X12-600 Theory of Operation
8/7/01

X12-600 Overview

The X12-600 is an ECG amplifier with digital conversion and integrated RF transmitter. The ECG amplifier is a 12 lead device with diagnostic quality digital conversion. The RF transmitter operates in the TV channels 37 through 41 (608 to 632 MHz) meeting FCC Part 15.242. The X12 has a detachable light weight 12 lead patient cable. The X12-600 operates from 2 AA Alkaline batteries for over 30 Hours. When the battery compartment is removed, a power switch and RF channel select switches are exposed. The front panel has a two button keypad and a 51x27 mm segment LCD. The overall dimensions are 140x67x25 mm.

The X12 is made up of two circuit boards sandwiched together inside the unit. A single 8 pin header provides interconnectivity. The two boards are the Mortara Front End Card (MFC) and the Mortara Transmit Card (MTC). The MFC is screwed to the back half of the plastic housing. The MTC is screwed to the front plastic housing. The LCD is held in place by the MTC with conductive rubber strips. The rubber strips pass the electrical signals from the MTC to the LCD.

Exiting from the top of the unit is a 45mm long antenna. Internal attachment to the PC board is via a standard SMA connector. The antenna is collared by the case thus it is not replaceable unless the case is disassembled. The case mounting screws are hidden by the back label preventing easy removal. The mechanical antenna capture technique is identical to the FCC approved X12-915 (HJR-X12-915).

Mortara Front End Card (MFC)

The MFC is a low power ECG front end that converts the analog patient signals to digital data. The MFC is designed to operate in handheld or portable devices and to operate from two AA alkaline batteries. The MFC has the patient cable connector mounted directly on the PC board. The digital data and clock interface to the transmit card is through an 8 pin header. There is no isolation boundary required for this board so all signals and power lines connect directly to the transmitter.

The two AA Alkaline batteries connect to the MFC through the slide switch. The battery voltage is stepped up to 5 volts by switching regulators U2. This step up supply can operate with the two AA batteries down to ½ volt each. This effectively uses all the energy stored in the batteries. The 5V output is first linear regulated (U3) to 4.3V and then linear regulated (U4) to 3.3V. The 4.3V is only used to power the linear op amps. The 3.3V is 1% accurate and powers the custom A/D converter, voltage references, and other logic components. The linear regulator U3 keeps the MFC in reset until the supply is within operating range.

The ECG signals are digitized by a custom 8 channel A/D converter with 20 bit resolution (U1). The A/D is clocked by the 5.12 MHZ clock from the transmit card. The true sample rate for each channel is 10 KHz. A 2.56 MHz serial data stream comprised of all 8 channels encoded in 32 bit packets is sent to the transmit card for processing .

Mortara Transmit Card (MTC-600)

The X12-600 processing is performed by a Motorola 68HC711 microcontroller on the MTC board. The microcontroller runs at the system clock speed of 5.12 MHz. Besides processing the digital ECG data the microcontroller performs the following tasks.

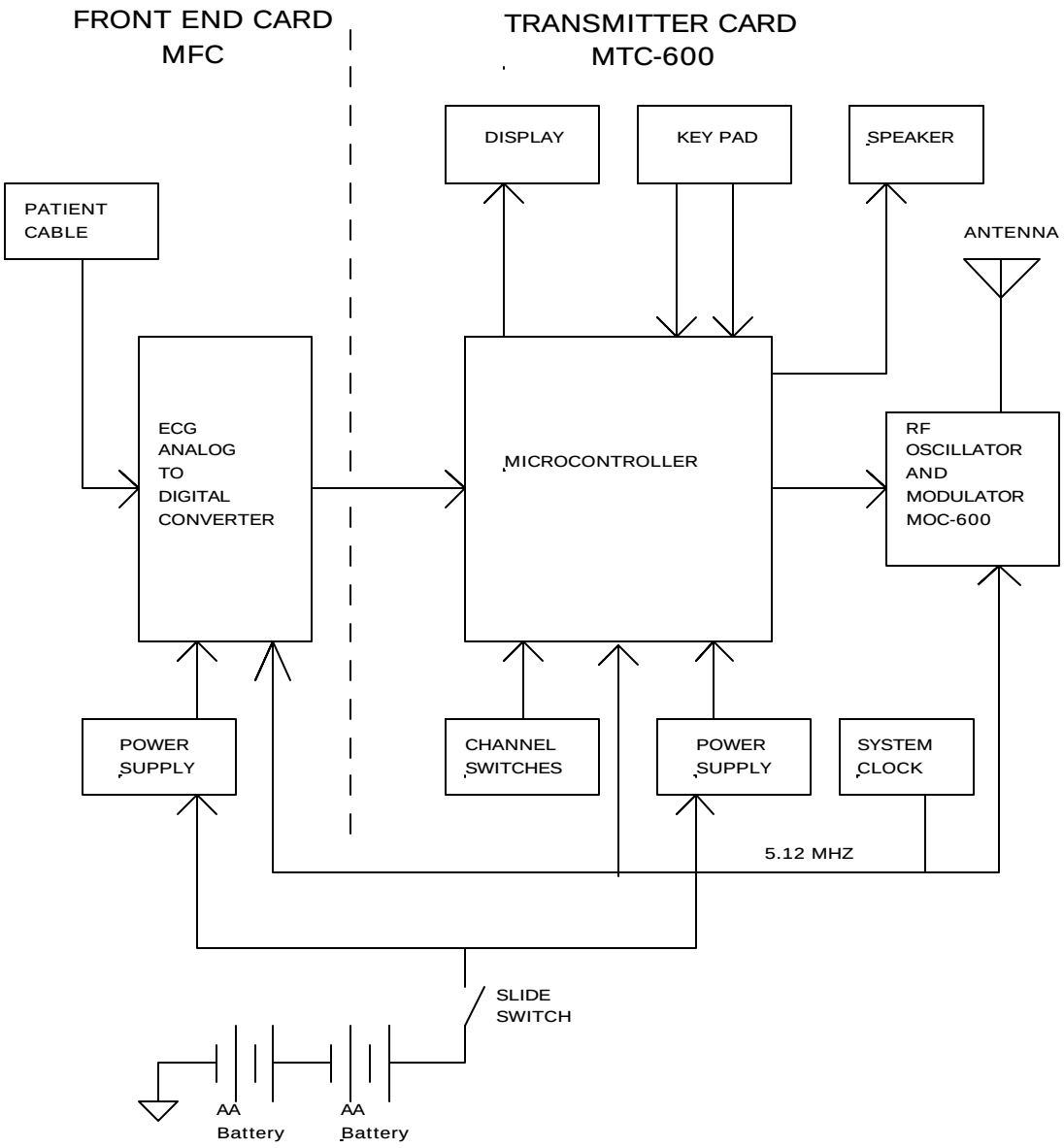
* Writing data to the LCD controller (U13).
* Reading the RF channel select switches (S2 and S3).
* Reading the key pad.
* Activating the speaker tones.
* Program the RF oscillator phase locked channel.

The two AA Alkaline batteries connect to the MTC through the slide switch. The battery voltage is stepped up to 3.3 by switching regulator U3. This step up supply can operate with the two AA batteries down to ½ volt each. This effectively uses all the energy stored in the batteries. U2 provides a regulation drop out flag that will reset the processor when the 3.3V switcher supply drops below a defined threshold. This condition occurs either at start-up or at battery depletion. Either case, halting the processor prevents transmission of erroneous data or other system malfunction until the supplies are valid. The microcontroller, other logic, and RF oscillator are all powered by the 3.3V supply.

The RF oscillator is controlled by a phase locked loop (PLL). The PLL is programmed by the microcontroller based on the channel switch settings. The channel switches and subsequently the channel itself have hexadecimal labels. The lowest channel is 00 and the highest channel is FF. The Table I. below lists the channel numbers and the center RF frequencies.

The 2.56 MHz serial data stream from the MFC A/D converter is first processed by U9 the Receiver Gate Array. This device decimates the 10KHz sample rate and formats the data for each sample and channel into two 16 bit words. The effective sample rate out the Receiver is 500 Hz for each channel. The output data is dumped into FIFO's U7 and U9. When the microcontroller U4 is ready, it reads the data samples from the FIFO's.

The microcontroller processes the ECG data including detecting lead fail. If lead fail is detected the display driver is also informed resulting in the lead fail message being displayed. If in the impedance check mode the microcontroller detects the small stimulus voltages in the data for its magnitude and derives the quality of electrode placement. Finally, the ECG data, lead fail data, error correction, RF channel number, pace maker detect, and ancillary data is formatted into a 40K baud serial data stream. This data stream is Gaussian Filtered then FM modulates the RF carrier with a 20 KHz deviation.



X12-600 Block Diagram

Table I. X12-600 Channel Assignments

TV37		TV38		TV39		TV40	
CH#	MHz	CH#	MHz	CH#	MHz	CH#	MHz
00	608.48	40	614.48	80	620.48	C0	626.48
01	608.56	41	614.56	81	620.56	C1	626.56
02	608.64	42	614.64	82	620.64	C2	626.64
03	608.72	43	614.72	83	620.72	C3	626.72
04	608.8	44	614.8	84	620.8	C4	626.8
05	608.88	45	614.88	85	620.88	C5	626.88
06	608.96	46	614.96	86	620.96	C6	626.96
07	609.04	47	615.04	87	621.04	C7	627.04
08	609.12	48	615.12	88	621.12	C8	627.12
09	609.2	49	615.2	89	621.2	C9	627.2
0A	609.28	4A	615.28	8A	621.28	CA	627.28
0B	609.36	4B	615.36	8B	621.36	CB	627.36
0C	609.44	4C	615.44	8C	621.44	CC	627.44
0D	609.52	4D	615.52	8D	621.52	CD	627.52
0E	609.6	4E	615.6	8E	621.6	CE	627.6
0F	609.68	4F	615.68	8F	621.68	CF	627.68
10	609.76	50	615.76	90	621.76	D0	627.76
11	609.84	51	615.84	91	621.84	D1	627.84
12	609.92	52	615.92	92	621.92	D2	627.92
13	610	53	616	93	622	D3	628
14	610.08	54	616.08	94	622.08	D4	628.08
15	610.16	55	616.16	95	622.16	D5	628.16
16	610.24	56	616.24	96	622.24	D6	628.24
17	610.32	57	616.32	97	622.32	D7	628.32
18	610.4	58	616.4	98	622.4	D8	628.4
19	610.48	59	616.48	99	622.48	D9	628.48
1A	610.56	5A	616.56	9A	622.56	DA	628.56
1B	610.64	5B	616.64	9B	622.64	DB	628.64
1C	610.72	5C	616.72	9C	622.72	DC	628.72
1D	610.8	5D	616.8	9D	622.8	DD	628.8
1E	610.88	5E	616.88	9E	622.88	DE	628.88
1F	610.96	5F	616.96	9F	622.96	DF	628.96
20	611.04	60	617.04	A0	623.04	E0	629.04
21	611.12	61	617.12	A1	623.12	E1	629.12
22	611.2	62	617.2	A2	623.2	E2	629.2
23	611.28	63	617.28	A3	623.28	E3	629.28
24	611.36	64	617.36	A4	623.36	E4	629.36
25	611.44	65	617.44	A5	623.44	E5	629.44
26	611.52	66	617.52	A6	623.52	E6	629.52
27	611.6	67	617.6	A7	623.6	E7	629.6
28	611.68	68	617.68	A8	623.68	E8	629.68
29	611.76	69	617.76	A9	623.76	E9	629.76
2A	611.84	6A	617.84	AA	623.84	EA	629.84
2B	611.92	6B	617.92	AB	623.92	EB	629.92
2C	612	6C	618	AC	624	EC	630
2D	612.08	6D	618.08	AD	624.08	ED	630.08
2E	612.16	6E	618.16	AE	624.16	EE	630.16
2F	612.24	6F	618.24	AF	624.24	EF	630.24
30	612.32	70	618.32	B0	624.32	F0	630.32
31	612.4	71	618.4	B1	624.4	F1	630.4
32	612.48	72	618.48	B2	624.48	F2	630.48
33	612.56	73	618.56	B3	624.56	F3	630.56
34	612.64	74	618.64	B4	624.64	F4	630.64
35	612.72	75	618.72	B5	624.72	F5	630.72
36	612.8	76	618.8	B6	624.8	F6	630.8
37	612.88	77	618.88	B7	624.88	F7	630.88
38	612.96	78	618.96	B8	624.96	F8	630.96
39	613.04	79	619.04	B9	625.04	F9	631.04
3A	613.12	7A	619.12	BA	625.12	FA	631.12
3B	613.2	7B	619.2	BB	625.2	FB	631.2
3C	613.28	7C	619.28	BC	625.28	FC	631.28
3D	613.36	7D	619.36	BD	625.36	FD	631.36
3E	613.44	7E	619.44	BE	625.44	FE	631.44
3F	613.52	7F	619.52	BF	625.52	FF	631.52