any CTCSS tone frequency within the range of 62.5Hz to 251Hz under the control of externally provided commands.

3.2 Group CTCSS decoding

Support for group calling also requires an FRS radio to quickly recognize or 'decode' one of several received CTCSS tones because it must open squelch (turn on the loudspeaker) upon receiving transmissions from any and all configured group's members. Decoder speed is very important because no received speech is heard at the receiving radio until the decoder responds. As a result, slow decoder response can dissatisfy users by causing the initial portion of received speech to be blanked and never heard.

Rapid one-of-many tone decoding is an especially challenging requirement in tone decoding technology. The CMX808A uses an innovative tone decoder technology to decode any one of 7 tones (to support up to 7 user groups) in less time than other decoder approaches take to decode a single, predicted tone. This makes the CMX808A uniquely suited to deliver and support a practical (fast) group calling FRS radio feature.

3.3 Tone Cloning™

To support maximum tone cloning™ an FRS radio must be able to quickly identify ANY valid received CTCSS tone, without prior knowledge of what that tone will be. The CMX808A's innovative tone decoder technology is so quick that it can clone any received valid tone in approximately ½ a second. (This includes: identify arbitrary received CTCSS tone; configure both tone encoder and decoder to match the identified tone; and restore the pre-cloning configuration for the 6 remaining decoder tones.)

Other common tone decoder techniques could require 10 seconds or more to perform the same function and would be unsatisfactory to radio users.

The Cloning Procedure Sequence in Table 1, illustrates the tone cloning™ procedure.

	User Action		
	@ 'Master' Radio	**@ 'Clone' Radio**	**Internal Procedure at 'Clone' Radio**
1.	Select call group of interest[1]	Select call group of interest[1]	Identifies group to be cloned for later association with group selections[1]
2.	Depress and hold PTT		
3.		While 'clone' radio is within strong signal range of the 'master' radio, depress, then release, clone button	Initiate tone cloning™ process.
4.	continue	Wait for clone finish indicator[2]	Blank audio path to avoid acoustic feedback if 'master' and 'clone' radio happen to be very near each other. Identify and store master tone by quickly performing non-predictive CTCSS decode scan and determining which CTCSS tone is being received.
5.	continue	wait	Set CTCSS decoder to cloned master tone (for this particular group, if multiple groups are supported).
6.	continue	wait	Set CTCSS encoder to master tone (for this particular group, if multiple groups are supported).
7.	continue	wait	Indicate that cloning is complete e.g. by flashing burst on LED, an LCD "cloned" message, issuing a 'successful clone' audio tone signal, etc.
8	Release PTT	[done]	Resume normal radio operation.

Table 1: Cloning Procedure Sequence

[1] If multiple call groups are supported.

[2] Although CMX808A tone cloning is very quick, some 'operator entertainment', such as a specific 'cloning' LCD message or a special LED flashing pattern, could be displayed during the cloning process. The clone finish indicator may be visual, audible or both. Use of an audible indicator allows cloning to be done without the need for a display.

4. Proper Design for CTCSS Applications

Some FRS designers may not be familiar with best industrial/commercial radio CTCSS design practices. This section describes related issues and makes recommendations to achieve the best CTCSS performance and audio quality.

4.1 CTCSS performance

As described in section 2.1.1, CTCSS places a hidden continuous tone signal in a reserved band, the 'subaudio band,' that is transmitted simultaneously with voice signals that occupy a higher frequency 'audio band'. The hidden tone signal is used in a receiver as a squelch control signal that responds (turns on the loudspeaker – opens squelch) only when the proper, CTCSS tone is received.

Creation of a composite CTCSS tone + voice signal is illustrated in Figure 1.

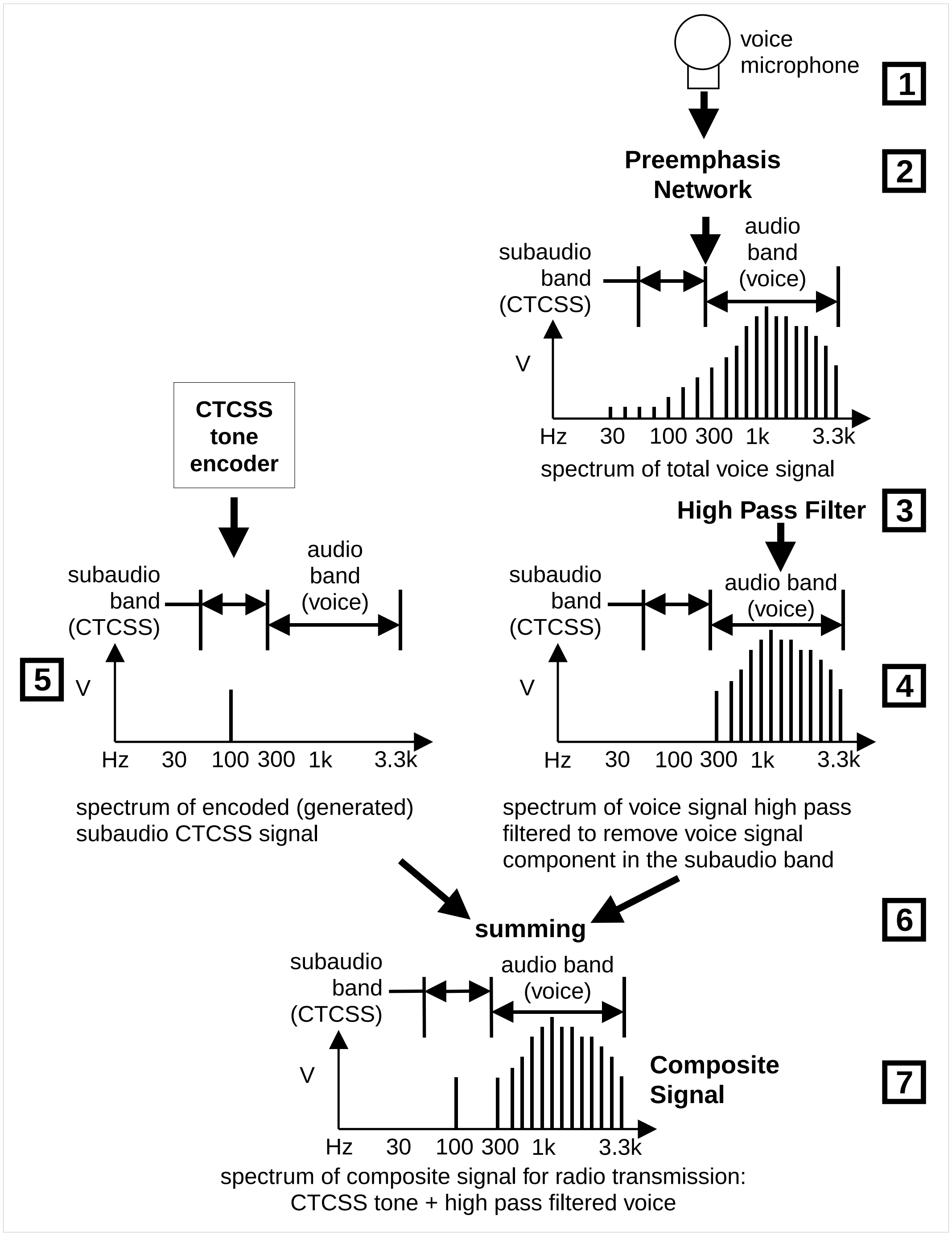

Figure 1: Tx CTCSS & Voice Processing

The numbered items in the following table describe the required functions for high performance CTCSS signaling.

Item #	Description	Function
1.	Microphone	Develop voice signal
2.	Preemphasis network	Boost high frequency voice content and remove low frequency voice content (see Section 4.2).
3.	High pass filter	Remove voice low frequency content that acts as noise in CTCSS subaudio band.
4.	High pass filtered voice	Voice signal in audio band.
5.	CTCSS encoder output	Develop CTCSS subaudio tone signal
6.	Sum CTCSS subaudio tone signal with audio voice signal	Develop composite signal.
7.	Composite CTCSS tone + voice signal	Voice signal with 'hidden' tone signal for selective calling control.

Table 2, Tx CTCSS & Voice Processing Sequence

It is especially important to apply a high pass filter (HPF) to the voice signal prior to summing it with the CTCSS tone because low frequency (subaudio) voice content otherwise presents a noise signal in the CTCSS subaudio signaling channel. The CMX808A includes a configurable HPF that should be configured to process Tx voice signals whenever the CMX808A is used in Tx mode.

4.2 Audio quality

Preemphasis and matching deemphasis is a well established voice signal processing technique for analog FM radios to significantly improve received voice quality. Preemphasis, applied in a transmitter, and deemphasis, applied in a receiver, are inverse functions so their combination causes no net change in the transmitted voice signal.

Preemphasis is a HPF response function that boosts the high frequency content in the voice signal so that its received signal-to-noise ratio becomes more favorable when demodulated (received) RF noise is considered. Such demodulated RF noise is greater in the higher frequency portion of the audio spectrum and so reduces the received sound quality of higher frequency voice content unless preemphasis and deemphasis are employed.

TIA/EIA-603 specifies a frequency spectrum template for preemphasis response. A recommended preemphasis circuit, similar to the response described in TIA/EIA-603, is shown in Figure 2. Note that either opamp feedback resistor may be trimmed to adjust overall gain of the network, as desired.

Also note that this circuit assumes that the microphone's frequency response is flat in the subaudio frequency range. Some microphones have an inherent high pass response characteristic that should be taken into account when selecting a specific preemphasis circuit. In such a case, the microphone high pass response may provide one of the two poles needed in the total response of the preemphasis circuit and so allow the two pole circuit shown to be reduced into a single pole (one stage) circuit.

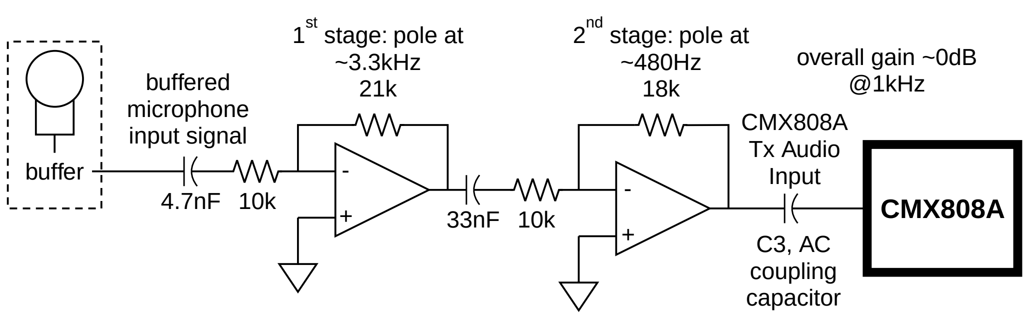

Figure 2: Recommended Preemphasis Circuit

It is important to include this preemphasis circuit or its near equivalent both to (1) optimize received speech sound quality and (2) improve the signal-to-noise ratio in the CTCSS tone subaudio band. Refer also to Figure 1, for an illustration of the placement of preemphasis in the Tx signal path.

Deemphasis is used in a receiver to perform the inverse function of preemphasis and so recover improved audio (voice) quality when compared to a system without preemphasis and deemphasis. The deemphasis function may be modified, as desired. An example single pole deemphasis circuit is shown Figure 3. Note that the input series resistor may be trimmed to adjust the overall gain of the network, as desired.

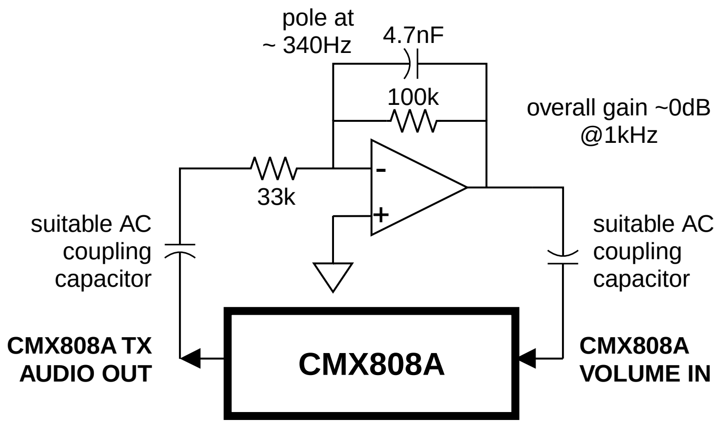

Figure 3: Single Pole Deemphasis Network

5. CMX808A Tone Clone™ Operating Sequence

Tone cloning™ makes use of two powerful and unique abilities of the CMX808A CTCSS tone decoder:

1. The decoder recognizes when *any valid tone has been received*, even if it is not one of the (up to) 7 tones it was configured to decode.
2. After detecting an 'unknown' tone that does not match any of those (up to) 7 already configured in the decoder, the decoder can be immediately reconfigured to test for 7 new tone frequencies and nearly instantly (100 microseconds later) be queried to see if any of them match the unknown tone *without having to wait for additional tone decoder responses*.

The tone clone™ sequence involves presenting the decoder's 'matching engine' with successive configurations of 7 candidate tones that may be thought of as 'blocks' of 7 'adjacent' candidate tones. With this concept in mind the heart of the tone clone™ operating sequence, after initialization, proceeds in the following steps:

1. Configure the CMX808A tone decoder with the first block of 7 candidate tones.
2. Query the CMX808A decoder to see if the received tone matches any of the configured candidate tones.
3. If 'yes' then the candidate tone is directly identified by the CMX808A response.
4. Immediately reconfigure the CMX808A tone decoder with the next block of 7 candidate tones. (If all blocks of candidate tones have been attempted without achieving a match then the initially received tone was not continuously provided and so the tone cloning sequence has failed and should be stopped.)
5. Wait >=100 microseconds for the CMX808A to internally compare the unknown tone with each of the 7 new candidate tones.
6. Jump back to Step 2, above.

Variations on this algorithm may be developed to suit specific needs. For example, if only TIA/EIA-603 specified tones are to be cloned then, at most, only 39 specific tones (5 blocks of 7 tones and a last block of 4 tones) need to be successively configured and checked for a match. This same approach may be used for larger, tone sets.

If completely arbitrary valid tones must be cloned then the candidate tone blocks may be chosen to overlap in bandwidth (according to the current bandwidth configuration) and, upon achieving a tone match, a final block of closely spaced candidate tones might be configured to 'fine tune' the tone match identification.

5.1 Tone Cloning™ Procedure

CMX808A tone cloning™ is performed according to Figure 4 and Figure 5. For satisfactory results, it is important to accurately follow the CMX808A tone cloning™ procedure sequence e.g. CMX808A bandwidth configuration must not be modified during tone cloning™ except where indicated.

For completeness, some error handling is described for cases where user error or severe interference prevent proper reception of a reference signal to clone e.g. if cloning is started without providing a good signal at the proper time.

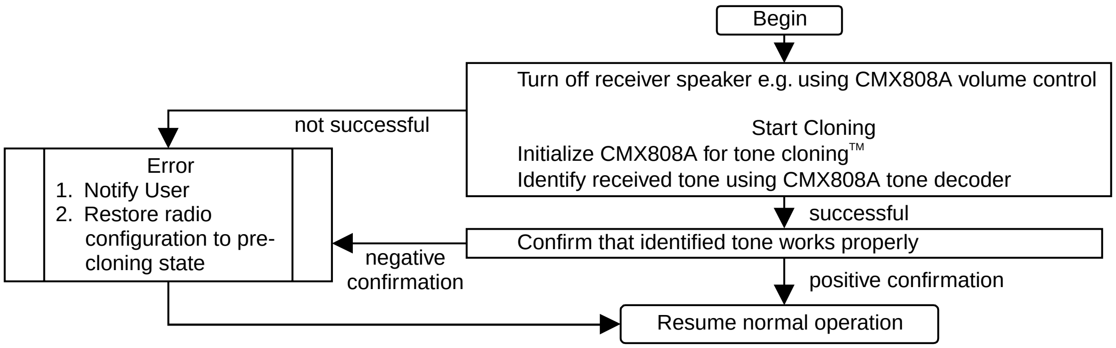

Figure 4: Tone Cloning™ Procedure Overview

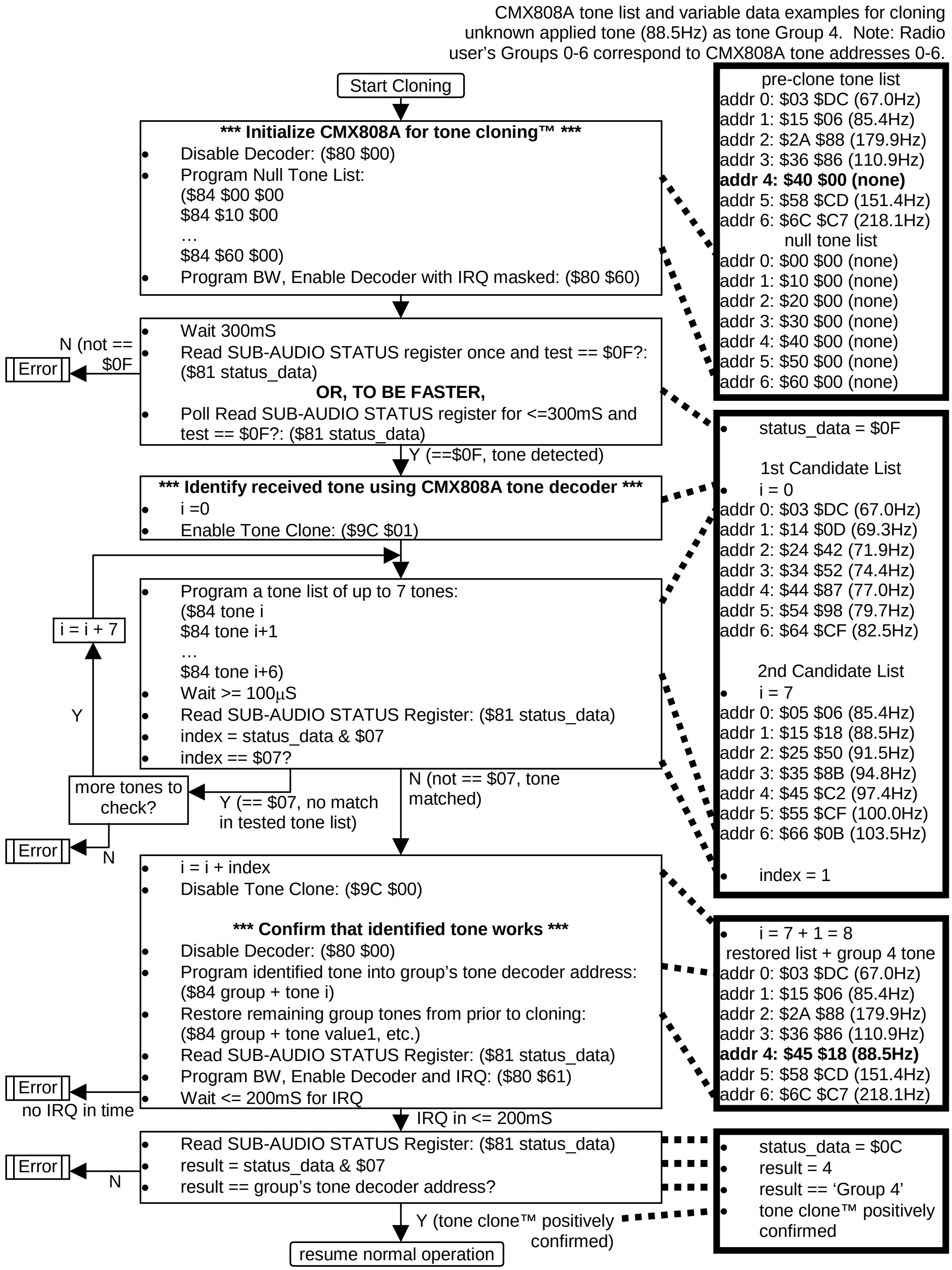

Figure 5: Tone Cloning™ Operating Sequence Details

6. Conclusion

The innovative features of the FRS-focused CMX808A are the key to a new generation of FRS-type radios that consumers will find easier to operate, more capable and more compatible than previously available models. To deliver maximum end customer satisfaction, tone cloning™ may be used in combination with RF channel scanning to provide complete radio cloning™ of two-way radios.

The CMX808A's high performance CTCSS processor, integrated digital volume control, very small size, low power consumption, mass production status, and attractive price make it the premier performer and selection for competitive FRS radio designs.