XIX IMEKO World Congress
Fundamental and Applied Metrology
September 6–11, 2009, Lisbon, Portugal

PORTABLE MP3 PLAYER AS LOW-COST DATA LOGGER

Samuel E. de Lucena

UNESP - São Paulo State University, Department of Electrical Engineering, Microprocessors & Instrumentation Laboratory, Guaratinguetá, Brazil, lucena@feg.unesp.br

Abstract – Non-audio signals have been recorded in the flash ROM memory of a portable MP3 player, in WAV format file, to examine the possibility of using these cheap and small instruments as general-purpose portable data loggers. A 1200-Hz FM carrier modulated by the non-audio signal has replaced the microphone signal, while using the REC operating mode of the MP3 player, which triggers the voice recording function. The signal recovery was carried out by a PLL-based FM demodulator whose input is the FM signal captured in the coil leads of the MP3 player's earphone. Sinusoidal and electrocardiogram signals have been used in the system evaluation. Although the quality of low frequency signals needs improvement, overall the results indicate the viability of the proposal. Suggestions are made for improvements and extensions of the work.

Keywords: data logger, MP3 player, ECG

1. INTRODUCTION

There is an ever-increasing demand for low-cost, portable data loggers for analog signals stemming from a variety of sensors such as temperature, pressure, humidity, pH, and biopotentials. They find their way in industrial and commercial applications as wells as in medical and biological, clinical and research use. Whatever the application field, users welcome data loggers which present longer recording time, greater portability (battery fed, low weight), and non-volatility of data.

The combination of powerful Internet on-line music distribution, low-cost MP3 hardware, and MP3 high compression ratio, while achieving near-CD music quality, has paved the path to the ubiquitous portable MP3 players [1]. MP3 lossy compression algorithm, based on the application of Psycho-Acoustic Model (PAM) and Huffman encoding, although providing a perceptually lossless compression from the human hearing viewpoint [2], most probably prevent its use as a general propose recorder. Accordingly, in order to record data besides audio into MP3 players, researchers have developed MP3 players that incorporate their own data acquisition algorithm and signal-conditioning circuit [3]. This solution, however, render the MP3 player an application specific data logger, i.e., in this case, capable of recording only the user's heart rate, besides audio, obviously.

Some researchers have developed application-specific, portable data loggers based on SRAM cards [4]-[5], serial EEPROM [6], [7], and flash memory cards [8]. Unfortunately, these use 2Mb SRAM memory cards [4]-[5], 64MB EEPROM bank [6], [7], and 32MB flash ROM [8]. None of them can rival the gigabyte capacity of MP3 flash ROMs.

Portable MP3 players are normally equipped with a voice recording function (REC operating mode), which allows the recording of the sound, captured by built-in electret microphone, in lossless file formats, the most popular of which is the WAV format [9], [10]. This paperwork addresses the question of recording analog signals into commercial, portable MP3 players via the microphone channel and then recovering the signals on the earphone output, by employing commercial off-the-shelf integrated circuits.

2. PROPOSED APPROACH

2.1. General description

Fig. 1 depicts the method utilized to save and recall analog signals into commercial, portable MP3 players. First, the instrument's embedded electret microphone must be withdrawn, leaving intact the rest of the signal path towards the processor. Bypassing the ac-coupling capacitor of the MP3 player does not seem attractive, as long as it may be located in a hidden place (e.g., under a connector). Second, as the instrument refuses to record non-audio signal *x(t)*, this is used to modulate the frequency of an audio-range sinusoidal

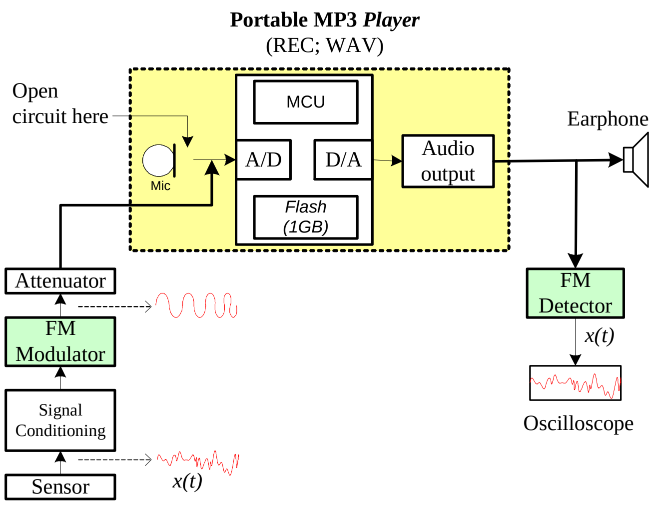


Fig. 1. Block diagram of technique to use MP3 player as a non-audio signal data logger.

carrier. The FM signal must be attenuated to circa 10 mV of typical microphone sensors. To recover the analog signal, first the “voice” option must be chosen on the MP3 player, followed by the selection of the file number. FM receiver whose central frequency equals that of the FM modulator carries out signal detection. The modulating signal, i.e. the sensor signal, can be visualized on an oscilloscope, for example.

2.2. FM modulator

EXAR XR-2206 (monolithic function generator) has been chosen to implement the FM modulator (Fig. 2), for the ease of construction, sinusoidal output with low sine-wave distortion, and small component count. Central frequency is 1200 Hz, for the values shown in Fig. 2.

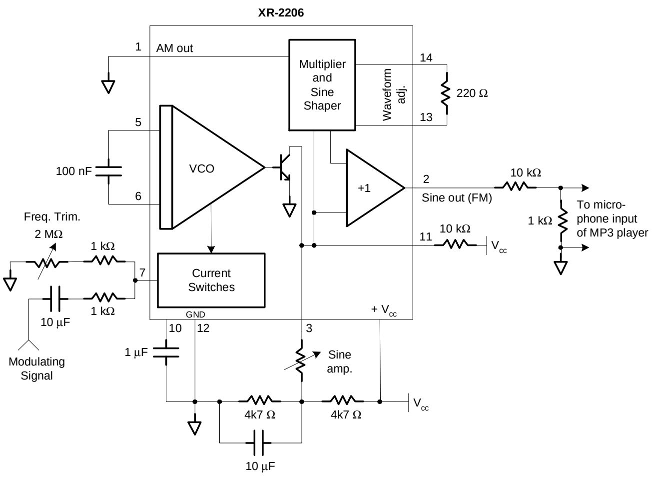


Fig. 2. Circuit diagram of the FM modulator and attenuator.

2.3. FM demodulator

The FM detector (Fig. 3) has been constructed around Philips NE564N PLL (phase-locked loop). The central frequency of the VCO has been adjusted to 1200 Hz. Loop filter and loop gain have been designed following the data-sheet equations. An instrumentation amplifier (INA101) detects the audio signal on the earphone’s coil, provides a gain of 5 and couples it to the demodulator.

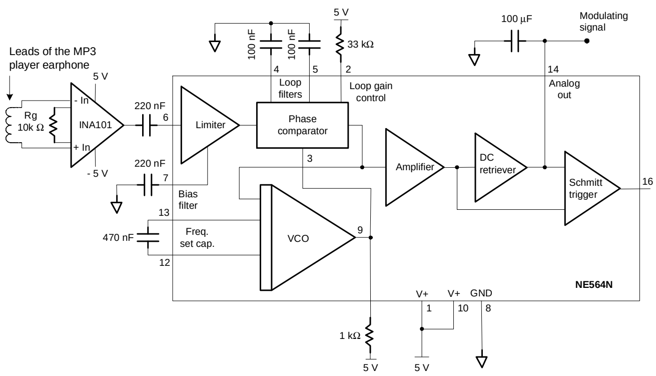


Fig. 3. Circuit diagram of the FM demodulator.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Sinusoidal and electrocardiogram (ECG) signals have been applied to the FM modulator and saved by the MP3 player into WAV files, while this executed the REC function. Then the MP3 player has been switched to *play recorded track* operating mode and a digital oscilloscope has captured the FM demodulator output.

3.1. Sinusoidal signal

Fig. 4 shows the opened MP3 player that has been modified as discussed in the section above. A signal generator (HP 33120A) has been employed to apply sinusoidal signals to the FM modulator. Fig. 5(a) shows a FM signal gathered at the microphone input. Carrier is a 1200-Hz sine wave and the modulating signal is a 100-Hz sine wave.

As can be easily observed in Fig. 5(b), the 100-Hz modulating signal has been satisfactorily detected. The sig-

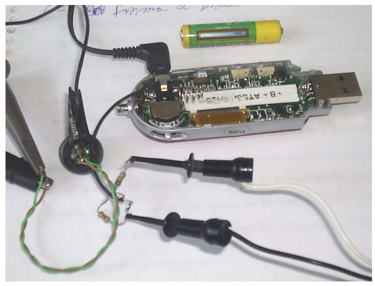
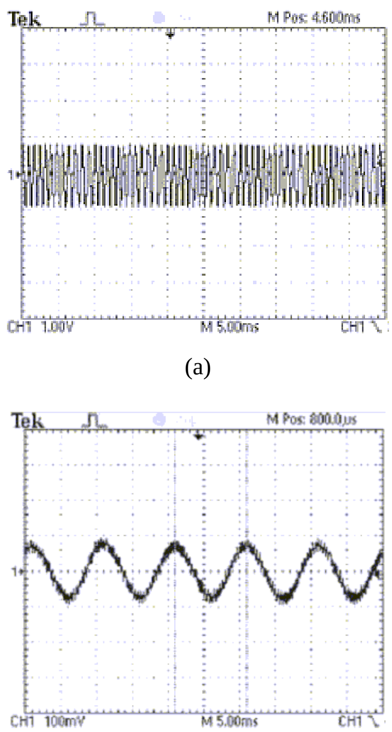


Fig. 4. Photography of the modified MP3 player.



(a)

(b)

Fig. 5: (a) FM signal applied to microphone input of the MP3 player. (b) Output of FM demodulator.

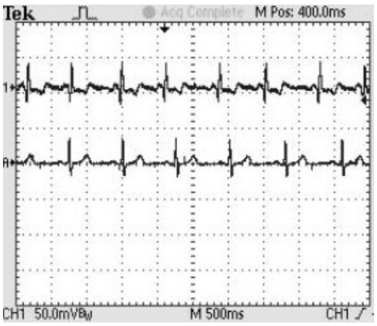
nal is to some extent contaminated by the FM carrier, but it is believed that this can be lessened by suitably low-passing it or redesigning the PLL loop filters. Signal frequency as low as 5 Hz has been saved into the MP3 player and then recovered. However, it has been observed that the signal-to-noise ratio (SNR) of the detected signal decreases considerably in this low frequency range [11].

3.2. ECG signal

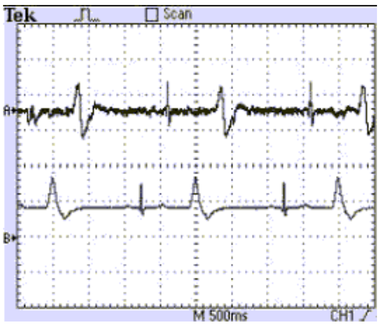
A battery-fed instrumentation amplifier has been assembled to amplify the ECG of a patient wearing three Ag-AgCl electrodes that have been applied to his right leg, left leg, and right arm. As usual, the right leg electrode has been used as reference and has received the inverted common-mode signal, to lower power line interference [12]. Also, the ECG of an arrhythmia simulator [13] has been used.

Fig. 6 shows two oscilloscope screens, each of which contains (bottom trace) the signal applied to the FM modulator and (top trace) the output signal of the FM detector. The top screen shows a patient ECG, whereas the bottom one presents a simulated arrhythmia signal. The recording time of every signal lasted more than 2 minutes. The signals shown in every individual screen of Fig. 6 are not synchronized, i.e., they do not correspond to the same time interval. Furthermore, small fluctuations in frequency of resting ECG are normal, as seen in the top trace of Fig. 6(a).

Although the retrieved signal (simulated or real) agrees somehow with the original one, besides the degraded SNR of the former, it is evident that a very low frequency distortion is introduced in the signal somewhere along its path.



(a)



(b)

Fig. 6. (a) Patient ECG: (bottom trace) input to FM modulator; (top trace) output of FM detector. (b) Simulated ECG: (bottom trace) input to FM modulator; (top trace) output of FM detector.

More arrhythmia signals have been recorded and retrieved which the reader can find in [11]. In spite of the low-frequency distortion, the retrieved signals allowed easy identification of the arrhythmia types (e.g., premature ventricular contraction, ventricular couplets, ventricular bigeminism, R-on-T phenomena, ventricular tachycardia, ventricular fibrillation). It is believe that the low-frequency distortion is due to the FM modulator limitations, specially the relatively high frequency of its high-pass coupling filter (see pin 7 of Fig. 2).

4. CONCLUSIONS

Non-audio signals have been recorded in a commercial portable MP3 player via its microphone signal path, by substituting the microphone with an FM modulated signal. The signal is sampled and saved, in WAV format, in the MP3 player flash ROM, using the recording function of the own instrument (available in most portable MP3 players). The signals have been recovered by demodulating the FM signal captured at the earphone coils, while the MP3 player played the recorded WAV file.

Bench tests using sine wave and ECG signal are encouraging and have made it clear that the method should be improved in order to decrease or even eliminate the low frequency distortion introduced in the signals (ECG). Once this is achieved, maybe portable MP3 players, with the help of some low-cost, auxiliary external circuits, will play the role of analog, non-audio, data loggers. To that end, it is of paramount importance the development of computer program to digitally demodulate de FM signal, using the WAV file transferred from the MP3 player to the computer via the USB port. Yet another appealing progress would be the acoustic coupling of the external FM signal directly to the built-in microphone of the MP3 player. Both these developments are under way at our instrumentation laboratory and the results will be published elsewhere.

ACKNOWLEDGMENTS

The author wishes to acknowledge the financial assistance of Fundunesp, PROPG/UNESP and Capes.

REFERENCES

[1] M. McCandless, “The MP3 revolution”, *IEEE Intelligent Systems and their Applications*, vol. 14, nº. 3, pp. 8-9, 1999.

[2] E. Ruzanski, “Effects of MP3 encoding on the sounds of music”, *IEEE Potentials*, vol. 25, nº. 2, pp. 43-45, 2006.

[3] J. Kim, M. Lee, H.-K. Lee, K. Choi, S. Bang, S. Kim, “Heart rate monitor for portable MP3 player”, *27th IEEE Annual Conference on Engineering in Medicine and Biology*, pp. 5207-5210, Shanghai, China, Sept. 2005.

[4] K. Aminian, P. Robert, E. Jéquier, and Y. Schutz, “Estimation of speed and incline of walking using neural network”, *IEEE Transactions on Instrumentation and Measurement*, vol. 44, nº. 3, pp. 743-746, 1995.

[5] M. Yoshida, K. Akazawa, “Monitoring of muscle power during walking”, *19th IEEE Annual Conference on Engineering in Medicine and Biology*, pp. 1899-1901, Chicago, USA, Oct. 1997.

[6] R. Luharuka, R. X. Gao, and S. Krishnamurty, "Design and realization of a portable data logger for physiological sensing", *IEEE Transactions on Instrumentation and Measurement*, vol. 52, nº. 4, pp. 1289-1295, 2003.

[7] R. Kuchta, P. Stefan, Z. Barton, R. Vrba, M. Sveda, "Wireless temperature data logger", *Asian Conference on Sensors and the International Conference on New Techniques in Pharmaceutical and Biomedical Research*, pp. 208-212, Kuala Lumpur, Malaysia, Sept. 2005.

[8] M. Cifrek, S. Mrvos, P. Zufic, "Portable data logging system for long-term continuous monitoring of biomedical signal", *12th IEEE Mediterranean Electrotechnical Conference, MELECON 2004*, vol. 1, pp. 399-402, Dubrovnik, Croatia, May 2004.

[9] C. S. Sapp, "Wave PCM sound file format", [online] available: *http://ccrma.stanford.edu/CCRMA/Courses/422/projects/WaveFormat/*

[10] [Online] available: *http://www.s1mp3.org/pt/index.php*

[11] S. E. de Lucena, "A data logger for analog signals based on the portable MP3 player equipped with voice input," *Livre-Docência* thesis, Dept. Elect. Engineering, São Paulo State University, Guaratinguetá, São Paulo, Brazil, 2008 (in Portuguese).

[12] J. G. Webster (ed.), *Medical Instrumentation: Application and Design*, John Wiley, New York, 1998.

[13] LM Sistemas Eletrônicos Ltda. *Arrhythmia Simulator*, Campinas, SP, Brazil, 1991.