Telephony Solutions: DTMF Detection with SX Microcontroller

Application Note 5
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Introduction

This application note outlines the hardware and software needed to DTMF detection. This software may be used alone or combined with other telephony modules as required.

Hardware

Certain basic isolation circuitry is required to properly interface to the telephone network - there are many possible variations in requirements based on area and telephone network providers, so check with your network provider first.

The DFT used for DTMF detection requires some basic filter and feedback circuitry outside of the SX, and this is shown in Figure 1.

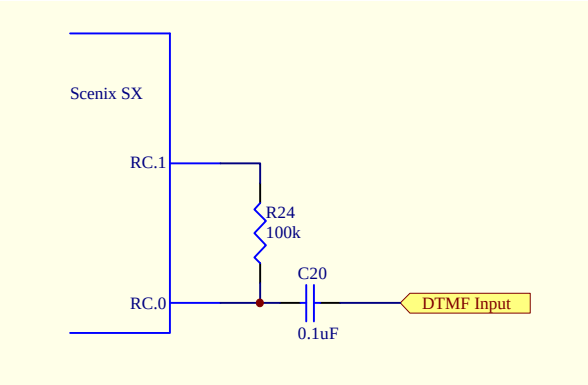

Figure 1.

Software Theory

The DTMF detection algorithm uses a modified version of the Goertzel algorithm DFT. In this algorithm, the input signal is digitized and compared to the sines and cosines of the 8 DTMF composite frequencies. For each composite frequency, a sine and cosine sum-of-products accumulator register is incremented or decremented depending on whether the input signal matches or does not match its corresponding reference sine or cosine. If a sine or cosine reference signal is found to be present in the input signal, its corresponding accumulator will increase in magnitude. If not, each accumulator will hover around zero. Figure 1 shows an example of this technique. To meet the Bellcore specifications [GR-506-CORE] of >40ms for DTMF receiver signal duration, the current version of code uses 8 DFT's operating in parallel to compute all 8 frequencies at the same time.

Software

The DFT requires a sine and cosine reference signal to be generated for each target frequency. This is because, if only a sine reference was provided, it would be possible to end up with a small magnitude in the accumulator even if the two signals are the same frequency and the input signal was phase-shifted relative to the sine reference (see Figure 2a & b). By providing an additional cosine reference and summing the absolute magnitudes in the sine and cosine accumulators, detection of a phase-shifted signal is still possible (see Figure 2c). These references are generated on every pass of the interrupt service routine (ISR) to ensure their accuracy.

The sampling is done in a separate piece of code, so that the sample frequency can be controlled. As the DFT's can be setup for any target frequency, this ensures that the sample frequency is always above Nyquist frequency of >2fin. Every pass of the sample routine increments the 16-bit tone_count registers, so testing this count can determine the length of time to sample. When this count is reached, the ISR sets a flag to indicate that a DFT was performed. In our example, this takes approximately 7ms.

At this point, we can determine whether DTMF tones are indeed present and choose to continue, or clear the accumulators to start over. Figure 3 shows an example of DFT sum-of products for DTMF input, music and voice as an example of the kind of frequency result which must be handled. In our example, the high frequency band of DTMF tones are monitored for a magnitude, since the high frequencies are less affected by any noise which may be present on the line. The function get_winner returns the highest and second highest frequencies found in a band in the winner register. If a high frequency is found, we continue for another 7ms, if not we reset the DFT accumulators. Because the DFT is so fast (14ms to get both high and low tones), we over-sample the input digits received by 3 to provide error-correction. It will not accept the input digit as being a good result until it has received the same digit 3 times. Another function, skill_testing_question, is used to provide another test to ensure that the highest and second highest frequencies

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found in each band have a significant difference. This provides the ability to accept a frequency result only if it is a specified amount above ambient. By providing these two conditional tests, we can ensure a reliable detection of DTMF tones even in the presence of music or voice. See flowchart in Figure 4 for program execution.

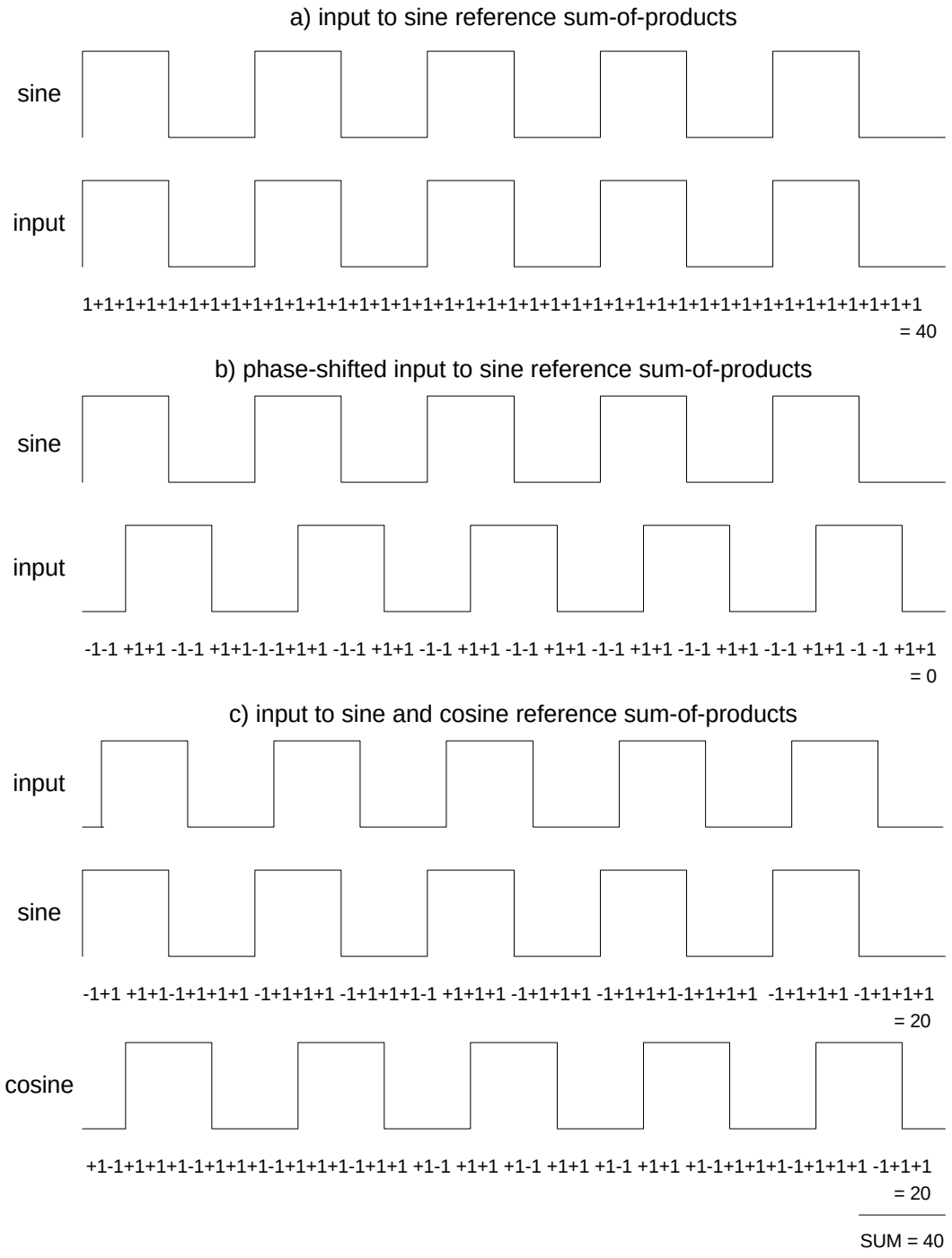

Figure 2. Sum-of-Products Examples

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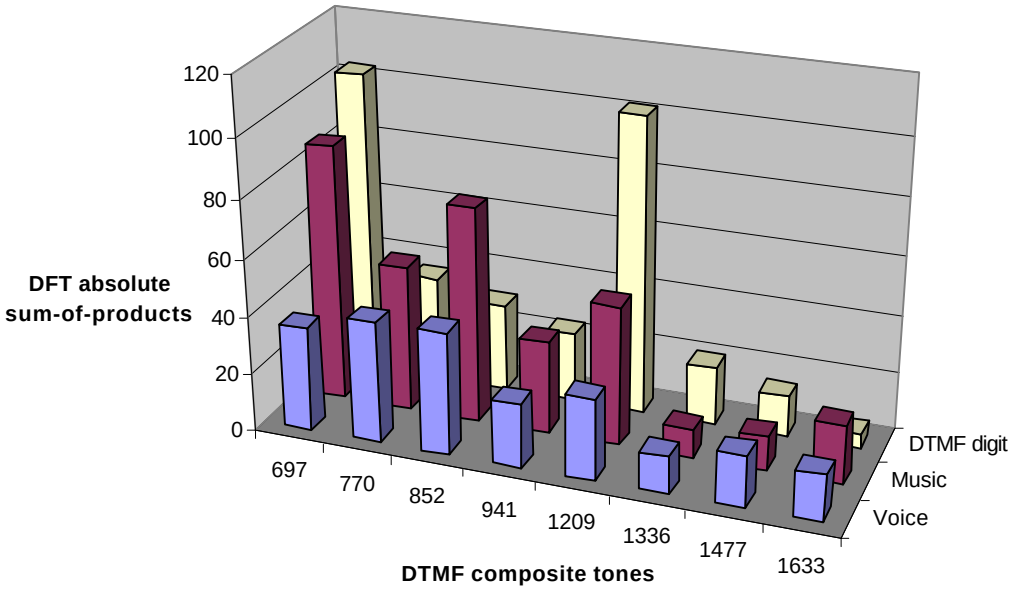

Figure 3. 8DFT results for DTMF, Music and Voice

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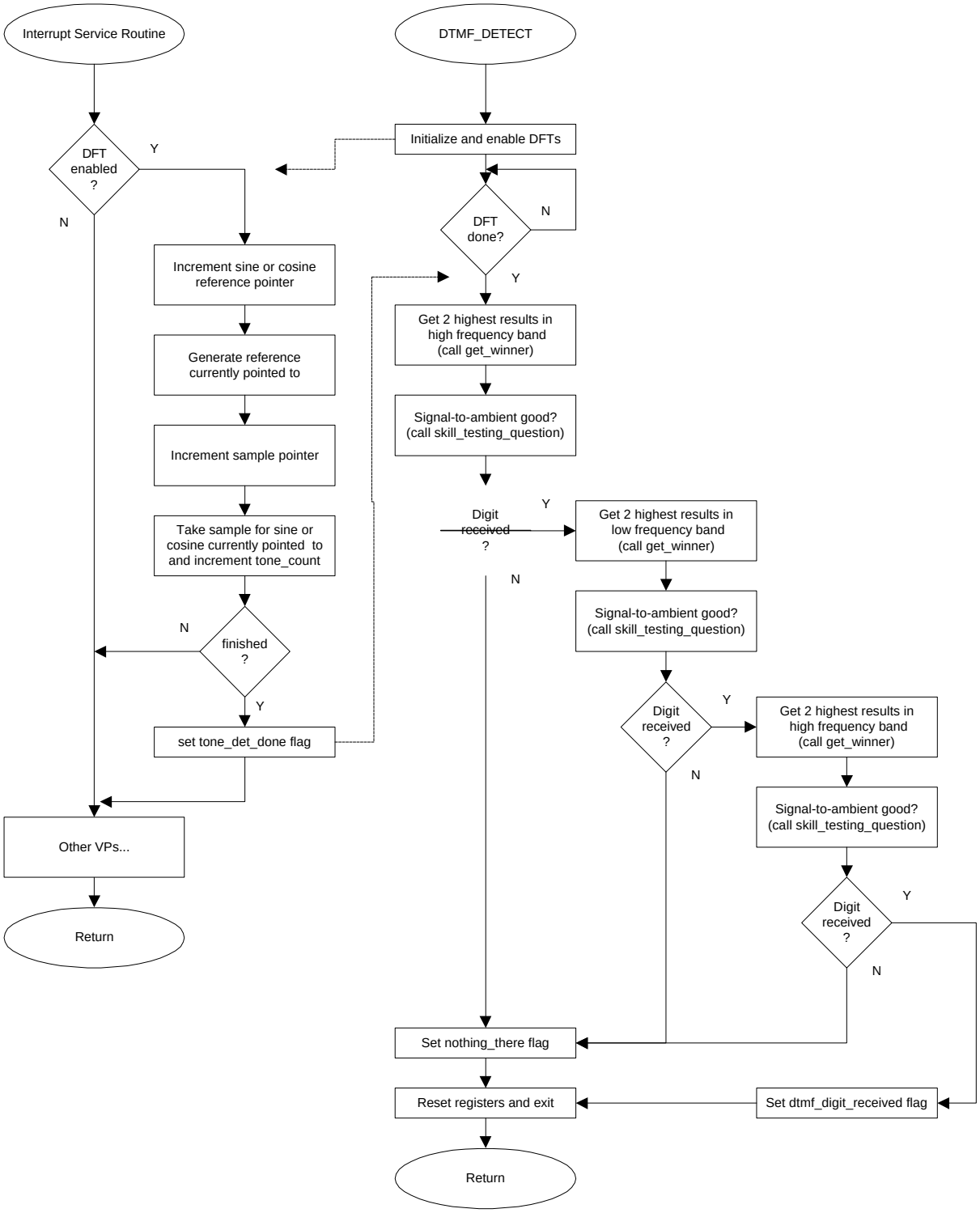

Figure 4. DTMF Detection

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