

APPLICATION NOTE

GC2011-AN9803

Band Splitting Using Two GC2011 Digital Filter Chips

April 28, 1998

Revision 0.0

This application note describes how to use a two GC2011 chips to split a wide bandwidth, high sample rate, signal into two overlapping bandwidths at half the input sample rate. The lower band will cover from 0 to $0.2F_S$, where F_S is the input sample rate. The upper band runs from $0.15F_S$ to $0.35F_S$. A third chip may be used to cover the range from $0.3F_S$ to $0.5F_S$.

1.0 BAND SPLITTING WITH GC2011 CHIPS

This application note describes how to use two GC2011 chips to provide twice the input bandwidth to a bank of digital receivers such as the GC1011A, GC1012, GC4014, or GC4016 chips. Fundamentally each GC2011 chip isolates a portion of the input spectrum and decimates it by two. This results in two input bands with the lower band (L-band) covering DC to $0.2F_S$ and the upper band (U-band) covering from $0.15F_S$ to $0.35F_S$, where F_S is the input sample rate. The upper band is mixed down by $F_S/8$. The GC4014 and GC4016 chips have input crossbar switches which will allow them to accept data from both bands. The GC1011A and GC1012 have a single input port so a 2:1 multiplexer would be required.

The figure below shows a block diagram of the processing.

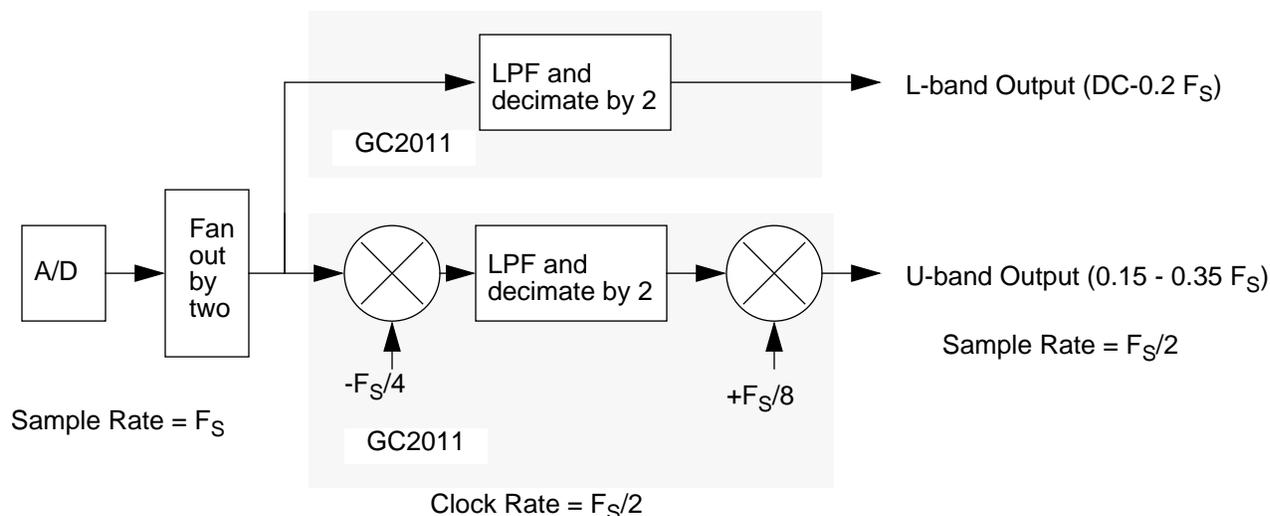


Figure 1. Signal Processing and Hardware Block Diagram

Sample rates up to 160 MHz can be supported by the GC2011 chips. If the outputs are feeding GC4014 digital receiver chips, then the sample rate can be up to 125 MHz. If it is feeding the GC1011A, GC1012A or the (TBD) GC4016 chip, then the sample rate can be up to 140 MHz. Data from the A/D is fanned out by two. Even time samples are sent to the A port of both GC2011 chips and odd time samples are sent to the B port of both chips. The A/D clock is divided by two and sent to the two GC2011 chips.

1.1 The L-Band GC2011 Chip

In the L-band the GC2011 is programmed for double rate real in, full rate real out decimate by two mode. The filter should be a 63 (or 64) tap filter with a folding frequency of $F_s/4$. Figure 2 shows the frequency response of one such filter (63 taps, 0.04dB p-p ripple to 0.22 F_s , 70 dB stop band from 0.28 F_s).

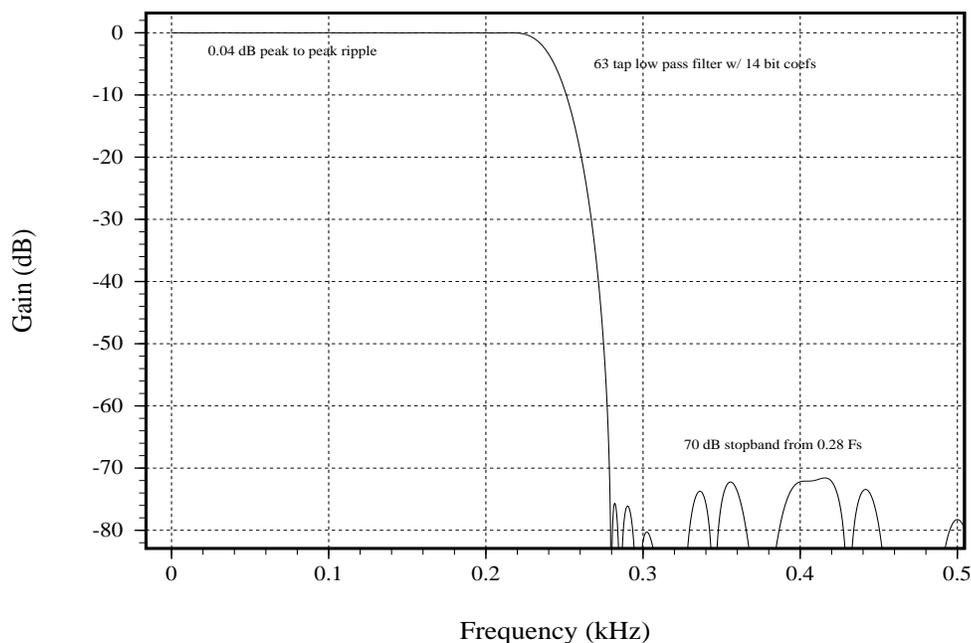


Figure 2. Frequency Response of 63 Tap Low Pass Filter with 14 Bit Coefficients

Unique coefficients are: 6, 14, 6, -15, -11, 22, 21, -30, -36, 40, 57, -51, -85, 63, 123, -76, -173, 88, 240, -100, -330, 112, 455, -122, -644, 130, 968, -137, -1690, 141, 5190, 8034. Details for configuring the GC2011 in this mode are included in Section 3.4 of the GC2011 datasheet.

1.2 The U-Band GC2011 Chip

The U-band processing uses the front end negation circuit to mix the input down by $F_s/4$. The data is then low pass filtered and decimated by two. Finally, the output negation circuit is used to mix the signal up by $F_s/8$ (due to the decimation by two this is equivalent to mixing up by the $F_{out}/4$). The lowpass filter should have a passband running from $-F_s/8$ to $+F_s/8$. The GC2011 in the mode which combines the $F_s/4$ down convert, the decimate by two and the $F_s/8$ up convert allows odd length filters up to 127 taps to be used. Figure 3 shows the frequency response of one such filter.

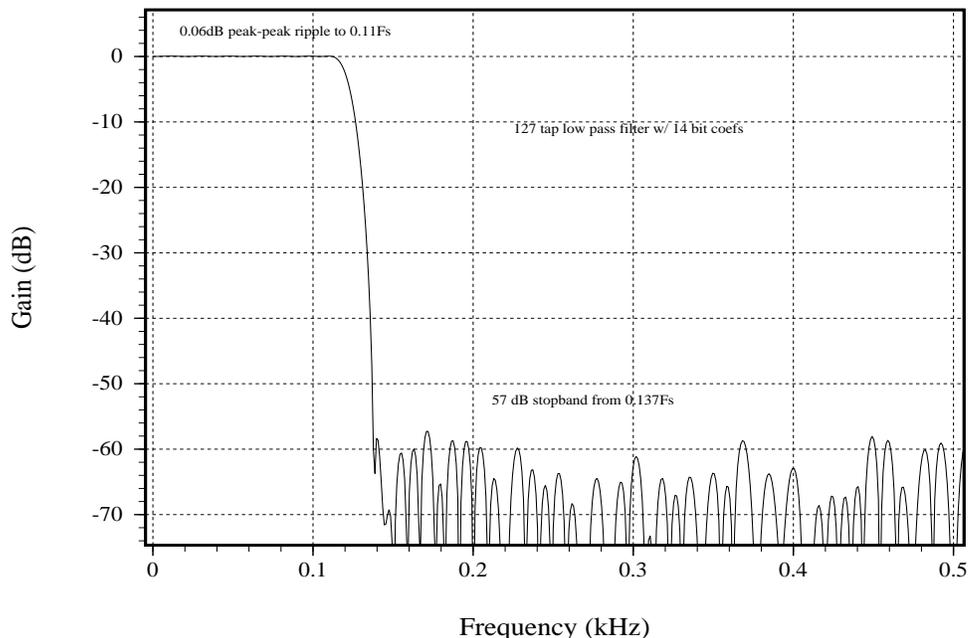


Figure 3. Frequency Response of 127 Tap Low Pass Filter

This filter has a passband from $-0.11F_S$ to $+0.11F_S$. Since the input signal is mixed down by $F_S/4$, it passes signals from $0.14F_S$ to $0.36F_S$ of the input spectrum. After mixing up by $F_S/8$ the signals are centered from $0.015F_S$ to $0.235F_S$. This mode is not described in the datasheet so the details follow here:

Table 1: Control Register Settings

Register	Address	Value (hex)
A Path Reg 0	0	0x348B
A Path Reg 1	1	0x2E12
B Path Reg 0	2	0x048B
B Path Reg 1	3	0x2E91
Cascade Reg	4	0x2000
Output Reg	7	0x0012

In this mode the coefficients are stored in registers 0 and 1 of each filter cell. In this mode store $h(k)$ in addresses:

Store $h(4k)$ in address $128+4k$ for $k = 0$ to 15

Store $h(4k+1)$ in address $192+4k$ for $k = 0$ to 15

Store $h(4k+2)$ in address $129+4k$ for $k = 0$ to 15

Store $h(4k+3)$ in address $193+4k$ for $k = 0$ to 15

where $h(63)$ is the center tap.

The specific coefficients used for this filter are: 0, 0, 0, 4, 4, 3, -1, -5, -8, -7, -3, 3, 8, 8, 3, -6, -13, -14, -7, 6, 17, 19, 9, -8, -24, -27, -15, 9, 31, 37, 21, -11, -41, -50, -29, 12, 53, 66, 41, -14, -68, -89, -57, 15, 89, 119, 80, -16, -119, -166, -116, 17, 168, 245, 182, -18, -268, -424, -349, 18, 623, 1297, 1824, 2024.

1.3 An Optional Third Band

A third GC2011 chip can be configured to cover the range from $0.35F_S$ to $0.5F_S$. The third chip is configured identical to the L-band GC2011 chip, except that the input data is mixed down by $F_S/2$ before filtering. The mix down by $F_S/2$ is accomplished by multiplying the input data by the alternating sequence $+/-1$. I.E., multiply the even samples by $+1$, and the odd samples by -1 . Since the data is fanned out by two, the odd samples can be multiplied by -1 by simply choosing the "always negate" input mode for the B-path in the GC2011 chip (see bits 10-12 of address 2). The output spectrum will be inverted by the $F_S/2$ mix. The inversion can be removed by multiplying the output sequence by alternating $+/-1$. This is done by setting the NEG_OUT control in the GC2011 to negate full rate output samples (see bits 0 and 1 in address 7).

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products

Amplifiers	amplifier.ti.com
Data Converters	dataconverter.ti.com
DSP	dsp.ti.com
Clocks and Timers	www.ti.com/clocks
Interface	interface.ti.com
Logic	logic.ti.com
Power Mgmt	power.ti.com
Microcontrollers	microcontroller.ti.com
RFID	www.ti-rfid.com
RF/IF and ZigBee® Solutions	www.ti.com/lprf

Applications

Audio	www.ti.com/audio
Automotive	www.ti.com/automotive
Broadband	www.ti.com/broadband
Digital Control	www.ti.com/digitalcontrol
Medical	www.ti.com/medical
Military	www.ti.com/military
Optical Networking	www.ti.com/opticalnetwork
Security	www.ti.com/security
Telephony	www.ti.com/telephony
Video & Imaging	www.ti.com/video
Wireless	www.ti.com/wireless

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright 2008, Texas Instruments Incorporated