TR-48®/DES-30 HYBRID IMPLEMENTATION OF CORRELATION FUNCTIONS

By Omri Serlin & Peter J. Holsberg

INTRODUCTION

This study describes a method for obtaining an approximation to the auto- and cross-correlation functions, R_{xx} and R_{xy}. The method involves use of the EAI PACE® TR-48 General Purpose Analog Computer with Electronic Mode Control, used with the EAI DES-30 Digital Expansion System ... a low-cost, general-purpose, patchable digital logic system.

This logic package, although capable of operating autonomously as an aid in digital design or instruction, was designed primarily as an expansion to the TR-48 computer to provide basic hybrid capabilities for the small computer facility. Thus, the necessary logic and control functions for the hybrid implementation of this application are provided by the digital capabilities of this compact, completely self-contained unit.

Specifically, the study describes the implementation of an approximation to the auto-correlation function

$$R_{xx} = \lim_{T \to \infty} \frac{1}{2T} \int_{-T}^{T} x(t)\ x(t-\tau)\ dt$$

The extension to the cross-correlation function, R_{xy}, is obvious and requires no changes in the program.

METHOD OF SOLUTION

The problem is to plot $R_{xx}(\tau)$. A train of blips of period τ (variable) is generated. On each such blip the product $x(t)\ x(t-\tau)$ is sampled and then held on one track/store unit; then, the present value of $x(t)$ is also sampled and held...it is used to represent $x(t-\tau)$ on the next sampling pulse. Now the entire affair is run in the RO mode, with τ changing very slowly (so it may be considered constant for at least one RO cycle). A standard tandem track/store arrangement picks up and stores the present value of R_{xx} for presentation to the plotter.

THE PROGRAM

The program is shown in Figure 1. The components are labeled sequentially and do not represent an actual patching.

DA switch amplifier 08, multiplier 10, integrator 11 and electronic comparator 12 comprise the variable frequency pulse generator which generates blips with period τ. This is a standard HYDAC program. The blips are obtained at the output of differentiator 07.

MT06 generates two consecutive 100 μs signals. It does so as follows; the timing blip sets the MT through OR gate 17A. It also sets FF26A, which enables AND gate 17B. When the MT returns to 0, DIF 06 produces a blip which sets MT06 again for another 100 μs period (DES-30 monos are 100% duty cycle). The same blip from differentiator 06 also resets FF26A so it is ready for the next timing blip. Note that this means that τ cannot be less than 200 μs, and a practical minimum value is probably 400 μs. The timing just described is shown in Figure 2.

The output of MT 06 is "time-shared": When FF26A is set, the first 100 μs signal is routed through AND gate 17E to T/S 04 which tracks and holds the product of the present value of x, x(t), and the "delayed" value $x(t-\tau)$. The second 100 μs signal occurs after FF26A is reset, and it is routed through AND gate 17F to T/S 00 which tracks and holds x(t) (for use as $x(t-\tau)$ on the next timing blip).

Integrator 05 performs the integration involved in generating R_{xx}. The pot preceding integrator 05 is set to $K_1/2T$ where K_1 is a scale factor and T (not to be confused with τ) is the RO compute period, or the limits of the integration.

Bulletin No. ALAC 65073

Printed in U.S.A. 095

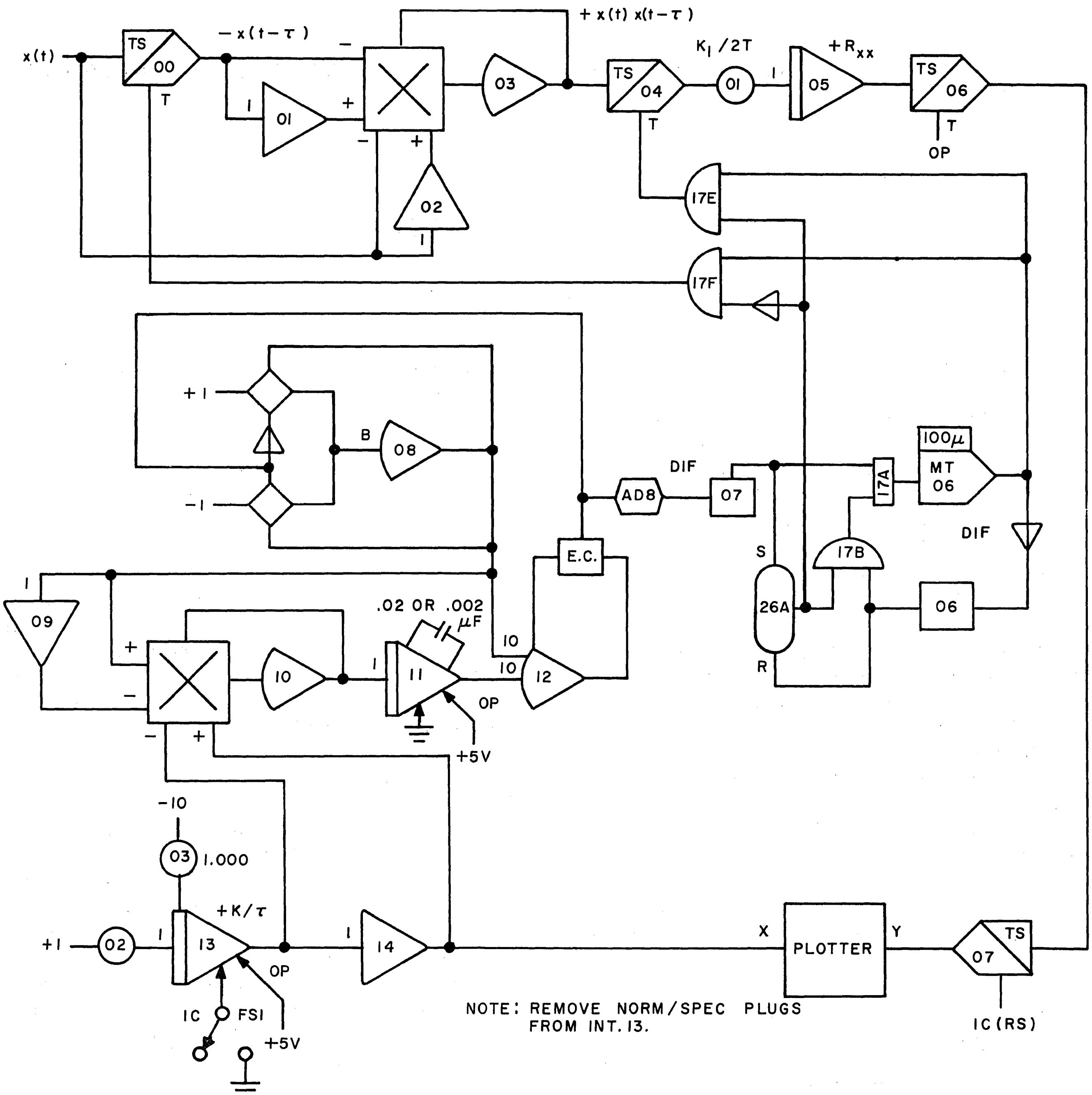

Figure 1: Computer Program

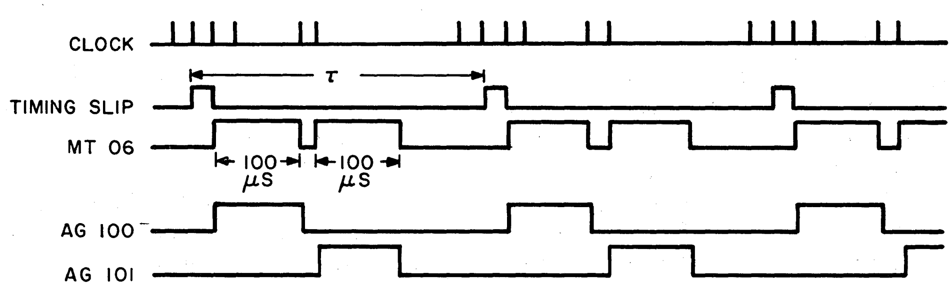

Figure 2: Timing Diagram (τ constant)

Track/stores 06, 07 are a standard tandem scheme for plotting a "high speed" variable in slow speed. The value of R_{xx} at the end of each RO cycle is determined by T/S 05 and transferred to T/S 06 where it is held unchanged until updated after the next run. The signals to operate T/S 06, 07 can be tapped from any integrator mode control bottle plug.

Integrator 13 controls the parameter τ and also provides a drive proportional to τ to the plotter arm. To obtain a "normal" plot (increasing τ), integrator 13 should start from maximum (+10V) and "integrate down" to 0. This corresponds to starting from the maximum pulse rate at DIF 07 (minimum τ) and decreasing frequency (increasing τ). The plotter arm is driven from -10 volts to 0, and proper parallax adjustment will have to be made.

The minimum value of τ can be varied by changing the feedback capacitor and/or changing the gain of integrator 11. Note that all capacitor values are obtainable by playing with the 0.1β and NORMAL/ SPECIAL bottle plug. Table 1 summarizes the situation:

TABLE 1, MINIMUM τ PERIOD

Normal	Special	0.1β	Capacitor	Gain 1	Gain 10
OUT	OUT	IN	10 μF	2 sec	200 ms
OUT	OUT	OUT	1 μF	200 ms	20 ms
OUT	IN	IN	.02 μF	4 ms	400 μs
OUT	IN	OUT	.002 μF	400 μs	40 μs

As indicated previously, 200 μs is the lowest practical τ since the track/stores 00; 03 require each 100 μs to track properly.

Note that integrator 11 is always in OP; integrator 13 operates at a normal rate, while integrator 05 is in the RO mode. Also note that the output of integrator 13 must not be allowed to go negative: the operator should monitor its output and flip FS 1 (also lift pen!) to the open position when the output gets close to zero. An automatic program to do this can easily be implemented but, unless plotter pen control is also available, the value of this addition is not justified.

LIMITATIONS

The substitution of track/store units for a continuous delay device imposes a severe limitation on τ. The value of τ may not exceed 1/100 of a cycle of x(t), or about .07 radians. Placing a linear interpolator between track/store 04 and integrator 05 may relax this limit somewhat. At .07 radians, the error is probably of the order of 1%.

A NOTE ON SYMBOLS

In this memo the following symbols are used:

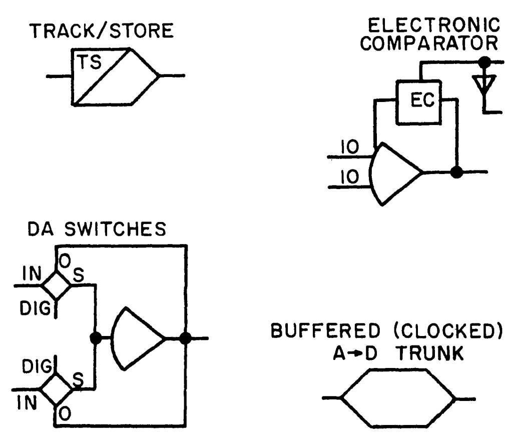

Figure 3: Definition of Symbols

All other symbols used are standard analog or HYDAC symbols.