The FUNcube Dongle

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Origins & Concept

FUNcube is a single CubeSat satellite project under the direction of AMSAT-UK, its goal - to enthuse and educate young people in the disciplines of radio, space, physics and electronics and support the educational Science, Technology, Engineering and Maths (STEM) initiatives here in the UK.

FUNcube will contain a materials science experiment linked to a 145MHz telemetry beacon. This will allow the target audience of primary and secondary school pupils the opportunity to receive, decode and compare the telemetry data with results they obtain from similar reference experiments in the classroom. As an additional resource FUNcube will feature a 435MHz to 145MHz, 500mW Linear Transponder for SSB/CW operation, this will be active when educational commitments permit.
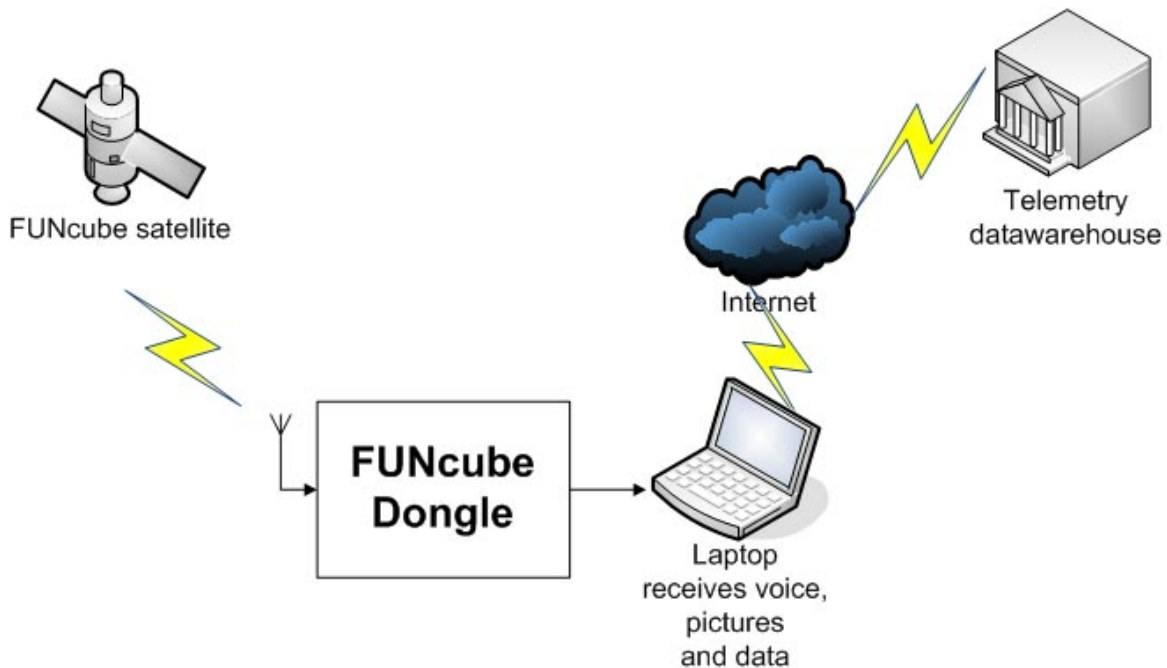
To provide the students with a simple and inexpensive means of receiving the telemetry signals enter - the FUNcube Dongle (FCD for short). The FCD is designed to connect directly between the antenna feed and PC and, by the use of appropriate software, enable the display and dissemination of the received telemetry.

Further details of the FUNcube Project can be found at: http://funcube.org.uk/

But of course the potential of the FCD does not end there…

Description

Similar to a USB TV Dongle, the FUNcube Dongle simply connects to the computer's USB port and appears as a "USB Audio Device". It works with Windows XP, Vista and Windows 7 (32 & 64bit). In addition, it is compatible with Linux* and MacOS* as it uses standard USB drivers already integrated into the operating system.

Whilst conceived as the "ground segment" of the FUNcube satellite project, the FCD is actually a fully integrated, wide band, high performance Software Defined Receiver (SDR) and as such has a far greater potential. In view of this there are two versions, the Base (or entry) and Pro. The entry level FCD is targeted at educational outreach and gives access to the satellite frequency band used by FUNcube and some other satellites, the Pro version covers 64MHz to 1,700MHz (there is a small gap between 1100MHZ & 1270MHz due to limitations within the tuner chip). Externally they are physically identical.

The FCD is capable of all-mode operation limited only by the application program running on the host computer. Similarly for data reception, as long as a data demodulator application exists that understands a standard stereo soundcard configured for quadrature, (I/Q) input, that too will work. As long as the signal fits within an 80KHz bandwidth, the FCD is capable of receiving it.

Many of the existing SDR applications, e.g. WRPlus, Spectravue, Rocky, LinRad, etc., may be used with the FCD to display and demodulate signals. Full control of the FCD from these packages may not be possible at this time however the library of links to enable this is constantly expanding.

The FCD has an 'onboard' microcontroller to store and run the Firmware which manages its internal functionality and interface with the controlling PC. This Firmware can be upgraded as improvements are made.

* Applications under development.

Hardware

The FCD consists of an upper and lower plastic case and printed circuit board (PCB) carrying all the components. The RF connector (SMA socket) can be seen at the left of the PCB and the USB (Type A) connector at the right. The overall dimensions of the unit when assembled, including the RF and USB connectors, are approximately 86mm x 23mm x 14mm. The PCB layout may differ slightly and there are a few components on the underside of the PCB.

Identifying the main components - immediately to the rear of the RF connector and nearest to the lower edge of the PCB is the Low Noise Amplifier (LNA), a BGA2717. To the right of the LNA are three larger square components. The first of these is an E4000 Silicon tuner, the second is a TLV320AIC3104 Audio Codec and the third a 24FJ32GB002 16bit Microcontroller. How they interconnect is shown below.
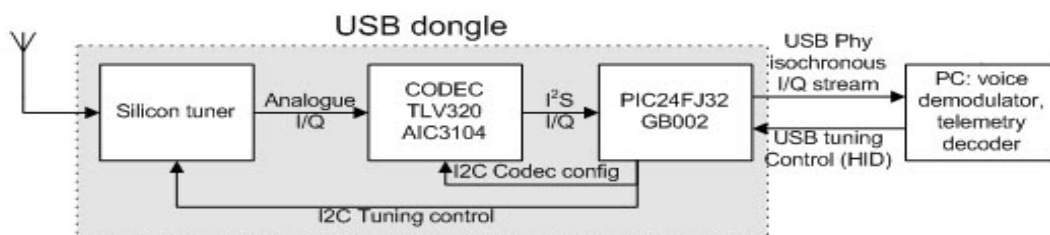
The LNA is not shown but is between the antenna and input to the Silicon tuner. The tuner has its own internal LNA but the addition of the external device improves overall sensitivity and noise figure.

Hardware cont…

In common with many such devices detailed technical information of the E4000 Silicon tuner is the subject of a non disclosure agreement between the manufacturer and systems integrator however the following diagram gives some indication of its internal structure.

RF LNA → RF FILTER → ⊗ → Mixer FILTER → IF AMP 1 → IF RC FILTER → IF AMP 2 – 4 → IFFILTER → IF AMP 5 -6
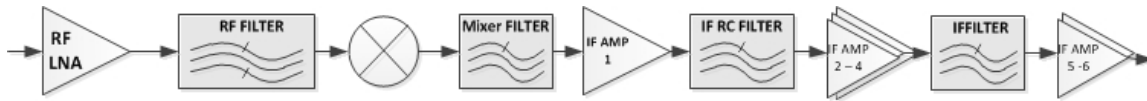
The FCD's application software allows the selection of various parameters associated with each stage allowing the optimum operating points to be set.

Although it can not be seen in the photo on the previous page, there is a BAV99 bidirectional diode across the FCD input for ESD protection and a high pass filter (HPF) before the first LNA to attenuate strong signals below the minimum operating frequency.

A few notes:

The FCD is a USB V1.1 device running at full speed (12Mbps).

Frequency coverage – 64MHz to 1700MHz (with gap as mentioned above) although operation above and below these limits is possible. Tests have shown a useable range extending down to 52MHz and slightly beyond 2GHz.

The reference oscillator is 24.576MHz, this is used throughout the device.
There is no 10MHz reference available.

Bandwidth - 96kHz is the quadrature sampling rate. Once the ADC's decimation filter skirts have been taken into account, you have about 80KHz.

Internal signal path is differential to maintain SNR.

Sensitivity - Each unit is tested for 0.15uV for 12dB SINAD NBFM at 145MHz and 435MHz.

The Base model is not field upgradeable to the Pro.

Firmware is user upgradeable on both versions but not interchangeable.

Firmware

Internally, the FCD is controlled by its own microcontroller and operating system known as Firmware. The Firmware is stored within the microcontroller which uses it to interpret and execute all incoming commands from the PC and to format all outgoing data. The Firmware is permanently retained when the FCD is left unpowered (there is no backup battery to replace) and may be updated by the user when new versions are released. These new releases can be downloaded from the "Downloads" page on the FCD website where a guide to the upgrade process is also available.

See: http://www.funcubedongle.com/

NOTE:

It is strongly recommended that the user tests their FCD with the installed Firmware and simple Front end / SDR application before moving on to more advanced operation.
(See Application Software & First Use)

When delivered, the FCD may not have the latest version of Firmware installed. However the version installed will be one which is considered stable and with which the FCD has been fully tested prior to despatch.

As of February 2011, all production FCDs have been shipped with firmware release 18b which has been in existence since October 2010. This has been through months of proving both before and after production release. There have been further firmware releases since then, all of which are designed to be backwards compatible so installing them should not break anything you were doing previously.

The newer firmware updates have been made available to provide a much more comprehensive Application Programming Interface (API) for third party developers, so please refer to any release notes / prerequisites for the host software. And would all developers please ensure that such prerequisites are displayed.

Application Software & First Use

Perhaps first a note of caution to those new to software defined receiver applications or those with experience of the high end systems such as Flexradio, Perseus, Winradio, etc.

Although the FCD is fully compatible with any of the SDR applications for demodulation purposes, full control of its features from within these applications is not currently possible (February 2011). Undoubtedly this will change over time but at present it is necessary to use a link such as ExtIO written by G0MJW or Front End software specifically written for the FCD.

The suggested starting point for new users is to download the following files:

From the FCD website - http://www.funcubedongle.com/?page_id=313

"Windows fully functional front end" - (Filename: FCHid003.zip)
"Setting up Spectravue with the FUNcube Dongle" - (SpectravueConfigurationForFCD.pdf)

From Moetronix website - http://www.moetronix.com/svdownload.htm

"SpectraVue Program Full Install" - (Filename: spectravueinstall.zip)

These few files and the steps shown below will allow testing of the FCD and provide confidence it is working correctly.

1) Install Spectravue.
2) Extract FCHid.exe from FCHid003.zip
3) Connect the FCD to the PC
4) Run FCHid
5) Run Spectravue
6) Configure Spectravue as described in the guide.

With no antenna connected, using Spectravue and pressing the "Defaults" button on the FCD controller software, a noise floor of around -100dB should be seen. Pressing the "Defaults" button is usually the right thing to do when you first plug in the FCD or launch the application as it sets the gains on the device to some sensible settings. Connecting an antenna may raise the noise floor considerably depending upon your local environment. It is suggested you initially tune the FCD to a known local station, of moderate strength, to familiarise yourself with its operation. It may be helpful to set the Mixer gain to 4dB and reduce the LNA gain to offset the effects of other strong local signals.

Hopefully you will now have a working system and an insight into operation of the FCD. Try experimenting with the various parameters, no harm can be done and a click on the "Defaults" button will return the original settings.

Firmware Update

Having tested the FCD, now is a good time to update the Firmware. All the files needed are on the FCD website and are listed below.

"Firmware Update Guide" - (Filename: FCDFirmwareUpdateGuide.pdf)
"Boot loader with source code" - (File name: FCHIDBL001.zip)
 "Firmware v18f (New!)" or later.

The FCHIDBL001.zip file contains a number of files however, as a user, the only one you need is "FCHIDBL.exe".

The guide contains all the information you need to complete the upgrade.

To go with the new Firmware there is an enhanced version of the FCD Front end application. Download this and use it in place of the original:

"Windows fully functional front end with source (needs firmware 18f or above)" (Filename: FCHID0006.zip)

The zip file contains a number of files but the only one you need is "FCHid.exe".

The upgraded Firmware allows full use of the latest ExtIO software from G0MJW. This is used with WRPlus and with DK3WN's Satcontrol application. Guides for these configurations are on the FCD website and the ExtIO and Satcontrol software can be downloaded from the "Files Section" of the FCD Yahoo Group:

http://uk.groups.yahoo.com/group/funcube/

Here too you will find useful information, be able to review the experiences of other users and be able to ask questions of your own.

So What Next?

As with any project of this nature the hardware, firmware and application software continue to evolve and improve. Much of this improvement is driven by the experiences of users and the applications they find for the device.

Currently (Feb 2011) work is in progress to identify a suitable filter or filter / preamp combination to enhance reception of signals within the 2m band. This is necessary because of the wide band reception capabilities of the FCD and the effects of the very strong commercial signals immediately above and below 2m. To enable the use of a preamp powered via the RF connector a software switchable 'phantom' 5v supply facility will be added to the FCD.
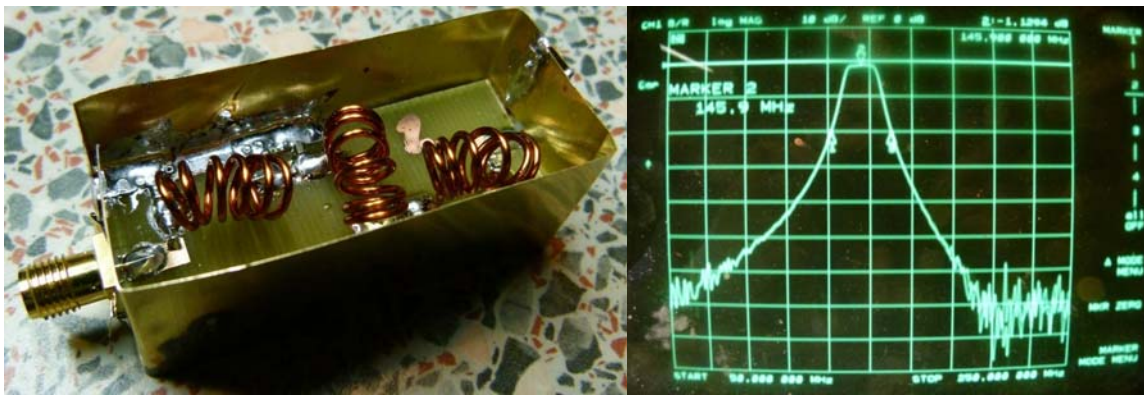
Bandpass filter – No preamp.
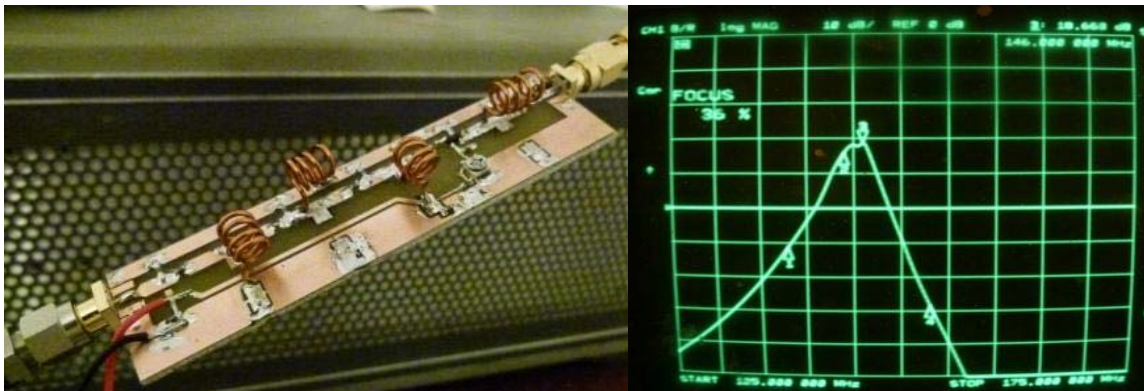
Bandpass filter – With preamp.

Acknowledgements

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	Roger – G7RUH
Component Data.	Elonics
	Texas Instruments
	Microchip Technology Inc.

LOW POWER CMOS MULTI-BAND TUNER

E 4000

FEATURES

- **Support for Multiple Standards**
  Surpasses NORDIG 2.0 and D-Book
  Fully Compatible with other Digital TV and Radio Standards

- **Scalable Power Consumption**
  105mW Typical Operation
  13mW in DVB-H Mode
  3mW in Standby Mode

- **Variable Gain, Single Input Low Noise Amplifier (LNA)**
  3.5dB Receiver Noise Figure
  64MHz to 1700MHz Input Frequency Range

- **Flexible IF Amplifier and Channel Filter**
  Programmable Bandwidth and Cut-Off Frequency
  Logical Up/Down or Digital PWM Gain Control

- **Flexible Clocking Modes**
  Fractional-N Synthesiser with Fully Integrated VCO and Loop Filter
  15 – 30MHz Input Clock Frequency Range
  Programmable Output Clock Frequency Range

- **I²C Control Bus**
  3.3V Tolerant Interface
  4 Addresses for MIMO and Diversity Applications

- **1.5V Analogue and Digital Supply Operation**

- **32-Pin QFN Package**
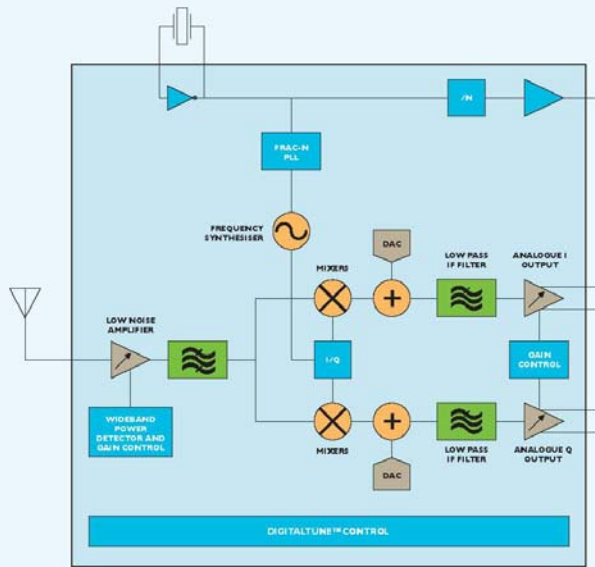 5x5x0.9mm Body Size, Pb Free, RoHS Compliant

TYPICAL APPLICATIONS

- Digital Terrestrial Set-Top Boxes
- NIM and Half NIM Modules
- Computer TV Cards and USB TV Dongles
- DVD-Rs and PVRs
- Mobile TV Enabled Cell Phones
- MP3 and Portable Multi-Media Players
- In-Car TV Car TV

THE E4000 IS A HIGHLY INTEGRATED MULTI-BAND RF TUNER IC IMPLEMENTED IN CMOS, IDEAL FOR DIGITAL TV AND RADIO BROADCAST RECEIVER SOLUTIONS. THE DIGITALLY PROGRAMMABLE MULTI-BAND TUNER ARCHITECTURE COVERS THE COMPLETE SPECTRUM FROM VHF TO L BAND (64MHz TO 1.70GHz) AND ALLOWS THE USER TO RE-CONFIGURE THE RF FRONT END FOR DIFFERENT BROADCAST STANDARDS.

At the heart of the E4000 is Elonics innovative DigitalTune™ architecture, which allows the designer to adjust the performance of the tuner for optimum linearity or noise figure according to the signal conditions. It enables manufacturers to significantly improve reception quality whilst supporting multiple broadcast standards including DVB-T/H, ISDB-T, D-TMB, T-DMB, CMMB, and DAB/DAB+. The E4000 contains a single input LNA with a unique programmable RF tracking filter, whose centre frequency can be programmed over the complete frequency range from 64MHz to 1.7GHz. This greatly simplifies antenna management especially for applications that require support for more than one broadcast standard.

The E4000 tuner uses a zero IF architecture, which dramatically reduces the number of external components and allows power consumption to be minimised to as low as 12mW for a 10% duty cycle. It makes the E4000 a cost effective and very low power solution for the digital TV and radio market.

elonics
WIRELESS SILICON FOR A DIGITAL AGE

E℮™

E 4000

PB-E4000-10/2009

Block diagram labels:

/N

FRAC-N PLL

FREQUENCY SYNTHESISER

DAC

LOW PASS IF FILTER

ANALOGUE I OUTPUT

MIXERS

LOW NOISE AMPLIFIER

I/Q

GAIN CONTROL

WIDEBAND POWER DETECTOR AND GAIN CONTROL

MIXERS

LOW PASS IF FILTER

ANALOGUE Q OUTPUT

DAC

DIGITALTUNE™ CONTROL

ORDERING INFORMATION

ORDER CODE	TEMPERATURE RANGE	PACKAGE
E4000EQGD	-40 to +85°C	QFN-32 5x5mm body (Pb-free)
E4000EQGR[1]	-40 to +85°C	QFN-32 5x5mm body (Pb-free, tape and reel)

NOTE:(1) A reel contains 3500 devices

EVALUATION AND SUPPORT

Elonics provides a complete range of product support collateral including tuner reference designs, schematics and layouts. Our products are supported by extensive parametric performance data, easy to use evaluation boards and GUIs. We can also provide firmware scripts to aid system integration.

ABOUT ELONICS

Elonics is a fabless semiconductor company specialising in the development and supply of multi-band radio frequency (RF) IC products. Founded in 2003 and based in Livingston, United Kingdom, Elonics has developed an innovative radio frequency architecture called DigitalTune™ that is the foundation for a family of re-configurable CMOS RF tuner products.

Elonics innovative technology allows manufacturers to design high performance multi-band tuners with unrivalled power consumption and low system cost. Our products are targeted at high volume consumer electronics applications that require wireless multi-media connectivity where size, performance, price and power consumption are paramount.

Appendix B

LOW-POWER STEREO AUDIO CODEC FOR PORTABLE AUDIO/TELEPHONY

FEATURES

- Stereo Audio DAC
  - 102-dBA Signal-to-Noise Ratio
  - 16/20/24/32-Bit Data
  - Supports Sample Rates From 8 kHz to 96 kHz
  - 3D/Bass/Treble/EQ/De-Emphasis Effects
  - Flexible Power Saving Modes and Performance are Available
- Stereo Audio ADC
  - 92-dBA Signal-to-Noise Ratio
  - Supports Sample Rates From 8 kHz to 96 kHz
  - Digital Signal Processing and Noise Filtering Available During Record
- Six Audio Input Pins
  - One Stereo Pair of Single-Ended Inputs
  - One Stereo Pair of Fully Differential Inputs
- Six Audio Output Drivers
  - Stereo Fully Differential or Single-Ended Headphone Drivers
  - Fully Differential Stereo Line Outputs
- Low Power: 14-mW Stereo 48-kHz Playback With 3.3-V Analog Supply
- Ultralow-Power Mode with Passive Analog Bypass
- Programmable Input/Output Analog Gains
- Automatic Gain Control (AGC) for Record
- Programmable Microphone Bias Level
- Programmable PLL for Flexible Clock Generation
- I²C Control Bus
- Audio Serial Data Bus Supports I²S, Left/Right-Justified, DSP, and TDM Modes
- Extensive Modular Power Control
- Power Supplies:
  - Analog: 2.7 V–3.6 V.
  - Digital Core: 1.525 V–1.95 V
  - Digital I/O: 1.1 V–3.6 V

- Package: 5-mm × 5-mm 32-Pin QFN

APPLICATIONS

- Digital Cameras
- Smart Cellular Phones
- PDAs
- Portable Computing
- Communication
- Entertainment Applications

DESCRIPTION

The TLV320AIC3104 is a low-power stereo audio codec with stereo headphone amplifier, as well as multiple inputs and outputs that are programmable in single-ended or fully differential configurations. Extensive register-based power control is included, enabling stereo 48-kHz DAC playback as low as 14 mW from a 3.3-V analog supply, making it ideal for portable battery-powered audio and telephony applications.

The record path of the TLV320AIC3104 contains integrated microphone bias, digitally controlled stereo microphone preamplifier, and automatic gain control (AGC), with mix/mux capability among the multiple analog inputs. Programmable filters are available during record which can remove audible noise that can occur during optical zooming in digital cameras. The playback path includes mix/mux capability from the stereo DAC and selected inputs, through programmable volume controls, to the various outputs.

The TLV320AIC3104 contains four high-power output drivers as well as two fully differential output drivers. The high-power output drivers are capable of driving a variety of load configurations, including up to four channels of single-ended 16-Ω headphones using ac-coupling capacitors, or stereo 16-Ω headphones in a capless output configuration.

⚠ These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.
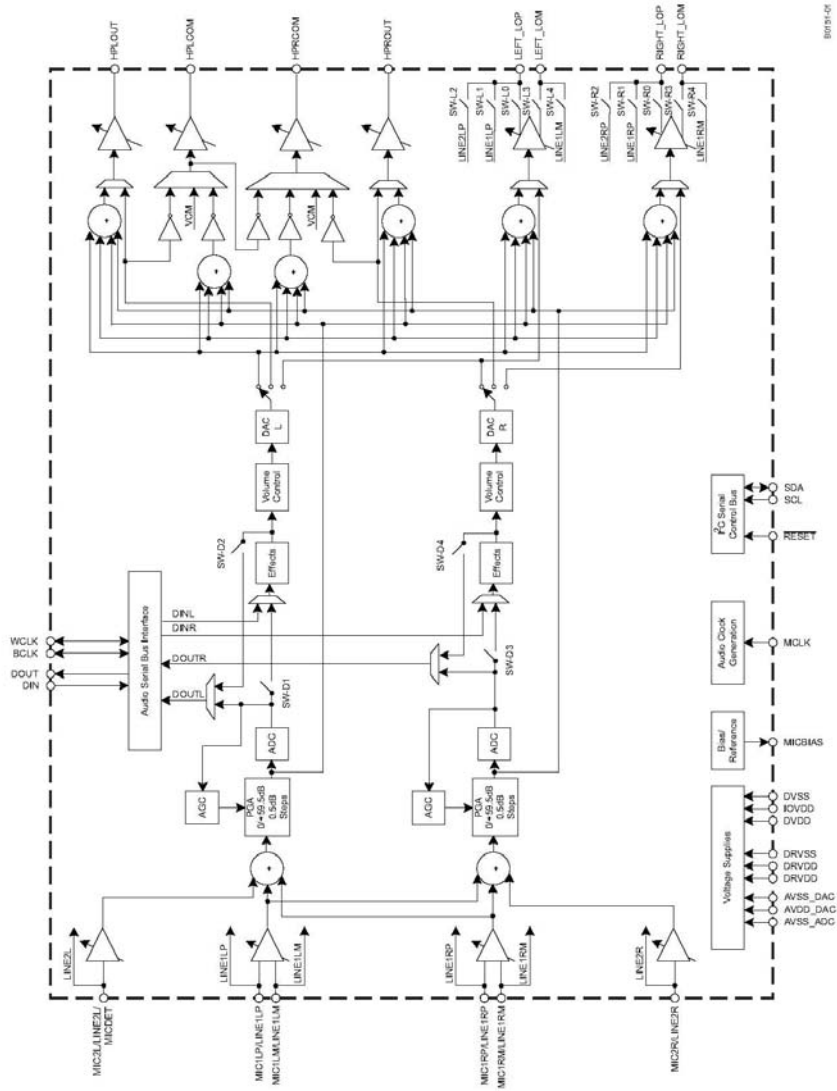
DESCRIPTION (CONTINUED)

The stereo audio DAC supports sampling rates from 8 kHz to 96 kHz and includes programmable digital filtering in the DAC path for 3D, bass, treble, midrange effects, speaker equalization, and de-emphasis for 32-kHz, 44.1-kHz, and 48-kHz sample rates. The stereo audio ADC supports sampling rates from 8 kHz to 96 kHz and is preceded by programmable gain amplifiers or AGC that can provide up to 59.5-dB analog gain for low-level microphone inputs. The TLV320AIC3104 provides an extremely high range of programmability for both attack (8–1,408 ms) and for decay (0.05–22.4 seconds). This extended AGC range allows the AGC to be tuned for many types of applications.

For battery saving applications where neither analog nor digital signal processing are required, the device can be put in a special analog signal passthrough mode. This mode significantly reduces power consumption, as most of the device is powered down during this passthrough operation.

The serial control bus supports the I^2C protocol, whereas the serial audio data bus is programmable for I^2S, left/right-justified, DSP, or TDM modes. A highly programmable PLL is included for flexible clock generation and support for all standard audio rates from a wide range of available MCLKs, varying from 512 kHz to 50 MHz, with special attention paid to the most-popular cases of 12-MHz, 13-MHz, 16-MHz, 19.2-MHz, and 19.68-MHz system clocks.

The TLV320AIC3104 operates from an analog supply of 2.7 V–3.6 V, a digital core supply of 1.525 V–1.95 V, and a digital I/O supply of 1.1 V–3.6 V. The device is available in a 5-mm × 5-mm 32-pin QFN package.

SIMPLIFIED BLOCK DIAGRAM

Appendix C

24FJ32GB002 Microcontroller

Data on the 24FJ32GB002 Microcontroller is available here:

http://www.microchip.com/wwwproducts/Devices.aspx?dDocName=en536120

http://www.funcubedongle.com/   http://funcube.org.uk/

V1.0