FlexRadio Systems
Software Defined Radios

Introducing the FLEX-5000A
Ultra High Performance Software Defined Radio

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With the introduction of the FLEX-5000 family, Software Defined Radio transceivers enter the second generation for amateur radio applications. In May of 2003, FlexRadio Systems shipped the first GPL Open Source Software Defined Radio Transceiver for amateur radio use. Many TAPR members were early adopters as well as contributors to the open source development. The HPSDR project and SoftRock (Tony Parks, KB9YIG) kits sprang from the FlexRadio users and email reflector.

The original SDR-1000 was simply an amateur radio hobby project that turned out better than any of us expected. Over the last four years, it evolved from the original three-board kit running a VB6 console into a full 100W HF transceiver and PowerSDR™. Frank Brickle (AB2KT) and Bob McGwier (N4HY) volunteered to design a new DSP core that built on the experimental SDR concepts demonstrated in SDRConsole™. They have delivered and continued to enhance a world-class radio DSP transceiver kernel called DttSP™. In early 2004, Eric Wachsmann (KE5DTO) joined FlexRadio to develop the new operating console, PowerSDR™. PowerSDR and DttSP have undergone literally thousands of improvements that are available to users on a daily basis through our public SVN server. There have been many open source contributors and beta testers who have contributed significantly to the development of this new technology.

Over the last four years, we have processed many suggestions from our SDR-1000 customers concerning what they would like to see in the second-generation transceiver. The FLEX-5000 family is the culmination of those suggestions as well as a few improvements of our own. The FLEX-5000 is a full duplex/triplex, HF-6m, 100W transceiver. Since it uses the same open source PowerSDR software, it leverages all of the SDR-1000 development while adding significant new features and performance enhancements. SDR-1000 users have already benefited from improvements derived from FLEX-5000 development such as enhanced CW and digital mode performance and better calibration techniques.

The FLEX-5000 delivers top class receiver performance as independently measured by Sherwood Engineering, Inc. Their measurements (provided by permission herein) of narrow spaced, two-tone, third order, IMD dynamic range, places the FLEX-5000 as the top performing amateur radio product at 96 dB according to their website update of April 23, 2007. Note that the data on the FLEX-5000 was just received directly from Sherwood and has not yet been posted to their website. Narrow spaced IP3 was reported at +29 dBm. The FLEX-5000 does not degrade at any close spacing, even below 2 kHz. Note that Sherwood uses a 1dB rise in the noise floor to measure IP3 instead of the S5 IM3 method used by the ARRL. Therefore the Sherwood number for IP3 is phase noise limited. Our published numbers use the ARRL lab method to measure IP3 and IMD DR3. Depending on the band in use, we measure +33 dBm to +40 dBm using the S5 method at 2 kHz tone spacing.

The FLEX-5000 is designed with three completely independent (triplex) RF signal paths. The FLEX-5000A provides full duplex signal paths that provide for satellite operation, cross band operation, and built in test equipment. The receiver can even monitor to the transmitter output to allow development of transmitter pre distortion software to improve PA linearity. A second full performance receiver option will be available in a few months that will allow triplex operation. That means that you could be monitoring 6m on a panadapter display while simultaneously carrying on a QSO on 20m. It further opens the door for SO2R in a box.

What about Digital and Experimentation?

The Flex 5000, with its independent receivers will allow us to have an all software tuned broadside endfire tuned array of verticals. We will be able to do spatial diversity of other types as well. We have already seen that the Flex 5000 has 192 kHz wide IF. This provide opportunities and challenges. The modifications to the receiver and transmitter which provide the increased performance, also cause us to have to work hardware to deliver excellent features in a SSB base band radio. Elsewhere in this conference, the image rejection algorithm needed to ensure this radio is the ultimate SSB radio with a clean transmitter is discussed. It applies to both the transmitter and the receiver. The DttSP experimentation in the next few months will include the ability to take watch receivers (software on the

same IF) or the second hardware receiver and do adjacent channel and splatter mitigation. We will be adding impulse characterization and detection to our noise elimination apparatus. Impulse noise is a real killer on HF communications whether it be digital or voice.

Flex radio built a virtual sound card support system into PowerSDR. It made use of the polyphase resampler in DttSP to adapt the virtual sound card rate to that expected by the digital programs such as MixW. Virtual com ports allow for external control by these same digital programs. In addition to this, the Flex 5000 has extremely versatile inputs and outputs for audio and a separate computer or program and sound card could be used to run these programs but these need wires.

The flexibility and open source nature of the DttSP and PowerSDR projects should be a major enabler of digital experimentation on the HF band. We could easily transmit and receive signals much wider than are probably legal. It will be interesting to see if the low power flux density of some experimental use of these wide band HF modems could even be detectable to the average HF user. This experimentation will likely need to be conducted under an STA but the Flex 5000 and possibly some HPSDR equipment not yet available will be the only platforms that will easily allow this new digital experimentation.

And in conclusion

The FLEX-5000 is a family of three models, the first of which is the FLEX-5000A that connects to the customer's PC over a single IEEE-1394 cable. The FLEX-5000C integrates the PC into the radio and the FLEX-5000D will add a 9-inch touch screen display, 300W PA, and standard second receiver and ATU. A complete feature comparison is provided below. The FLEX-5000 family of amateur radio transceivers provides a hardware platform that will allow significant new software developments to occur. Many of these enhancements will even benefit SDR-1000 owners because they use the same PowerSDR software. Stay tuned for years to come because this is a Software Defined Radio.

Sherwood Engineering Receiver Test Form

Mode: SDR-5000A Serial # 3207-5025 Test Date: 08/15/2007

IF BW 6.6 kHz –6 / -60, kHz	6.60 / 6.74	Ultimate	86 noise	dB	
IF BW 2.4 kHz –6 / -60, kHz	2.39/ 2.54	Ultimate	90 noise	dB	
IF BW 500 Hz –6 /-60, Hz	500 / 640	Ultimate	98 noise	dB	
Front End Selectivity (A – F)		11th order low pass		B+	
First IF (image) Rejection @ +/- 18 kHz			90	dB	
Dynamic Range 50 kHz		dB	IP3		dBm
Dynamic Range 20 kHz	96	dB	IP3	+29	dBm #
Dynamic Range 5 kHz	96	dB	IP3	+29	dBm
Dynamic Range 2 kHz		dB	IP3		dBm
Dynamic Range 1 kHz		dB	IP3		dBm
Blocking above noise floor at 100 kHz spacing w/ 1.0 uV signal			123		dB

Phase noise (normalized) at 10 kHz spacing:	-123 (flat)	dBc *
Noise floor, SSB bandwidth 14 MHz, preamp off / on	-115/-127	dBm
Noise floor, CW bandwidth 14 MHz, preamp off / on	-123/-135	dBm
Sensitivity at 14 MHz, preamp off / on	1.3 / 0.3	uV
Noise floor, SSB, 10 MHz	-128	dBm
Noise floor, CW, 10 MHz	-135	dBm
Sensitivity 10 MHz	0.25	uV
Noise floor, SSB, 5 MHz	-128	dBm
Noise floor, CW, 5 MHz	-135	dBm
Sensitivity 5 MHz	0.25	uV
Noise floor, SSB, 2 MHz	-122	dBm
Noise floor, CW, 2 MHz	-130	dBm
Sensitivity, 2 MHz	0.6	uV
Noise floor, SSB, 1 MHz	-122	dBm
Sensitivity, 1 MHz	0.5	uV
Noise floor, SSB, 200 kHz	-122	dBm
Sensitivity, 200 kHz	0.6	uV
AGC Threshold at -3 dB, preamp off / on (Depends on setting of AGC threshold / RF gain setting) (Was set at 100 out of max setting of 120)	2.0 / 0.5	uV
Drift		1 Hz
Notch filter (auto notch)		35 dB
Preamp		16 dB
Attenuator		None

Distortion:	SSB		AM		AM Sync	
100 Hz	<0.1	%	<0.3	%	<0.3	%
200 Hz	<0.1	%	<0.3	%	<0.3	%
400 Hz	<0.1	%	<0.3	%	<0.3	%
1 kHz	<0.1	%	<0.3	%	<0.3	%
2 kHz	<0.1	%	<0.3	%	<0.3	%
3 kHz	<0.1	%	<0.3	%	<0.3	%

IP3 was calculated from the noise floor and the dynamic range. The S5 method was NOT used.

* Phase noise does not fall off at 6 dB per octave as expected. Flex believes the present phase noise limitations are caused by A/D clock jitter.

Features and Options	SDR-1000	FLEX-5000A	FLEX-5000C	FLEX-5000D
Industry leading **2 KHz** spacing, two-tone, third-order dynamic range performance (IMD DR3 @ 14 MHz Using S5 IM3 Measurements)	99 dB[1] Preamp Med	>100 dB Preamp Off	>100 dB Preamp Off	>100 dB Preamp Off
Top performing **2 KHz** spacing third-order intercept point (IP3 @ 14 MHz Using S5 IM3 Measurements)	+26 dBm[1] Preamp Med	+33 dBm Preamp Off	+33 dBm Preamp Off	+33 dBm Preamp Off
Receiver frequency range (MHz) [optimized for amateur bands]	1.8 – 60 MHz	1.8 – 60 MHz	1.8 – 60 MHz	1.8 – 60 MHz
Transmitter frequency range (MHz)	160-6m Amateur Bands	160-6m Amateur Bands	160-6m Amateur Bands	160-6m Amateur Bands
Operating modes	USB, LSB, DSB, CWL, CWU, AM, SAM, DRM, DIGIU, DIGIL FM (narrow)	USB, LSB, DSB, CWL, CWU, AM, SAM, DRM, DIGIU, DIGIL FM (narrow)	USB, LSB, DSB, CWL, CWU, AM, SAM, DRM, DIGIU, DIGIL FM (narrow)	USB, LSB, DSB, CWL, CWU, AM, SAM, DRM, DIGIU, DIGIL FM (narrow)
RF power output	100W 160-10m 0.5W 6m	100W 160-6m	100W 160-6m	300W 160-10m, 100@ 6m
Frequency stability [after warm up]	No data	± 0.5 ppm	± 0.5 ppm	± 0.005 ppm
DDS clock frequency	200 MHz	500 MHz	500 MHz	500 MHz
Control interface	USB or Parallel	External IEEE 1394	Internal IEEE 1394	Internal IEEE 1394
TX/RX Antenna connections	(1) BNC	(3) SO-239	(3) SO-239	(3) SO-239
RX only antenna connections	N/A	RX1 (BNC) [2] RX2 (BNC)	RX1 (BNC) [2] RX2 (BNC)	RX1 (BNC) [2] RX2 (BNC)
Transmitter 1 antenna routing options	BNC	ANT1, ANT2 or ANT3	ANT1, ANT2 or ANT3	ANT1, ANT2 or ANT3
Receiver 1 antenna routing options	BNC	ANT1, ANT2, ANT3 or RX1	ANT1, ANT2, ANT3 or RX1	ANT1, ANT2, ANT3 or RX1
Receiver 2 antenna routing options	N/A	RX1 (tap) or RX2	RX1 (tap) or RX2	RX1 (tap) or RX2
Physical dimensions (inches)	10.00" W 4.50" H	9.27" W 8.72" H	17.67" W 8.72" H	44.9 cm W 22.1 cm H

Features and Options	SDR-1000	FLEX-5000A	FLEX-5000C	FLEX-5000D
	9.50" D	12.4" D	14.67" D	37.3 cm D
Physical dimensions (cm)	24.1 cm W 11.4 cm H 25.4 cm D	23.5 cm W 22.1 cm H 31.5 cm D	44.9 cm W 22.1 cm H 37.3 cm D	44.9 cm W 22.1 cm H 37.3 cm D
Open Source PowerSDR™ DSP/User Interface software compatible				
192 KHz wide, low-latency Panadapter spectrum display				
Narrow band, real-time spectrum analyzer				
Point and click snap tuning of signals on spectrum display				
Balanced & unbalanced microphone inputs				
Two year factory warranty				
External PTT controls				
High volume, internally mounted, quiet cooling fan				
Audio line-in & line-out (RCA jacks)				
Three (3) RCA keying outputs	DB-15 Connector			
QSK	Semi QSK Only			
External frequency reference input	Optional			
Internal 2 meter transverter	Optional	Future Option	Future Option	Future Option
Full duplex transmit and receive on HF-6m and external transverters				
Built-in ultra-high performance A/D and D/A converters (external sound card not required)				
Variable bias for class A, AB power amplifier control				
11th order optimized receive filters for each ham band 160-6m				
Self test & diagnostics with				

Features and Options	SDR-1000	FLEX-5000A	FLEX-5000C	FLEX-5000D
built-in signal generator				
Receiver can monitor transmitter output	✗	✓	✓	✓
External transverter ready through 2 BNCs on back panel	✗	✓	✓	✓
Headphone, powered speaker, and line-level output jacks	✗	✓	✓	✓
Receiver in/out BNC for external dedicated receive antenna, filters and preamps	✗	✓	✓	✓
FlexWire™ connector for future peripheral control modules	✗	✓	✓	✓
High speed T/R switching for digital modes	✗	✓	✓	✓
Peak reading wattmeter	✗	✓	✓	✓
High performance, fully independent second receiver	✗	Optional	Optional	✓
True diversity reception	✗	Requires optional second receiver	Requires optional second receiver	✓
Internal AC power supply	✗	✗	Optional	✓
High-speed ,*fully integrated*, Core2 Duo processor	✗	✗	✓	✓
Internet access capable (requires local broadband access)	✗	✗	✓	✓
Video monitor connector on the transceiver	✗	✗	✓	✓
Integrated internal 7W audio amplifier and speaker	✗	✗	✓	✓
Wireless keyboard and mouse included	✗	✗	✓	✓
Nine inch (9”) touch screen LCD display	✗	✗	✗	✓
Front panel main tuning knob	✗	✗	✗	✓

All features and specifications are subject to change without notice.

✓ Feature included. ✗ Feature not available. ⚠ Line-in / line-out I/Q audio only. ℹ Cooling fan front mounted.

Note 1: Dependent on the sound card used. (All values stated are for the M-Audio Delta-44)
Note 2: RX1 can be configured as an in/out loop for adding pre-selectors or preamps. The RX signal is routed in through ANTx out to RX1 and looped back to RX2.