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**A CAMAC Modular
Programmable Function
Generator**

G. W. Turner
S. Suehiro
R. W. Hendricks

**OPERATED BY
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DEPARTMENT OF ENERGY**

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Metals and Ceramics Division

A CAMAC MODULAR PROGRAMMABLE FUNCTION GENERATOR

G. W. Turner, S. Suehiro, and R. W. Hendricks

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A CAMAC MODULAR PROGRAMMABLE FUNCTION GENERATOR

G. W. Turner,* S. Suehiro,[†] and R. W. Hendricks

ABSTRACT

A CAMAC modular programmable function generator has been developed. The device contains a 1024 word by 12-bit memory, a 12-bit digital-to-analog converter with a 600 ns settling time, an 18-bit programmable frequency register, and two programmable trigger output registers. The trigger registers can produce programmed output logic transitions at various (binary) points in the output function curve, and are used to synchronize various other data acquisition devices with the function curve.

INTRODUCTION

In our laboratory small-angle x-ray and neutron scattering experiments are performed on instruments which are operated with pinhole collimation and which are equipped with two-dimensional position sensitive detectors.¹⁻³ It has been found that the data acquisition rates with these instruments are sufficiently high that dynamic experiments performed during crystallization of polymers in situ in the x-ray beam are feasible.⁴ In addition, the high speed and the time-switching capabilities of the data acquisition system available on these instruments¹ lead one of us (RWH) to propose that dynamic experiments performed in situ during the mechanical deformation of polymeric and biological samples could be performed.^{1,5,6} For such experiments to be successful, it is necessary to: (1) deform the sample under programmably variable stress-strain relationships, (2) record the stress-strain during the deformation, (3) synchronize the acquisition

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of the small-angle scattering diffraction pattern with the deformation, and (4) switch between acquisition arrays in memory at known and programmable times in the deformation cycle.

The availability of a fast-response CAMAC crate controller⁷ for the ModComp computers used with our small-angle scattering cameras made a CAMAC data acquisition system a logical choice for the complex control system required by this problem. With the exception of a programmable function generator capable of providing the necessary timing and synchronizing signals, all of the necessary CAMAC modules were commercially available. It is the purpose of this report to describe our development of such a CAMAC programmable function generator.

DESCRIPTION OF FUNCTION GENERATOR

Overview

A block diagram of the programmable function generator is shown in DWG Q-5747-1* and photographs of the completed module are shown in Fig. 1. The CAMAC functions to which it responds are given in Table 1. As may be seen in the block diagram, the module has been designed to store and independently execute a program (CAMAC loaded and controlled) to drive the digital-to-analog converter (DAC) which generates a -10 V to +10 V analog signal. The module has a $1K \times 12$ -bit random access memory (RAM) and an independent program counter (PC) which are used to store and execute the program. An on-board 1 MHz clock is used to shift the stored memory contents (analog waveform) out to the 12-bit DAC. The clock frequency may be divided by a factor which ranges from 1 to 2^{18} and which may be loaded from the dataway. In addition, there are two independent synchronization signals, each of whose frequency may also be loaded from the dataway into separate registers. Logic has also been provided to control and select various LAM (interrupt) signals. A variety of status and control LED indicators have been provided on the front panel as may be seen in Fig. 1(a).

* The schematic drawings for the function generator are found as foldouts in Appendix A.

Fig. 1. The ORNL Q-5747 programmable function generator. (a) Front view, (b) wirewrap side.

Table 1. Programmable Function Generator CAMAC Commands

Function	Operation
F(0)A(0)	Read memory; advance memory address; Q = 1 on address overflow
F(16)A(0)	Write memory; advance memory address; Q = 1 on address overflow
F(17)A(0)	Load clock frequency register (W1-W18)
F(17)A(1)	Load trigger registers; (W1-W8 for C = M register; W9-W12 for ADC register)
F(10)A(1)	Clear ADC (C = T) LAM
F(10)A(2)	Clear PCOVFL (PC = 0) LAM
F(10)A(3)	Clear C = M LAM
F(11)A(0)	Module zero; clear PC; disable clock; disable all LAMs; clear all LAMs; clear all registers and latches.
F(24)A(0)	Disable LAM
F(24)A(1)	Disable ADC trigger (C = T) LAM
F(24)A(2)	Disable PCOVFL (PC = 0) LAM
F(24)A(3)	Disable C = M LAM
F(24)A(4)	Disable clock
F(25)A(0)	Execute; start function generator
F(25)A(1)	Advance PC
F(26)A(0)	Enable LAM
F(26)A(1)	Enable ADC trigger (C = T) LAM
F(26)A(2)	Enable PCOVFL (PC = 0) LAM
F(26)A(3)	Enable C = M LAM
Z	Same as F(11)A(0)
C	Same as F(11)A(0)

The various sections and their operation are described in the following paragraphs. The entire module has been constructed on a Standard Engineering Corp. WW-3 prototype wirewrap card. Low power Schottky (LS) TTL logic has been used throughout. (An exception is the CD4001 CMOS chip used in the clock circuit.) This was especially important because with standard TTL the high power consumption of several chips (notably the 'LS193 counters) made the power consumption of the module exceed the CAMAC specification of 2A on the +6 V power supply.

Memory and Program Counter

The Memory is a block of 1024×12 bits constructed from twelve Advanced Micro Devices AM9102 random access memory chips* (11A-13B). The AM9102 chips are 1024 bit static N-channel MOS devices organized as 1024×1 and have a power saving standby mode. Their access time is 650 ns. The RAMs are bused together on a 12-bit address bus as shown on Q5747-2. The memory is written into from the dataway (W1-W12) with $[F(16)A(0)]$; write memory and increment program counter. The write lines W1-W12 are enabled to the "data-in" leads of the RAMs by $\overline{WRT}$. This is a 300 ns negative pulse generated by the retriggeable, resettable monostable multivibrator in 10D when triggered by $[F(16)A(0)]$. $\overline{WRT}$ enables the tristate hex bus drivers ('LS367) in 7G and 8G and is also bused to the write enable of the RAM. The memory address (A0-A9) is generated in the program counter as discussed in the next paragraph. The data out (D01-D012) of the RAM is connected directly to the DAC input buffer (D01 LSB) and also to the 'LS367 hex bus drivers (8E and 8F) on Q5747-3. These drivers are enabled by $[F(0)A(0)]$ which gates D01-D012 onto R1-R12 of the dataway. Thus, data may be written from the dataway into memory, read from memory to the DAC, and read from memory onto the dataway.

The program counter (PC) generates the address for the memory. The PC is an incremental up counter built around LS193's (9E, 10A, 10B) as shown on Q5747-3. There are four conditions which may increment the PC: write data $[NF(16)A(0)S2']$; read data $[NF(0)A(0)S2']$, advance PC $[NF(25)A(1)S2']$, and $\overline{CLK'}$. (The latter is present only when the module is in the execute mode.) These four signals are ORed since any one should cause the memory address to be incremented. There are two conditions which can clear (zero) the PC. These are module zero $[MZ; F(11)A(0)]$ (on Q5747-2) and execute $[EXE; F(25)(A0)]$. MZ clears all registers including the PC and the memory. EXE clears the PC in order to force the memory to start at location zero when the function generator is started. This is accomplished by using the leading edge of EXE to clear the PC and the trailing edge to set the execute flag (see Q-5747-2).

*AM9102 are plug compatible with Intel 2102, Signetics 2602, Intersil IM7552, and Mostek 4102.

During operation of the module it is necessary to know when the memory goes through a full cycle and to have a signal available for external devices. In addition, if enabled, a LAM may be generated. The end of cycle is detected by NANDing the carry of the second PC counter with the two high order bits of the third counter. This signal presets the overflow flag and is gated onto the Q line of the dataway with N'. The overflow flag is cleared with the next S2'. With this procedure, it is possible to either read or write the entire memory (1024 words) in the Q-stop controlled block transfer mode.⁸

Digital-to-Analog Converter

The digital-to-analog converter is a model DAC-DG12B1 from Datel-Intersil, Inc. The unit is a 12-bit DAC with a fast voltage output and is organized in three sections. These are: a 12-bit strobed digital input buffer, an ultra-fast 12-bit current conversion block with a deglitched switch and a stable Zener reference, and a fast-response operational amplifier. The DAC and associated logic are shown on Q-5747-2. The manufacturers specifications are given in Appendix B.

The required +15 and -15 V supplies are derived from /815 and /915 voltage regulators, respectively, which operate off the CAMAC +24 V and -24 V supplies. The +VCC logic supply which used to power the DAC input register is drawn from the +5 V regulator used to power the TTL logic. The DAC may be connected for 0-10 V, -5 to +5 V, or -10 to +10 V output peak to peak. We have implemented the latter by using pins 31 and 32 for the DAC output. The analog ground is connected to pins 29 and 30. Care has been taken to keep the analog ground separate from the digital ground to ensure maximum isolation and noise immunity for the output signal. External trim pots (100 Ω) are provided as shown for the gain and bipolar offset adjustments. The gain adjustment assures a symmetrical plus and minus swing. The bipolar offset adjustment is to ensure that the digital code at the input register is calibrated to give the proper output. The 12-bit input register is connected to the twelve data bits from RAM D01-D012. The data are strobed into the register with STB' which is generated as shown on Q-5747-3. The leading edge of CLK' initiates a 650 ns

delay generated by the monostable multivibrator in 10C (on Q-5747-3). This delay is to ensure data D01-D012 are valid to the DAC before actually generating the strobe pulse (RAM worst case access = 650 ns). The 80 ns pulse produced at the end of the delay is the actual strobe. Note that STB' is locked out during a memory read to the dataway [F(0)A(0)] to ensure that the DAC is isolated from the data lines during a read operation.

Programmable Frequency Clock

The basic clock frequency of 1 MHz is provided by a crystal oscillator and a CMOS pulse-shaping circuit as shown in Q-5747-2. In order to ensure that the clock pulses are not clipped on either STOP or START, a 74120 pulse synchronizer is used to gate the clock signal. The clock is gated to three separate counters by a START flag which is derived from the EXE command [F(25)A(0)] through the flip-flop in 6A. The flag is clocked high enabling the synchronizer when EXE is given. Note that a memory read [F(0)A(0)], memory write [F(16)A(0)], disable clock [F(24)A(4)] and master clear (MZ) all clear the flag to ensure that the clock is disabled during these operations. This is important since accidentally operating the PC with CLK and Read or Write simultaneously would be catastrophic. This clock signal (CLK) is the base frequency for the programmable up counters. The preset number (binary divisor) is loaded in 2's complement and latched from the Dataway W1-W18 lines via the three hex D flip-flops (7A-7C) which connect to the counter preset lines. These latches are cleared with MZ and loaded with [F(17)A(0)S1'] (Load Clock Frequency register). It is important to note that the data loaded in the latches are then loaded into the counters at [F(17)A(0)S2']. In this way, when the module is started the first CLK' pulse will appear at the correct time following EXE. Otherwise, the first CLK' pulse would appear after 2^{18} pulses or 262 ms. The counters are used as modulo-N divider counters with the [F(17)A(0)S1'] data used as an off-set. The last carry out is used to edge trigger a D flip-flop producing CLK' (programmed clock) on the Q output. CLK' is also used to reload the latched preset number to the counters. The next CLK pulse will clear the flip-flop and the entire cycle will repeat.

The crystal oscillator frequency (1 MHz) can be divided by any binary number between 1 and 2^{18} . Since the PC always counts through 1024 locations, the frequency range of the function generator is from 0.003725 to 976.6 Hz.* Of course, if less resolution is required in the output waveform, more than one period of the desired function could be loaded into the memory in order to increase the output frequency.

Programmable Synchronization Registers

Two additional registers were implemented to allow programmed control of data acquisition. One signal is used to strobe a pair of CAMAC analog-to-digital converters (ADCs) which are connected to the sample displacement linear variable differential transformer (LVDT) signal conditioner and the load cell signal conditioner. In order to obtain accurate stress-strain relationships it is necessary to measure numerous points (e.g., 128) in each function generator cycle. Similarly, in order to synchronize the diffraction pattern data acquisition system with the function generator output, it is necessary at various pre-programmed times to signal either a Signetics 8X300 microcontroller^{1,9} or the Time Correlator of the new LASL-ORNL fast digital data acquisition system¹⁰ that they must change the origin of the data acquisition array. The ADC and Time Correlator triggers are strobe pulses, while the 8X300 signal is a latched handshaking signal which is cleared only

*With an 18-bit divisor and a 1 MHz clock, the high frequency repetition rates have little selectability. The available frequencies are $976.6 \cdot 2^{-n}$ ($n = 0, 1, 2, \dots, 262, 144$) or 976.6, 488.2, 325.5, 244.1, 195.3, 162.8, 139.5 For the present application, where we are concerned with the very low frequency region, such limitations are unimportant. However, in other applications where greater selectability at higher frequencies is necessary, two possibilities exist. If the present dynamic range is satisfactory, one must merely replace the crystal oscillator with one of higher frequency. On the other hand, if a greater dynamic range is required, it is straightforward to provide a 24-bit divisor by adding an 'LS193 counter, an 'LS174 data latch, and a hex 'LS04 inverter.

on acknowledgment by the 8X300. These two signals, labeled $C = T$ (ADC trigger) and $C = M$ (memory map) are generated in a manner similar to CLK' .

The two registers use the divided clock (CLK') as their base frequency. Although sharing the same base frequency the two registers are completely independent. They are loaded simultaneously with their preset numbers (in 2's complement); W1-W8 for $C = M$ and W9-W12 for $C = T$ (7D-7E). The preset number on W1-W12 is latched in the hex D flip-flops with [F(17)A(1)S1'] (Load Trigger Registers). The registers are connected to the preset of 'LS193 up/down binary counters which are used as modulo-N dividers. The data are loaded into the counters with [F(17)(A1)S2'] as with the programmable frequency clock in order to ensure proper synchronization with EXE. The carry out of 9C is used to edge trigger the D flip-flop in 14A which in turn uses $\overline{Q}$ to (a) reload the counters (9A-9C) to preset values, (b) to produce $\overline{C = M}$ for the flip-flop at 6A and (c) to provide the "1" for next edge trigger. The next CLK' (beginning of next cycle) will clear the $\overline{C = M}$ flip-flop (14A). The $\overline{C = M}$ signal is also latched and sent to the status input word of the microprocessor communication module⁹ (so it can be used to change the memory map). The flip-flop is cleared when the microprocessor responds with a status acknowledgment. The $\overline{C = T}$ signal (14A and 10D) is generated in the same manner as $\overline{C = M}$ utilizing the logic shown on Q5747-2. The $\overline{C = T}$ is used to trigger an adjustable (150-250 ns) monostable multivibrator in 10D which produces the negative asserted pulse which goes to the ADC trigger.

LAM Control Logic

It is often necessary to generate computer interrupts via the CAMAC LAM (look-at-me) signals when certain events occur. In the present module, depending on experimental conditions, it may be desirable to generate a LAM: (1) when $PC = 0$, (2) when $C = M$, or (3) when $C = T$ (i.e., when the address counter overflows, when the ADC trigger is set, or when the microprocessor communication module or Time Correlator trigger is set).

The logic on Q5747-3 performs this task. First, the LAM line itself may be enabled with an [F(26)A(0)S1'] or may be disabled with an

[F(24)A(0)S1' + MZ]. The enable/disable is controlled by an 'LS74 D flip-flop. The three signals which can generate a LAM are handled similarly. They may all be selectively enabled or disabled, and the actual LAM may be selectively cleared (allowing priority servicing). The enable is implemented with [F(26)A(n)S1'], disable is [F(24)A(n)S1'] and clear is [F(10)A(n)S1']. The three subaddresses are organized as follows: A(1) - ADC trigger; A(2) - PC = 0; and A(3) - C = M trigger. The logic is organized similarly for all three with the left bank of D flip-flops used as an enable/disable latch which opens or closes the appropriate gate leading to the LAM logic. The actual signals are latched in the right bank of D flip-flops and remain there until they are selectively cleared. Front panel LEDs indicate which LAM is enabled and whether or not a LAM is present. The LAM status is displayed until cleared by [F(10)A(n)S1'].

SOFTWARE

A function generator driver program called FGEN has been coded in top-down structured FORTRAN¹¹ using the SFORTRAN precompiler.¹² A source listing is given in Appendix C. This program contains six sections:

- (1) a function form generator,
- (2) write memory,
- (3) verify memory,
- (4) set frequency registers,
- (5) LAM enables, and
- (6) run/stop.

All CAMAC communication with the module is via the standard CAMAC sub-routines CFSA, CSSA, and CVSA as defined in the CAMAC tutorial articles⁸ and as implemented by King and Hendricks¹³ for the ORNL ModComp computers. The various commands to which the program responds are summarized in Table 2. The program response to each command guides the user as to what information is required and the necessary input format. Although this code currently generates sine, triangular or

Table 2. Summary of FGEN Commands

COMMAND*	Purpose
<u>EXIT</u>	Exit from program.
<u>HALT</u>	Stop function generator.
<u>LAM</u>	Enable, disable and clear LAMs.
<u>PARAM</u>	Enter execution parameters (frequency and trigger registers).
<u>RUN</u>	Start function generator in execution.
<u>VERIFY</u>	Read memory and compare with WRITE command.
<u>WRITE</u>	Write desired function curve into memory.

*The command may be abbreviated to the underlined characters. All commands must be terminated by a carriage return.

square waves, clearly any form of input can be easily coded. A typical operating sequence which loads and verifies the memory, loads the counter registers, and then starts the function generator in execution is shown in Example 1. It is important to note that once the generator is started in execution, FGEN is no longer required to remain in core. Thus, core can be utilized by other programs once the unit is running.

Acknowledgments

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```

JOB
$
ASS 5=TY 6=TY
$
EXE FGGEN
PROGRAM FGGEN
VERSION A.06 04 MAY 80
WHERE IS FG(I2)?
20
SELECT FUNCTION
WRITE
ENTER WAVE FORM
- 1(COSINE)
- 2(TRIANGULAR)
- 3(SQUARE)
AND VOLTAGE SCALE FACTOR BETWEEN 0.0 AND 10.0 (I1,F5.0)
3 5.
SELECT FUNCTION
VERIFY
VERIFY COMPLETE 8604
SELECT FUNCTION
PARAM
ENTER FREQ, NADC, AND NCM (F6.0,2I5)
(0.0038 <= FREQ <= 977.0 64 <= NADC <= 1024 4 <= NCM <= 1024)
100. 128 4
FREQUENCY = 108.5069 ( 0.1085069E+03) NADC = 128 NCM = 4
SELECT FUNCTION
LAM
ENTER - 0(ALL), 1(ADC TRIG), 2(PC=0), 3(C=M)
1
ENTER - C(CLEAR), D(DISABLE), E(ENABLE)
E
SELECT FUNCTION
LAM
ENTER - 0(ALL), 1(ADC TRIG), 2(PC=0), 3(C=M)
0
ENTER - C(CLEAR), D(DISABLE), E(ENABLE)
E
SELECT FUNCTION
RUN
SELECT FUNCTION
HALT
SELECT FUNCTION
EXIT
$

```

Example 1

Operator Response to Program FGGEN in Order to Load, Verify, and Start the FUNCTION GENERATOR in Operation.

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APPENDIX A

Circuit Diagrams

ORNL Model Q-5747 Programmable Function Generator

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APPENDIX B

Manufacturers' Specifications*

DATEL — INTERSIL MODEL DAC-DG12B1

Digital-to-Analog Converter

*Taken with permission from DATEL "Modules for Data Conversion" handbook.

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FAST 12-BIT DEGLITCHED DAC

MODEL DAC-DG12B

FEATURES

- ▶ ± 2 LSB Max. Glitch
- ▶ 600 nsec. Settling Time
- ▶ Up to 2.5 MHz Update Rate
- ▶ 12 Bit Resolution
- ▶ Self-Contained Module

GENERAL DESCRIPTION

Model DAC-DG12B is a deglitched 12-bit D/A converter with a fast voltage output. The maximum output glitch amplitude is ± 2 LSB's while settling time for a 10 volt output change is 600 nsec. to 1 LSB. For a 10 volt change to 1% the settling time is 250 nsec., and for small output changes it is only 400 nsec., permitting update rates as fast as 2.5 MHz.

The unique circuit design of the DAC-DG12B realizes both small size and low price at the same time. Unlike other deglitched DAC's which are comprised of several inter-connected modules mounted on a circuit card, the DAC-DG12B is completely self-contained in a compact 4 x 2 x 0.4 inch (102 x 51 x 10 mm) module. It consists of several optimized circuit functions: digital input register, ultra-fast 12-bit current DAC, stable Zener voltage reference, fast deglitching switch, and a fast output operational amplifier.

The DAC-DG12B has three voltage output ranges determined by external pin connection: 0 to -10 V, ± 5 V and ± 10 V. Output current is ± 10 mA with output short circuit protection; for higher output current requirements an external current booster amplifier may be connected inside the feedback loop of the output amplifier. There are two input coding options: complementary binary/complementary offset binary or complementary two's complement.

The DAC-DG12B is an ideal device for fast CRT display applications and for other test and measurement applications where monotonic output changes are required.

MECHANICAL DIMENSIONS—INCHES (MM)

INPUT/OUTPUT CONNECTIONS

PIN	FUNCTION
1	+5 V POWER
2	5 V GND
3	STROBE
4	BIT 1 IN (MSB)
5	BIT 2 IN
6	BIT 3 IN
7	BIT 4 IN
8	BIT 5 IN
9	BIT 6 IN
10	BIT 7 IN
11	BIT 8 IN
12	BIT 9 IN
13	BIT 10 IN
14	BIT 11 IN
15	BIT 12 IN (LSB)
16	DIGITAL GND
18	+15 V POWER
19	-15 V POWER
20	15 V GND
21	OFFSET
22	REF OUT
23	REF IN
28	ANALOG GND
30	FEEDBACK 1
31	ANALOG OUT
32	FEEDBACK 2

SPECIFICATIONS, DAC-DG12B

(Typical at 25° C, ±15 V and ±5 V supplies unless otherwise noted)

INPUTS

Resolution	12 bits
Coding, unipolar	Complementary Binary
Coding, bipolar	Complementary Offset Binary Complementary Two's Comp. ¹
Input Logic Level, bit ON ("0")	0V to +0.8 V
Input Logic Level, bit OFF ("1")	+2.0 V to +5.5 V
Logic Loading	1 TTL load
Input Strobe Pulse ²	HJ to LO transition causes transfer of data from register to DAC.
Input Strobe Loading	2 TTL loads

OUTPUTS

Output Voltage, unipolar ³	0 to -10 V
Output Voltage, bipolar ³	±5 V, ±10 V
Output Current, S.C. protected	±20 mA typ., ±10 mA min.
Output Impedance, DC	0.05 ohm

PERFORMANCE

Linearity Error	±½ LSB max.
Differential Nonlinearity	±½ LSB max.
Zero Error, before trimming	±½ LSB max.
Gain Tempco	±35 ppm/° C max.
Offset Tempco, bipolar	±15 ppm/° C max.
Zero Tempco, unipolar	±5 ppm/° C of FS max.
Diff. Nonlinearity Tempco	±2 ppm/° C of FS
Monotonicity	0° C to 70° C
Settling Time, 10 V change to 1 LSB	600 nsec. typ., 700 nsec. max.
Settling Time, 20 V change to 1 LSB	1.0 µsec. typ., 1.2 µsec. max.
Settling Time, 10 V change to 1%	250 nsec. max.
Settling Time, 20 V change to 1%	550 nsec. max.
Settling Time, ±4 LSB change	400 nsec.
Slew Rate	50 V µsec.
Glitch Amplitude ⁴	±1 LSB typ., ±2 LSB max.
Glitch Area	250 mV-nsec.
Power Supply Rejection	0.01%/V supply

POWER REQUIREMENT	+15 VDC ±0.5 V @ 50 mA -15 VDC ±0.5 V @ 35 mA + 5 VDC ±0.25 V @ 230 mA
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PHYSICAL-ENVIRONMENTAL

Operating Temperature Range	0° C to 70° C
Storage Temperature Range	-55° C to +125° C
Case Size	4 x 2 x 0.4 inches (101.6 x 50.8 x 10.2 mm)
Case Material	Black Diallyl Phthalate per MIL-M-14
Pins	0.020" round, gold plated, 0.200 lg. min.
Weight	4 oz. max. (114 g)

NOTES

1. Because the analog output is inverted, in the bipolar mode the complementary offset binary code is equivalent to offset binary and the complementary two's complement code is equivalent to two's complement. See Technical Note 4.
2. Has same logic levels as data inputs.
3. Determined by external pin connection.
4. Measured with 20 MHz bandwidth oscilloscope at major carry (half scale) and at 7 transitions either side of major carry.

TECHNICAL NOTES

1. The sequence of operations inside the DAC-DG12B after the input strobe changes from HI to LO are:
 - a. the pulse transformer and switch are activated and turn ON
 - b. within 11 nanoseconds (typically) the data in the input register is transferred to the current DAC
 - c. during the next 19 nanoseconds (typically) the DAC output current changes
 - d. after 30 nanoseconds (typically) from the strobe change the pulse transformer and switch are deactivated, turning OFF
 - e. the output amplifier begins to change to its new output value
2. A 5 nanosecond minimum setup time is required for the input data to be valid before the input strobe goes from HI to LO. The input strobe then should not go HI again for at least 40 nanoseconds.
3. The maximum update rate for the DAC-DG12B is 25 MHz, based on the 400 nanosecond settling time for small output changes (±4 LSB's max.). For 10 V changes to 1% of final value the maximum update rate is 4 MHz and for 10 V changes to within 1 LSB of final value the maximum update rate is 1.6 MHz.
4. From the coding tables it should be noted that each model of the DAC-DG12B has its coding defined in two ways when operating in bipolar mode. For the DAC-DG12B1 the complementary offset binary coding with inverted (negative) analog output is the same as offset binary coding with non-inverted (positive) analog output except for an analog shift of 1 LSB. The converter therefore can be externally calibrated for either code. For the DAC-DG12B2 the complementary two's complement coding with inverted (negative) analog output is the same as two's complement coding with noninverted (positive) analog output except for an analog shift of 1 LSB.
5. The DAC-DG12B is internally calibrated at zero for unipolar operation, with a zero error of ±½ LSB maximum. In many applications, therefore, no external zero adjustment is required. For exact calibration the external zero adjustment should be used. The DAC-DG12B2 operates in unipolar mode except that its input code is complementary binary with the MSB inverted.
6. For higher output current drive capability a wideband current booster amplifier with unity voltage gain may be enclosed inside the feedback loop of the output amplifier.

ORDERING INFORMATION**DAC-DG12B****CODING**

1=COMP. BINARY/COMP. OFFSET BINARY
2=COMP. TWO'S COMPLEMENT

PRICES (1-9)**DAC-DG12B1 \$275.00****DAC-DG12B2 \$275.00****MATING SOCKETS: DILS-2
(2/MODULE) AT \$5.00/PAIR****TRIMMING POTENTIOMETERS:**

TP100 (100 ohms), TP10K (10 K ohms) AT \$3.00 EACH

For extended temperature range operation, the following suffixes are added to the model number. Consult factory for pricing.

-EX	-25° C to +85° C operation
-EXX-HS	-55° C to +85° C operation with hermetically sealed semiconductor components

THE DAC-DG12B IS COVERED BY GSA CONTRACT

TIMING DIAGRAMS

INTERNAL TIMING

EXTERNAL TIMING

CODING TABLES

UNIPOLAR OPERATION

SCALE	VOLTAGE RANGE	DAC-DG12B1
	0 TO -10 V	COMP. BINARY
0	0 0000	1111 1111 1111
0-1 LSB	-0 0024	1111 1111 1110
-1/4 FS	-2 5000	1011 1111 1111
-1/2 FS	-5 0000	0111 1111 1111
-3/4 FS	-7 5000	0011 1111 1111
-FS + 1 LSB	-9 9976	0000 0000 0000

BIPOLAR OPERATION

SCALE	VOLTAGE RANGE		DAC-DAC-DG12B1		DAC-DG12B2	
	$\pm 5 \text{ V}$	$\pm 10 \text{ V}$	COMP. OFFS. BIN	OFFSET BINARY	COMP. 2's COMP.	2's COMPLEMENT
+FS	+5 0000 V	+10 0000 V	1111 1111 1111	1111 1111 1111	0111 1111 1111	0111 1111 1111
+FS-1 LSB	+4 9976	+9 9951	1111 1111 1110	1111 1111 1111	0111 1111 1110	0111 1111 1111
0 + 1 LSB	+0 0024	+0 0049	1000 0000 0000	1000 0000 0001	0000 0000 0000	0000 0000 0001
0	0 0000	0 0000	0111 1111 1111	1000 0000 0000	1111 1111 1111	0000 0000 0000
-FS + 1 LSB	-4 9976	9 9951	0000 0000 0000	0000 0000 0001	1000 0000 0000	1000 0000 0001
-FS	-5 0000	10 0000		0000 0000 0000		1000 0000 0000

CONNECTIONS AND CALIBRATION

CALIBRATION PROCEDURE

Select the desired output voltage range (0 to -10 V, ± 5 V, or ± 10 V) and make the connections shown in the diagrams below. To calibrate refer to the coding tables on the previous page.

UNIPOLAR OPERATION (0 TO -10 V OUTPUT)

1. **Zero Adjustment:** Set the digital input code to 1111 1111 1111 and adjust the ZERO ADJ. potentiometer to give 0.0000 V output
2. **Gain Adjustment:** Set the digital input code to 0000 0000 0000 and adjust the GAIN ADJ. potentiometer to give 9.9976 V output

BIPOLAR OPERATION (± 5 V OR ± 10 V OUTPUT)

1. **Offset Adjustment:** Set the digital input code to 0111 1111 1111 (comp. offset binary), 1000 0000 0000 (offset binary), 1111 1111 1111 (comp. two's complement), or 0000 0000 0000 (two's complement) and adjust the BIPOLAR OFFSET ADJ. potentiometer to give 0.0000 V output
2. **Gain Adjustment:** Set the digital input code to 0000 0000 0000 (comp. offset binary), 0000 0000 0001 (offset binary), 1000 0000 0000 (comp. two's complement), or 1000 0000 0001 (two's complement) and adjust the GAIN ADJ. potentiometer to give 4.9976 V output (for ± 5 V range) or 9.9951 V output for ± 10 V range)
3. Repeat steps 1 and 2 to recheck adjustments

UNIPOLAR OPERATION—NO ZERO ADJ.

UNIPOLAR OPERATION—WITH ZERO ADJ.

BIPOLAR OPERATION

OUTPUT CONNECTIONS

APPENDIX C

Program FGEN Source Listing

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1 1 PROGRAM FGEN
1 2 C...
1 3 C... VERSION A.06 04 MAY 80
1 4 C...
1 5 DIMENSION KFRQ(2),KDATA(2)
1 6 INTEGER ANS(3),DATA(2)
1 7 INTEGER FNC,RD1,CLM,WT1,WT2,CL2,DIS,XEQ,ENB
1 8 INTEGER CDREGF
1 9 LOGICAL IS,ID,EXIT
1 10 DIMENSION IWAVE(1024,3),ICOS(1024),ITRI(1024),ISQU(1024)
1 11 EQUIVALENCE (IWAVE(1,1),ICOS(1)),(IWAVE(1,2),ITRI(1))
1 12 1,(IWAVE(1,3),ISQU(1))
1 13 DATA RD1/0/,CLM/10/,WT1/16/,WT2/17/,CL2/11/,DIS/24/,XEQ/25/,
1 14 1ENB/26/,IB/0/
1 15 C... CREATE WAVEFORM ( 2'S COMPLEMENT)
1 16 WRITE(6,8000)
1 17 READ(5,8005) N
1 18 DA=3.1415927/512.0
1 19 DOLOOP I=2,513
1 20 ICOSI=IFIX(2047.*COS(DA*FLOAT(I-1)))
1 21 ICOS(I)=ICOSI
1 22 ICOS(1026-I)=ICOSI
1 23 ITRII=1799-7*I
1 24 ITRI(I)=ITRII
1 25 ITRI(1026-I)=ITRII
1 26 ISQU(I)=-2047
1 27 ISQU(1026-I)=2047
1 28 ENDOLOOP
1 29 ICOS(1)=2047
1 30 ITRI(1)=1792
1 31 ISQU(1)=-2047
1 32 C... SET UP CAMAC LREG'S
1 33 IA=0
1 34 LREG=CDREGF(IB,N,IA)
1 35 IA=1
1 36 LREG1=CDREGF(IB,N,IA)
1 37 IA=4
1 38 LREG4=CDREGF(IB,N,IA)
1 39 C...
1 40 C... EXECUTE FUNCTIONS
1 41 C...
1 42 EXIT=.FALSE.
1 43 WHILE(.NOT.EXIT) DO
1 44 WRITE(6,8010)
1 45 READ(5,8015) IFNC
1 46 IF(IFNC.EQ.'WR') THEN
1 47 WRITE(6,8020)
1 48 READ(5,8025) IW,SF
1 49 SF=SF/10.
1 50 C... LOAD MEMORY
1 51 CALL RESETH(LREG,ISTAT)
1 52 DATA(1)=0
1 53 DOLOOP I=1,1024
1 54 IDATA =INVDFS(IFIX(SF*FLOAT(IWAVE(I,IW))))
1 55 CALL CSSA(WT1,LREG,IDATA,ISTAT,IERR)
1 56 ENDOLOOP
1 57 ELSEIF(IFNC.EQ.'VE') THEN
1 58 CALL RESETH(LREG,ISTAT)
1 59 C... VERIFY MEMORY
1 60 DOLOOP I=1,1024
1 61 CALL CSSA(RD1,LREG,IDATA,ISTAT,IERR)
1 62 IF(IDATA.GT.2047) IDATA=IDATA-4096
1 63 IWAV=INVDFS(IFIX(SF*FLOAT(IWAVE(I,IW))))
1 64 IF (IERR.NE.0.OR.IWAV.NE.IDATA) THEN
1 65 WRITE(6,8040) I,IWAV,IDATA,ISTAT
1 66 ENDF
1 67 ENDOLOOP
1 68 CALL CSSA(RD1,LREG,IDATA,ISTAT,IERR)
1 69 WRITE(6,8045) ISTAT

```

```

1 70      ELSEIF (IFNC.EQ.'PA') THEN
1 71 C... INPUT PARAMETERS
1 72      WRITE(6,8050)
1 73      READ(5,8055) FREQ,NADC,NCM
1 74      WHILE (FREQ.LE.0.0.OR.NADC.LE.0.OR.NCM.LE.0) DO
1 75          WRITE(6,8090)
1 76          READ(5,8055) FREQ,NADC,NCM
1 77      ENDDO
1 78      FRQ=1000./1.024/FREQ
1 79      IF (FRQ.LT.1.) FRQ=1.
1 80      IF (FRQ.GT.262143.) THEN
1 81          FRQ=0.
1 82          FREQX=1./1.024/262.144
1 83      ELSE
1 84          FREQX=1000./1.024/AINT(FRQ)
1 85      ENDIF
1 86      IF (NADC.GT.1024) NADC=1024
1 87      IF (NADC.LT.64) NADC=64
1 88      IF (NCM.GT.1024) NCM=1024
1 89      IF (NCM.LT.4) NCM=4
1 90      WRITE(6,8056) FREQX,FREQX,NADC,NCM
1 91      KFRQ(1)=INT(FRQ/65536.)
1 92      FRQ2=AMOD(FRQ,65536.)
1 93      IF (FRQ2.GE.32768.) FRQ2=FRQ2-65536.
1 94      KFRQ(2)=INT(FRQ2)
1 95      KADC=1024/NADC
1 96      KCM=1024/NCM
1 97 C... TWO'S COMPLEMENT KCM,KADC,KFRQ
1 98      KCM=256-KCM
1 99      KADC=16-KADC
1 100      IF (KFRQ(1).NE.0) KFRQ(1)=-KFRQ(1)
1 101      IF (KFRQ(2).NE.0) THEN
1 102          KFRQ(2)=-KFRQ(2)
1 103          KFRQ(1)=KFRQ(1)-1
1 104      ENDIF
1 105 C... WRITE CONTROL REGISTERS
1 106      CALL CFSA(WT2,LREG,KFRQ,ISTAT,IERR)
1 107      IDATA=KADC*256+KCM
1 108      CALL CSSA(WT2,LREG1,IDATA,ISTAT,IERR)
1 109      ELSEIF (IFNC.EQ.'RU') THEN
1 110 C... START
1 111      CALL CSSA(XEQ,LREG,IDATA,ISTAT,IERR)
1 112      ELSEIF (IFNC.EQ.'HA') THEN
1 113 C... STOP
1 114      CALL CSSA(DIS,LREG4,IDATA,ISTAT,IERR)
1 115      ELSEIF (IFNC.EQ.'AD') THEN
1 116 C... ADVANCE PC
1 117      CALL CSSA(XEQ,LREG1,IDATA,ISTAT,IERR)
1 118      ELSEIF (IFNC.EQ.'CA') THEN
1 119 C... CAMAC FUNCTION
1 120      WRITE(6,8060)
1 121      READ(5,8065) FNC
1 122      WRITE(6,8070)
1 123      READ(5,8075) ANS
1 124      ID=.FALSE.
1 125      IF (ANS(1).EQ.'Y') ID=.TRUE.
1 126      IS=.FALSE.
1 127      IF (ANS(3).EQ.'Y') IS=.TRUE.
1 128      CALL CMCFNC(FNC,ID,IS)
1 129      ELSEIF (IFNC.EQ.'LA') THEN
1 130 C... CAMAC LAM'S
1 131      WRITE(6,8080)
1 132      READ(5,8025) ILAM
1 133      IA=ILAM
1 134      LREGL=CDREGF(IB,N,IA)
1 135      WRITE(6,8085)
1 136      READ(5,8015) ILC
1 137      IF (ILC.EQ.'C') CALL CSSA(CLM,LREGL,IDATA,ISTAT,IERR)
1 138      IF (ILC.EQ.'D') CALL CSSA(DIS,LREGL,IDATA,ISTAT,IERR)
1 139      IF (ILC.EQ.'E') CALL CSSA(ENB,LREGL,IDATA,ISTAT,IERR)

```



```

1 140      ELSEIF(IFNC.EQ.'EX') THEN
1 141          EXIT=.TRUE.
1 142      ELSEIF(IFNC.EQ.'FN') THEN
1 143          WRITE(6,8100)
1 144      ELSE
1 145      C... ERROR
1 146          WRITE(6,8090)
1 147      ENDIF
1 148      ENDDO
1 149      STOP
1 150      8000 FORMAT(1H,'PROGRAM FCEN'/
1 151          11H,'VERSION A.06 04 MAY 80'/
1 152          21H,'WHERE IS FG(I2)?')
1 153      8005 FORMAT(I2)
1 154      8010 FORMAT(1H,'SELECT FUNCTION')
1 155      8015 FORMAT(A2)
1 156      8020 FORMAT(1H,'ENTER WAVE FORM'/
1 157          11H,'- 1(COSINE)'/
1 158          21H,'- 2(TRIANGULAR)'/
1 159          31H,'- 3(SQUARE)'/
1 160          41H,'AND VOLTAGE SCALE FACTOR BETWEEN 0.0 AND 10.0 (I1,F5.0)')
1 161      8025 FORMAT(I1,F5.0)
1 162      8030 FORMAT(1H,'ERROR IN MEMORY LOAD')
1 163      8035 FORMAT(1H,'WRITE COMPLETE',2X,Z4)
1 164      8040 FORMAT(1H,'ERROR IN VERIFYING ',3I10,2X,Z4)
1 165      8045 FORMAT(1H,'VERIFY COMPLETE',2X,Z4)
1 166      8050 FORMAT(1H,'ENTER FREQ, NADC, AND NCM (F6.0,2I5)'/
1 167          11H,'(0.0038 <= FREQ <= 977.0',
1 168          2' 64 <= NADC <= 1024',
1 169          3' 4 <= NCM <= 1024)')
1 170      8055 FORMAT(F6.0,2I5)
1 171      8056 FORMAT(1H,' FREQUENCY =',F9.4,' ('',E14.7,
1 172          1'') NADC =',I5,' NCM =',I5)
1 173      8060 FORMAT(1H,'ENTER CAMAC CONTROL FUNCTION')
1 174      8065 FORMAT(A2)
1 175      8070 FORMAT(1H,'DO YOU WANT DI AND/OR SI SET?')
1 176      8075 FORMAT(3A1)
1 177      8080 FORMAT(1H,'ENTER - 0(ALL), 1(ADC TRIG), 2(PC=0), 3(C=M)')
1 178      8085 FORMAT(1H,'ENTER - C(CLEAR), D(DISABLE), E(ENABLE)')
1 179      8090 FORMAT(1H,'ILLEGAL -- TRY AGAIN')
1 180      8100 FORMAT(1H,'THE FUNCTIONS ARE:')
1 181          11H,'AD = ADVANCE PC'/
1 182          21H,'CA = CAMAC CONTROL'/
1 183          31H,'EX = EXIT'/
1 184          41H,'HA = HALT GENERATOR'/
1 185          51H,'LA = LAM CONTROL'/
1 186          61H,'PA = INPUT PARAMETERS'/
1 187          71H,'RU = START GENERATOR'/
1 188          81H,'VE = VERIFY MEMORY'/
1 189          91H,'WR = WRITE MEMORY')
1 190      END

```

```

2 1      SUBROUTINE RESETH(LREG,ISTAT)
2 2          INTEGER DATA,CL2
2 3          CL2=11
2 4          CALL CSSA(CL2,LREG,DATA,ISTAT,IERR)
2 5          IF(IERR.NE.0) THEN
2 6              WRITE(6,8000) ISTAT
2 7          ENDIF
2 8          RETURN
2 9      8000 FORMAT(1H,'RESET ',2X,Z4)
2 10      END

```

```

1      FUNCTION INVOFS(K)
2      C... COMPUTE INVERTED OFFSET BINARY OF K(12 BIT INTEGER)
3      IF(K.GE.0) THEN
4          INVOFS=2047-K
5      ELSE
6          INVOFS=-2049-K
7      ENDIF
8      RETURN
9      END

```

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