TIMING VARIATION IN DUAL LOOP BENCHMARKS

CARNegie-MELLon UNIV PITTSBURGH PA SOFTWARE ENGINEERING INST N ALTMAN ET AL. OCT 87 CMU/SEI-87-TR-21

UNCLASSIFIED ESD-TR-87-172 F19620-85-C-0003 F/G 12/5 NL
Timing Variation in Dual Loop Benchmarks

Neal Altman
Nelson Welldan

October 1987
Timing Variation in Dual Loop Benchmarks

Neal Altman
Member of the Technical Staff
Ada Embedded Systems Testbed Project

Nelson Weiderman
Project Leader
Ada Embedded Systems Testbed Project

Approved for public release.
Distribution unlimited.

Software Engineering Institute
Carnegie Mellon University
Pittsburgh, Pennsylvania 15213
This technical report was prepared for the
SEI Joint Program Office
ESD/XRS
Hanscom AFB, MA 01731

The ideas and findings in this report should not be construed as an official DoD position. It is published in the interest of scientific and technical information exchange.

Review and Approval
This report has been reviewed and is approved for publication.

FOR THE COMMANDER

Karl H. Shingler
SEI Joint Program Office

This work is sponsored by the U.S. Department of Defense.

Copyright © 1987 by the Software Engineering Institute.

This document is available through the Defense Technical Information Center. DTIC provides access to and transfer of scientific and technical information for DoD personnel, DoD contractors and potential contractors, and other U.S. Government agency personnel and their contractors. To obtain a copy, please contact DTIC directly: Defense Technical Information Center, Attn: FDRA, Cameron Station, Alexandria, VA 22304-6145.

Copies of this document are also available through the National Technical Information Services. For information on ordering, please contact NTIS directly: National Technical Information Services, U.S. Department of Commerce, Springfield, VA 22161.

Ada is a registered trademark of the U.S. Government, Ada Joint Program Office. DEC, MicroVAX, ULTRIX, VAX, VAXELN, and VMS are trademarks of Digital Equipment Corporation. SD-Ada is a registered trademark of Systems Designers plc. VADS is a registered trademark and Verdix is a trademark of Verdix Corp. TeleGen2 is a trademark of TeleSoft.
## Table of Contents

1. Dual Loop Benchmarks: Purpose and Assumptions ........................................... 1  
2. Testing the Validity of the Dual Loop Design for Timing Benchmarks .......... 3  
3. Conclusion ........................................................................................................... 7  
References ............................................................................................................... 9  

Appendix A. Specific Configurations Tested ......................................................... 11  
   A.a. MicroVAX/VAXELN ................................................................. 11  
   A.b. MC68020/SD-Ada .................................................................... 11  

Appendix B. Raw Data .......................................................................................... 13  
   B.a. CAL2 for the MicroVAX/VAXELN .............................................. 13  
   B.b. CAL2 for the MC68020/SD-Ada .................................................... 14  

Appendix C. Test Programs .................................................................................. 17  
   C.a. CAL2 Source Code for the MicroVAX/VAXELN ....................... 17  
   C.b. CAL2 Source Code for the MC68020/SD-Ada .......................... 20  

Accesion For

<table>
<thead>
<tr>
<th>NTIS</th>
<th>CRA&amp;I</th>
<th>DTIC TAB</th>
<th>Unannounced</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

By

<table>
<thead>
<tr>
<th>Distribution</th>
</tr>
</thead>
</table>

Availability Codes

<table>
<thead>
<tr>
<th>Date Available</th>
<th>Special</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1</td>
<td></td>
</tr>
</tbody>
</table>
List of Tables

Table 2-1: CAL2 Test Results from VAXELN Ada (time in seconds) 4
Table 2-2: CAL2 Test Results from SD ADA-Plus on the 68020 (time in seconds) 5
Timing Variation in Dual Loop Benchmarks

Abstract

Benchmarks that measure time values using a standard system clock often employ a dual loop design. One of the important assumptions of this design is that textually identical loop statements will take the same amount of time to execute. This assumption was tested on two bare computers with Ada test programs and has been demonstrated to be inaccurate in these specific test cases.

1. Dual Loop Benchmarks: Purpose and Assumptions

Benchmarks are tests designed to measure the capabilities of a computer system. They are used to compare different computer systems and determine the suitability of a computer system for particular tasks. Benchmarks show a wide variation in what they are intended to measure, how they are designed, and how they are implemented. Many benchmarks produce outputs that are measurements of the time required to perform some task. A common technique is to write a program that performs some interesting bit of work (e.g., a rendezvous) sandwiched between calls to a system timer.

Benchmarks that use time as a unit of measure vary widely in the time they require to run. Some tasks are brief and can take fractional parts of a second to execute. Others measure durations of minutes or hours. The ability of computer clocks to measure this range of times also varies widely. A system clock available to a benchmark designer may be accurate only to a tenth of a second, far too slow to measure an event in the millisecond or microsecond range. More accurate timing devices are often available, but as an option rather than as a standard component. For benchmarks intended for general use, a dual loop benchmark design is often used to permit the benchmark to execute on an unmodified system.

Dual loop benchmarks handle the problem of imprecise clocks by extending the duration of the test to a length that the clock can readily measure. The time required for a test is extended by repeating the test numerous times between calls to the system timer. Repetition is usually programmed by inserting the test in a loop, where the number of repetitions may be conveniently changed. The increased time duration of the test series can be measured easily, and the time for the individual test can be determined by computing the average value for the test series. Introducing a loop construct into the test adds time, which must be factored out. This is done with a second loop, a control loop, which contains only the loop construct and not the actual test. The time required for the benchmark is assumed to be the value obtained by subtracting the control loop time from the test loop time. An Ada skeleton for a dual loop benchmark appears as follows:

1

This Ada program fragment requires that the constant SOME_VALUE and a procedure TEST be added before the program can actually be run. In actual practice, precautions must be taken to ensure optimization by the compiler does not alter the essential program structure. For example, because the empty loop contains no executable statements, it might be removed by a compiler.
with CALENDAR; use CALENDAR;

procedure DUAL_LOOP_EXAMPLE is

   NUMBER_OF_TESTS : constant INTEGER := SOME_VALUE;
   START_TEST      : CALENDAR.TIME;
   STOP_TEST       : CALENDAR.TIME;
   START_CONTROL   : CALENDAR.TIME;
   STOP_CONTROL    : CALENDAR.TIME;
   AVERAGE_TIME    : DURATION;

begin

   -- Test loop
   START_TEST := CALENDAR.CLOCK;
   for INDEX1 in 1..NUMBER_OF_TESTS loop
      TEST;
      -- Test.
      STOP_TEST := CALENDAR.CLOCK;
   end loop;

   -- Control loop
   START_CONTROL := CALENDAR.CLOCK;
   for INDEX1 in 1..NUMBER_OF_TESTS loop
      null;
      -- No Test.
      STOP_CONTROL := CALENDAR.CLOCK;
   end loop;

   AVERAGE_TIME := ((STOP_TEST - START_TEST) -
                     (STOP_CONTROL - START_CONTROL))
                    / NUMBER_OF_TESTS;

end DUAL_LOOP_EXAMPLE;

A critical assumption made by the dual loop benchmarking scheme is that textually equivalent code constructs require the same amount of time to execute. In other words, time required by the loop constructs and control loops are substantially identical.
2. Testing the Validity of the Dual Loop Design for Timing Benchmarks

The assumption that textually equivalent loops require similar amounts of time was subjected to test with Ada compilers for two bare machines: a DEC MicroVAX™ computer using VAXELN™ Ada Ver. 1.1, and a Motorola 68020 single board computer using Systems Designers' SD Ada-Plus™ Ver. 2B.01. Times were obtained using the routines in package CALENDAR. For DEC Ada, SYSTEM.TICK was 0.01 seconds. For SD Ada-Plus, SYSTEM.TICK was approximately 0.0078 seconds (actually 2^-7 seconds).

The test program, CAL2, used the format of the Ada dual loop skeleton, but it increased the number of loops to five. Each loop was inserted into a procedure. The source code for each loop was made as similar as possible. Only the names of the procedures containing the test loops were allowed to differ between loops. By calling the procedures in different sequences, the order of loop execution was varied (e.g., first order, 1-2-3-4-5; next order, 5-4-3-2-1; then, 2-5-1-3-4). This variation tested the hypothesis that the execution time for a loop may be affected by the run sequence. Rather than using completely empty loops, a call to a single subroutine was placed in each loop, and appropriate checks were made to ensure that the subroutine call was not optimized out of the loop by the Ada compiler during program translation. The light loading factor was imposed arbitrarily, but it matched the test loop of a benchmark measuring subroutine call overhead. Output of test results was initiated only after testing was complete. There were two versions of CAL2, one for VAXELN and one for the 68020, reflecting the differences in the I/O packages available under the two compilers. The VAXELN version is included as Appendix C.a (page 17), and the 68020 version as Appendix C.b (page 20). Note that the 68020 version uses the package TARGET_10 rather than TEXT_10.

The assembly language translations produced by each compiler were examined. The code for the loops proved to be identical except for names of variables, procedures, and labels.

The programs were run three times on each target and showed a consistent pattern. Times for individual loops were consistent, while times between loops showed noticeable variation (Tables 2-1 and 2-2). The timings were sensitive to the number of loop iterations, the exact format of the loop, the location of program code in memory, and other factors. The examples included here show a maximum difference between loops of about 12%. The raw output is included in Appendix B.

CAL2 showed a consistent pattern of variation on each of the tested systems. The MicroVAX/VAXELN Ada combination showed one "slow loop" and four "fast loops" with similar times. The 68020/SD-Ada combination showed two "slow loops" and three "fast loops." Again, the two categories of loops shared similar times. The order of execution of the individual loops had no effect on the times.

---

2 Complete information is provided in [1].
The cause of the variation in times was analyzed. For the MicroVAX, testing established that the loop position in memory was the critical factor. The virtual memory space of the MicroVAX is divided into 512-byte pages, which correspond to identically sized physical pages. The slow loop happened to span a page boundary and consequently ran more slowly due to the overhead inherent in shifting between pages; the loop changed as the program size changed. A suggestion that the variation was caused by the byte alignment of individual loops with respect to the four-byte MicroVAX word was considered, but the byte alignment of the loops was identical (compared to the start of word boundaries).

The 68020 processor accessed memory by word (four bytes), while the SD-Ada compiler placed the loop statement without regard to word boundaries. As a consequence, certain loops were aligned more advantageously and required fewer memory accesses to execute.

### Table 2-1: CAL2 Test Results from VAXELN Ada (time in seconds)

<table>
<thead>
<tr>
<th>Trial</th>
<th>Loop 1</th>
<th>Loop 2</th>
<th>Loop 3</th>
<th>Loop 4</th>
<th>Loop 5</th>
<th>Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Mode</td>
<td>4.38</td>
<td>4.38</td>
<td>4.91</td>
<td>4.38</td>
<td>4.38</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>4.38</td>
<td>4.38</td>
<td>4.91</td>
<td>4.38</td>
<td>4.38</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>.01</td>
<td>.02</td>
<td>.01</td>
<td>.01</td>
<td>.01</td>
</tr>
<tr>
<td>B</td>
<td>Mode</td>
<td>4.37</td>
<td>4.37</td>
<td>4.91</td>
<td>4.37</td>
<td>4.37</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>4.37</td>
<td>4.37</td>
<td>4.91</td>
<td>4.37</td>
<td>4.37</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>.02</td>
<td>.01</td>
<td>.01</td>
<td>.01</td>
<td>.01</td>
</tr>
<tr>
<td>C</td>
<td>Mode</td>
<td>4.37</td>
<td>4.37</td>
<td>4.91</td>
<td>4.37</td>
<td>4.37</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>4.37</td>
<td>4.37</td>
<td>4.91</td>
<td>4.37</td>
<td>4.37</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>.02</td>
<td>.01</td>
<td>.00</td>
<td>.01</td>
<td>.01</td>
</tr>
<tr>
<td>Loop 1</td>
<td>Loop 2</td>
<td>Loop 3</td>
<td>Loop 4</td>
<td>Loop 5</td>
<td>Variation</td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>-----------</td>
<td></td>
</tr>
<tr>
<td>Trial A</td>
<td>Mode</td>
<td>2.055</td>
<td>2.258</td>
<td>2.055</td>
<td>2.312</td>
<td>2.055</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>2.054</td>
<td>2.259</td>
<td>2.055</td>
<td>2.310</td>
<td>2.054</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>.008</td>
<td>.008</td>
<td>.008</td>
<td>.007</td>
<td>.008</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(20 samples, 100,000 iterations/loop)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Loop 1</th>
<th>Loop 2</th>
<th>Loop 3</th>
<th>Loop 4</th>
<th>Loop 5</th>
<th>Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial B</td>
<td>Mode</td>
<td>2.055</td>
<td>2.250</td>
<td>2.055</td>
<td>2.312</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>2.055</td>
<td>2.250</td>
<td>2.055</td>
<td>2.310</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>.008</td>
<td>.008</td>
<td>.008</td>
<td>.007</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Loop 1</th>
<th>Loop 2</th>
<th>Loop 3</th>
<th>Loop 4</th>
<th>Loop 5</th>
<th>Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial C</td>
<td>Mode</td>
<td>2.086</td>
<td>2.062</td>
<td>2.133</td>
<td>2.055</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>2.084</td>
<td>2.066</td>
<td>2.133</td>
<td>2.055</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>.008</td>
<td>.031</td>
<td>.000</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2-2: CAL2 Test Results from SD ADA-Plus on the 68020 (time in seconds)

---

3Minor changes to the source code forced the recompilation of CAL2 for Trial C. Note the difference in times when Trial C is compared to Trials A and B. The source code for Trial C is included in Appendix C.
3. Conclusion

It is not clear that the variation observed in these examples will be seen on all systems or that some variation in loop timings is sufficient to completely invalidate the technique. However, practitioners who simply prepare and run dual loop benchmarks without validation may garner results that are not accurate. This source of variation appears to be dependent on the specific hardware/software combination under test; thus, the amount of variation will vary depending upon the hardware, the system software, the format of the benchmark, and the specific load points selected by the interaction of these components. As a consequence, the accuracy of a dual loop benchmark depends upon a highly specific set of circumstances and cannot be controlled by a general technique when the benchmark is written.

Dual loop benchmarking is based on the assumption that the time taken to execute two textually identical loops will be substantially identical. Simple tests have demonstrated that textually identical loops exhibit substantial variation in execution time on specific test systems. The consequence of this variation is that benchmark programs using the dual loop paradigm to measure the execution time of a particular Ada feature (such as a subroutine call) can and do produce negative values. The positive values produced by such test suites can be erroneously accepted as accurate despite unbounded relative errors.
References

*Factors Causing Unexpected Variation in Ada Benchmarks.*  
Appendix A: Specific Configurations Tested

A.a. MicroVAX/VAXELN

System Type: MicroVAX II (two identical configurations, SEIYB and SEIYC)
Manufacturer: Digital Equipment Corporation
Processor: KA-630
Peripherals: Console terminal, KWV11 real-time clock; DRV11J parallel interface
Ada Compiler: DEC VAX™ Ada Ver. 1.3-23 (under MicroVMS™ Ver. 4.5); VAXELN Ada Ver. 1.1 (under MicroVMS Ver. 4.5)
Run Time: VAXELN, Ver. 2.3; VAXELN Ada, Ver. 1.1
Vendor: Digital Equipment Corporation

A.b. MC68020/SD-Ada

System Type: MVME™133 single board processor in Motorola VME bus enclosure
Manufacturer: Motorola Microsystems
Processor: MC68020, 12.5 Mhz.
Peripherals: Console terminal, two RS232 host connections
Ada Compiler: SD Ada-Plus VMS™ x 68020, Release 2B.01 (under MicroVMS Ver. 4.5)
Run Time: SD-Ada VMX® x 68020, Release 2B.01
Vendor: Systems Designers plc.
Appendix B: Raw Data

B.a. CAL2 for the MicroVAX/VAXELN

**CAL2—Multiple executions of identical loops—time in seconds:**

Run on SEYB on 4/6/87. Build parameters were:
characteristic /nofile /no server /debugon
program CAL2 /kernel stack=40 /user stack=40 /job priority=0 -
/process priority=0 /argument="("CONSOLE:"
"25""WA XXXXXXXX":":PS:[NA.REASON_T.CAL2]CAL2_VAXELN.LOG", "CONSOLE:"
device XQA /register=60774440 /vector=40120 /priority=4

<table>
<thead>
<tr>
<th>Test #</th>
<th>LOOP 1</th>
<th>LOOP 2</th>
<th>LOOP 3</th>
<th>LOOP 4</th>
<th>LOOP 5</th>
<th>Calling Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.38</td>
<td>4.39</td>
<td>4.91</td>
<td>4.38</td>
<td>4.38</td>
<td>1-2-3-4-5</td>
</tr>
<tr>
<td>2</td>
<td>4.37</td>
<td>4.37</td>
<td>4.91</td>
<td>4.38</td>
<td>4.38</td>
<td>5-4-3-2-1</td>
</tr>
<tr>
<td>3</td>
<td>4.37</td>
<td>4.38</td>
<td>4.91</td>
<td>4.38</td>
<td>4.38</td>
<td>2-5-1-3-4</td>
</tr>
<tr>
<td>4</td>
<td>4.37</td>
<td>4.38</td>
<td>4.91</td>
<td>4.38</td>
<td>4.38</td>
<td>4-1-5-2-3</td>
</tr>
<tr>
<td>5</td>
<td>4.37</td>
<td>4.38</td>
<td>4.91</td>
<td>4.38</td>
<td>4.37</td>
<td>1-2-3-4-5</td>
</tr>
<tr>
<td>6</td>
<td>4.37</td>
<td>4.38</td>
<td>4.91</td>
<td>4.38</td>
<td>4.38</td>
<td>5-4-3-2-1</td>
</tr>
<tr>
<td>7</td>
<td>4.38</td>
<td>4.38</td>
<td>4.91</td>
<td>4.37</td>
<td>4.38</td>
<td>2-5-1-3-4</td>
</tr>
<tr>
<td>8</td>
<td>4.38</td>
<td>4.38</td>
<td>4.91</td>
<td>4.38</td>
<td>4.38</td>
<td>4-1-5-2-3</td>
</tr>
<tr>
<td>9</td>
<td>4.37</td>
<td>4.38</td>
<td>4.91</td>
<td>4.38</td>
<td>4.38</td>
<td>1-2-3-4-5</td>
</tr>
<tr>
<td>10</td>
<td>4.38</td>
<td>4.38</td>
<td>4.91</td>
<td>4.38</td>
<td>4.38</td>
<td>5-4-3-2-1</td>
</tr>
<tr>
<td>11</td>
<td>4.38</td>
<td>4.38</td>
<td>4.91</td>
<td>4.38</td>
<td>4.38</td>
<td>2-5-1-3-4</td>
</tr>
<tr>
<td>12</td>
<td>4.38</td>
<td>4.38</td>
<td>4.91</td>
<td>4.38</td>
<td>4.38</td>
<td>4-1-5-2-3</td>
</tr>
<tr>
<td>13</td>
<td>4.38</td>
<td>4.38</td>
<td>4.91</td>
<td>4.38</td>
<td>4.38</td>
<td>1-2-3-4-5</td>
</tr>
<tr>
<td>14</td>
<td>4.38</td>
<td>4.38</td>
<td>4.91</td>
<td>4.38</td>
<td>4.38</td>
<td>5-4-3-2-1</td>
</tr>
<tr>
<td>15</td>
<td>4.38</td>
<td>4.38</td>
<td>4.91</td>
<td>4.38</td>
<td>4.38</td>
<td>4-1-5-2-3</td>
</tr>
<tr>
<td>16</td>
<td>4.38</td>
<td>4.38</td>
<td>4.91</td>
<td>4.38</td>
<td>4.38</td>
<td>1-2-3-4-5</td>
</tr>
<tr>
<td>17</td>
<td>4.38</td>
<td>4.38</td>
<td>4.91</td>
<td>4.38</td>
<td>4.38</td>
<td>5-4-3-2-1</td>
</tr>
<tr>
<td>18</td>
<td>4.38</td>
<td>4.38</td>
<td>4.91</td>
<td>4.38</td>
<td>4.38</td>
<td>2-5-1-3-4</td>
</tr>
<tr>
<td>19</td>
<td>4.38</td>
<td>4.38</td>
<td>4.91</td>
<td>4.38</td>
<td>4.38</td>
<td>4-1-5-2-3</td>
</tr>
<tr>
<td>20</td>
<td>4.38</td>
<td>4.38</td>
<td>4.91</td>
<td>4.38</td>
<td>4.38</td>
<td>1-2-3-4-5</td>
</tr>
</tbody>
</table>

**CAL2—Multiple executions of identical loops—time in seconds:**

Run on SEYC on 5/29/87. Build parameters were:
characteristic /nofile /no server /debugon
program CAL2 /kernel stack=40 /user stack=40 /job priority=0 -
/process priority=0 /argument="("CONSOLE:"
"25""WA XXXXXXXX":":PS:[NA.REASON_T.CAL2]CAL2_VAXELN.LOG", "CONSOLE:"
device XQA /register=60774440 /vector=40120 /priority=4

<table>
<thead>
<tr>
<th>Test #</th>
<th>LOOP 1</th>
<th>LOOP 2</th>
<th>LOOP 3</th>
<th>LOOP 4</th>
<th>LOOP 5</th>
<th>Calling Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.39</td>
<td>4.38</td>
<td>4.92</td>
<td>4.38</td>
<td>4.38</td>
<td>1-2-3-4-5</td>
</tr>
<tr>
<td>2</td>
<td>4.37</td>
<td>4.37</td>
<td>4.91</td>
<td>4.37</td>
<td>4.37</td>
<td>5-4-3-2-1</td>
</tr>
<tr>
<td>3</td>
<td>4.37</td>
<td>4.37</td>
<td>4.91</td>
<td>4.37</td>
<td>4.37</td>
<td>2-5-1-3-4</td>
</tr>
<tr>
<td>4</td>
<td>4.37</td>
<td>4.37</td>
<td>4.91</td>
<td>4.37</td>
<td>4.37</td>
<td>4-1-5-2-3</td>
</tr>
<tr>
<td>5</td>
<td>4.37</td>
<td>4.37</td>
<td>4.91</td>
<td>4.37</td>
<td>4.37</td>
<td>1-2-3-4-5</td>
</tr>
<tr>
<td>6</td>
<td>4.37</td>
<td>4.37</td>
<td>4.91</td>
<td>4.37</td>
<td>4.37</td>
<td>5-4-3-2-1</td>
</tr>
<tr>
<td>7</td>
<td>4.37</td>
<td>4.37</td>
<td>4.91</td>
<td>4.37</td>
<td>4.37</td>
<td>2-5-1-3-4</td>
</tr>
<tr>
<td>8</td>
<td>4.37</td>
<td>4.37</td>
<td>4.91</td>
<td>4.37</td>
<td>4.37</td>
<td>4-1-5-2-3</td>
</tr>
<tr>
<td>9</td>
<td>4.37</td>
<td>4.37</td>
<td>4.91</td>
<td>4.37</td>
<td>4.37</td>
<td>1-2-3-4-5</td>
</tr>
<tr>
<td>10</td>
<td>4.37</td>
<td>4.37</td>
<td>4.91</td>
<td>4.37</td>
<td>4.37</td>
<td>5-4-3-2-1</td>
</tr>
<tr>
<td>11</td>
<td>4.37</td>
<td>4.37</td>
<td>4.91</td>
<td>4.37</td>
<td>4.37</td>
<td>2-5-1-3-4</td>
</tr>
<tr>
<td>12</td>
<td>4.37</td>
<td>4.37</td>
<td>4.91</td>
<td>4.37</td>
<td>4.37</td>
<td>4-1-5-2-3</td>
</tr>
<tr>
<td>13</td>
<td>4.37</td>
<td>4.37</td>
<td>4.91</td>
<td>4.37</td>
<td>4.37</td>
<td>1-2-3-4-5</td>
</tr>
<tr>
<td>14</td>
<td>4.37</td>
<td>4.37</td>
<td>4.91</td>
<td>4.37</td>
<td>4.37</td>
<td>5-4-3-2-1</td>
</tr>
<tr>
<td>15</td>
<td>4.37</td>
<td>4.37</td>
<td>4.91</td>
<td>4.37</td>
<td>4.37</td>
<td>2-5-1-3-4</td>
</tr>
</tbody>
</table>
CAL2--Multiple executions of identical loops--time in seconds:

Run on SEITC on 5/29/87. Build parameters were:

```
characteristic /nofile /noserver /debug-money
program CAL2 /kernel_stack=40 /user_stack=40 /job_priority=0 /
/process_priority=0 /argument="CONSOLE:",
"25-1X XXXXXX":PS:[NA.RAISON T.CAL2]CAL2_VAXELN.LOG", "CONSOLE:"
```

device XQA /register=80774440 /vector=40120 /priority=4

Test # | LOOP_1 | LOOP_2 | LOOP_3 | LOOP_4 | LOOP_5 | Calling Order
--- | --- | --- | --- | --- | --- | ---
1 | 4.37 | 4.37 | 4.91 | 4.37 | 4.37 | 1-2-3-4-5
2 | 4.37 | 4.37 | 4.91 | 4.37 | 4.37 | 5-4-3-2-1
3 | 4.37 | 4.37 | 4.91 | 4.37 | 4.37 | 2-5-1-3-4
4 | 4.37 | 4.37 | 4.91 | 4.37 | 4.37 | 4-1-5-2-3
5 | 4.37 | 4.37 | 4.91 | 4.37 | 4.37 | 1-2-3-4-5
6 | 4.37 | 4.37 | 4.91 | 4.37 | 4.37 | 5-4-3-2-1
7 | 4.37 | 4.37 | 4.91 | 4.37 | 4.37 | 2-5-1-3-4
8 | 4.37 | 4.37 | 4.91 | 4.37 | 4.37 | 4-1-5-2-3
9 | 4.37 | 4.37 | 4.91 | 4.37 | 4.37 | 1-2-3-4-5
10 | 4.37 | 4.37 | 4.91 | 4.37 | 4.37 | 5-4-3-2-1
11 | 4.37 | 4.37 | 4.91 | 4.37 | 4.37 | 2-5-1-3-4
12 | 4.37 | 4.37 | 4.91 | 4.37 | 4.37 | 4-1-5-2-3
13 | 4.37 | 4.37 | 4.91 | 4.37 | 4.37 | 1-2-3-4-5
14 | 4.37 | 4.37 | 4.91 | 4.37 | 4.37 | 5-4-3-2-1
15 | 4.37 | 4.37 | 4.91 | 4.37 | 4.37 | 2-5-1-3-4
16 | 4.37 | 4.37 | 4.91 | 4.37 | 4.37 | 4-1-5-2-3
17 | 4.37 | 4.37 | 4.91 | 4.37 | 4.37 | 1-2-3-4-5
18 | 4.37 | 4.37 | 4.91 | 4.37 | 4.37 | 5-4-3-2-1
19 | 4.37 | 4.37 | 4.91 | 4.37 | 4.37 | 2-5-1-3-4
20 | 4.37 | 4.37 | 4.91 | 4.37 | 4.37 | 4-1-5-2-3

B.b. CAL2 for the MC68020/SD-Ada

Date: Friday, 24 April 1987 10:43:30 EST
From: John.Slusarski@sei.cmu.edu
To: nasei.cmu.edu

*** Note: Leading zeros added to fractional portions of times which
required them. This is a fix of the output problem with the
original version of CAL2_SD. NWA 5/28/87 ***

<table>
<thead>
<tr>
<th>Test #</th>
<th>LOOP_1</th>
<th>LOOP_2</th>
<th>LOOP_3</th>
<th>LOOP_4</th>
<th>LOOP_5</th>
<th>Calling Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.055</td>
<td>2.25</td>
<td>2.05</td>
<td>2.312</td>
<td>2.055</td>
<td>1-2-3-4-5</td>
</tr>
<tr>
<td>2</td>
<td>2.055</td>
<td>2.25</td>
<td>2.05</td>
<td>2.312</td>
<td>2.055</td>
<td>5-4-3-2-1</td>
</tr>
<tr>
<td>3</td>
<td>2.055</td>
<td>2.25</td>
<td>2.05</td>
<td>2.312</td>
<td>2.055</td>
<td>2-5-1-3-4</td>
</tr>
<tr>
<td>4</td>
<td>2.055</td>
<td>2.25</td>
<td>2.05</td>
<td>2.312</td>
<td>2.055</td>
<td>4-1-5-2-3</td>
</tr>
<tr>
<td>5</td>
<td>2.055</td>
<td>2.25</td>
<td>2.05</td>
<td>2.312</td>
<td>2.055</td>
<td>1-2-3-4-5</td>
</tr>
<tr>
<td>6</td>
<td>2.055</td>
<td>2.25</td>
<td>2.05</td>
<td>2.312</td>
<td>2.055</td>
<td>5-4-3-2-1</td>
</tr>
<tr>
<td>7</td>
<td>2.055</td>
<td>2.25</td>
<td>2.05</td>
<td>2.312</td>
<td>2.055</td>
<td>2-5-1-3-4</td>
</tr>
<tr>
<td>8</td>
<td>2.055</td>
<td>2.25</td>
<td>2.05</td>
<td>2.312</td>
<td>2.055</td>
<td>4-1-5-2-3</td>
</tr>
<tr>
<td>9</td>
<td>2.055</td>
<td>2.25</td>
<td>2.05</td>
<td>2.312</td>
<td>2.055</td>
<td>1-2-3-4-5</td>
</tr>
<tr>
<td>10</td>
<td>2.055</td>
<td>2.25</td>
<td>2.05</td>
<td>2.312</td>
<td>2.055</td>
<td>5-4-3-2-1</td>
</tr>
<tr>
<td>11</td>
<td>2.055</td>
<td>2.25</td>
<td>2.05</td>
<td>2.312</td>
<td>2.055</td>
<td>2-5-1-3-4</td>
</tr>
<tr>
<td>12</td>
<td>2.047</td>
<td>2.25</td>
<td>2.05</td>
<td>2.305</td>
<td>2.047</td>
<td>4-1-5-2-3</td>
</tr>
<tr>
<td>13</td>
<td>2.055</td>
<td>2.25</td>
<td>2.05</td>
<td>2.312</td>
<td>2.055</td>
<td>1-2-3-4-5</td>
</tr>
</tbody>
</table>
Another run:

CAL2 SD--Multiple executions of identical loops--time in seconds:

<table>
<thead>
<tr>
<th>Test #</th>
<th>LOOP 1</th>
<th>LOOP 2</th>
<th>LOOP 3</th>
<th>LOOP 4</th>
<th>LOOP 5</th>
<th>Calling Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.055</td>
<td>2.055</td>
<td>2.312</td>
<td>2.055</td>
<td></td>
<td>1-2-3-4-5</td>
</tr>
<tr>
<td>2</td>
<td>2.055</td>
<td>2.055</td>
<td>2.312</td>
<td>2.055</td>
<td></td>
<td>1-2-3-4-5</td>
</tr>
<tr>
<td>3</td>
<td>2.055</td>
<td>2.055</td>
<td>2.312</td>
<td>2.055</td>
<td></td>
<td>2-5-1-3-4</td>
</tr>
<tr>
<td>4</td>
<td>2.055</td>
<td>2.055</td>
<td>2.312</td>
<td>2.055</td>
<td>2.055</td>
<td>4-1-5-2-3</td>
</tr>
<tr>
<td>5</td>
<td>2.055</td>
<td>2.055</td>
<td>2.312</td>
<td>2.055</td>
<td>2.055</td>
<td>4-1-5-2-3</td>
</tr>
<tr>
<td>6</td>
<td>2.047</td>
<td>2.055</td>
<td>2.305</td>
<td>2.055</td>
<td>2.047</td>
<td>1-2-3-4-5</td>
</tr>
<tr>
<td>7</td>
<td>2.055</td>
<td>2.055</td>
<td>2.305</td>
<td>2.055</td>
<td>2.055</td>
<td>2-5-1-3-4</td>
</tr>
<tr>
<td>8</td>
<td>2.055</td>
<td>2.055</td>
<td>2.305</td>
<td>2.055</td>
<td>2.055</td>
<td>2-5-1-3-4</td>
</tr>
<tr>
<td>9</td>
<td>2.055</td>
<td>2.055</td>
<td>2.305</td>
<td>2.055</td>
<td>2.055</td>
<td>2-5-1-3-4</td>
</tr>
<tr>
<td>10</td>
<td>2.055</td>
<td>2.055</td>
<td>2.305</td>
<td>2.055</td>
<td>2.055</td>
<td>2-5-1-3-4</td>
</tr>
<tr>
<td>11</td>
<td>2.055</td>
<td>2.055</td>
<td>2.305</td>
<td>2.055</td>
<td>2.055</td>
<td>2-5-1-3-4</td>
</tr>
<tr>
<td>12</td>
<td>2.055</td>
<td>2.055</td>
<td>2.305</td>
<td>2.055</td>
<td>2.055</td>
<td>2-5-1-3-4</td>
</tr>
<tr>
<td>13</td>
<td>2.055</td>
<td>2.055</td>
<td>2.305</td>
<td>2.055</td>
<td>2.055</td>
<td>2-5-1-3-4</td>
</tr>
<tr>
<td>14</td>
<td>2.055</td>
<td>2.055</td>
<td>2.305</td>
<td>2.055</td>
<td>2.055</td>
<td>2-5-1-3-4</td>
</tr>
<tr>
<td>15</td>
<td>2.055</td>
<td>2.055</td>
<td>2.305</td>
<td>2.055</td>
<td>2.055</td>
<td>2-5-1-3-4</td>
</tr>
<tr>
<td>16</td>
<td>2.055</td>
<td>2.055</td>
<td>2.305</td>
<td>2.055</td>
<td>2.055</td>
<td>2-5-1-3-4</td>
</tr>
<tr>
<td>17</td>
<td>2.055</td>
<td>2.055</td>
<td>2.305</td>
<td>2.055</td>
<td>2.055</td>
<td>2-5-1-3-4</td>
</tr>
<tr>
<td>18</td>
<td>2.055</td>
<td>2.055</td>
<td>2.305</td>
<td>2.055</td>
<td>2.055</td>
<td>2-5-1-3-4</td>
</tr>
<tr>
<td>19</td>
<td>2.055</td>
<td>2.055</td>
<td>2.305</td>
<td>2.055</td>
<td>2.055</td>
<td>2-5-1-3-4</td>
</tr>
<tr>
<td>20</td>
<td>2.055</td>
<td>2.055</td>
<td>2.305</td>
<td>2.055</td>
<td>2.055</td>
<td>2-5-1-3-4</td>
</tr>
</tbody>
</table>

Date: Thursday, 28 May 1987 13:48:54 EDT
From: John.Slusars@seil.cmu.edu
To: nas@sei.cmu.edu

CAL2 SD--Multiple executions of identical loops--time in seconds:

loop alignment data:

loop 1 line 77: E82
Loops 2 and 4 have starting alignment on 32 bit boundary.
Loops 1, 3, 5 have starting alignment not on 32 bit.
Appendix C: Test Programs

C.a. CAL2 Source Code for the MicroVAX/VAXELN

---

---
CAL2 is a benchmark calibration routine intended to test the assumption
that textually identical loops will take (approximately) the same amount
of time to execute.
---
The routine was devised to verify that benchmarks which depend on a
dual test and control loop structure will execute correctly on the
target system.
---
Test format is to call five functions (LOOP 1..LOOP 5) executed in
succession. Each function returns a DURATION value, obtained using
the Ada CALENDAR.CLOCK routine. The time is obtained by subtracting
the time as the routine is entered from the time just
prior to the return to caller. Between the two calls, a tight loop is
executed LOOP REPETITIONS times. The loop contains a single call to
procedure PROC. PROC simply serves to place a light load in each of
the timing loops.
---
The test calls are made in a number of arbitrary orders to allow
detection of any effects relating to the total number of machine
cycles, as opposed to the ordering of the LOOP routines.
---
The test sequence is executed TEST REPETITIONS times to allow for system
initialization effects (and possibly interruptions during execution).
---
Results are output at the conclusion of all tests.
---
Programming notes:
---
- The package T_ROUTINE contains a small routine PROC, which simply
  assigns a fixed value to the single integer argument, ARG. It is
  isolated in a package to prevent its being optimized to an inline
  assignment.
---
Known bugs:
---<none>
---
Who  Date  Remarks
---------  ------  -----
WHA 16 June 87  Corrected comments.
WHA  4 April 87  Adapted from benchmarking test routine TEST_9.
---

package T_ROUTINE is
  procedure PROC(ARG: in out INTEGER);
end T_ROUTINE;

with T_ROUTINE; use T_ROUTINE;
with CALENDAR; use CALENDAR;
with TEXT_IO; use TEXT_IO;

procedure CAL2 is

  package TIME_IO is new FIXED_IO(DURATION); use TIME_IO;
  package INT_IO is new INTEGER_IO(INTEGER); use INT_IO;

  LOOP REPETITIONS: constant INTEGER := 100000;
  TEST REPETITIONS: constant INTEGER := 5;
  SEQUENCE COUNT: constant INTEGER := 4;
  LOOP COUNT: constant INTEGER := 5;

  package TROUTINE is
    procedure PROC(ARG: in out INTEGER);
  end TROUTINE;

  with TROUTINE; use TROUTINE;
  with CALENDAR; use CALENDAR;
  with TEXT_IO; use TEXT_IO;

  procedure CAL2 is

  package TIME_IO is new FIXED_IO(DURATION); use TIME_IO;
  package INT_IO is new INTEGER_IO(INTEGER); use INT_IO;

  LOOP REPETITIONS: constant INTEGER := 100000;
  TEST REPETITIONS: constant INTEGER := 5;
  SEQUENCE COUNT: constant INTEGER := 4;
  LOOP COUNT: constant INTEGER := 5;
 LOOP_TIMES: array (1..TEST_REPETITIONS, 1..SEQUENCE_COUNT, 1..LOOP_COUNT) of DURATION;

 SEQUENCE_LENGTH: constant INTEGER := (LOOP_COUNT * 2) - 1;
 CALLING_SEQUENCE: array (1..TEST_REPETITIONS, 1..SEQUENCE_COUNT) of STRING (1..SEQUENCE_LENGTH);

-- ----------------------------

 function LOOP_1 return DURATION is
 START_TIME: TIME; END_TIME: TIME; A_VALUE: INTEGER := 12;
 begin
 START_TIME := CLOCK;
 for INDEX in 1..LOOP_REPETITIONS loop
 PROC(A_VALUE);
 end loop;
 END_TIME := CLOCK;
 return END_TIME - START_TIME;
 end LOOP_1;

-- ----------------------------

 function LOOP_2 return DURATION is
 START_TIME: TIME; END_TIME: TIME; A_VALUE: INTEGER := 12;
 begin
 START_TIME := CLOCK;
 for INDEX in 1..LOOP_REPETITIONS loop
 PROC(A_VALUE);
 end loop;
 END_TIME := CLOCK;
 return END_TIME - START_TIME;
 end LOOP_2;

-- ----------------------------

 function LOOP_3 return DURATION is
 START_TIME: TIME; END_TIME: TIME; A_VALUE: INTEGER := 12;
 begin
 START_TIME := CLOCK;
 for INDEX in 1..LOOP_REPETITIONS loop
 PROC(A_VALUE);
 end loop;
 END_TIME := CLOCK;
 return END_TIME - START_TIME;
 end LOOP_3;

-- ----------------------------

 function LOOP_4 return DURATION is
 START_TIME: TIME; END_TIME: TIME; A_VALUE: INTEGER := 12;
begin
START_TIME := CLOCK;
for INDEX in 1..LOOP_REPETITIONS loop
    PROC(A_VALUE);
end loop;
END_TIME := CLOCK;
return END_TIME - START_TIME;
end LOOP_4;

function LOOP_5 return DURATION is
    START_TIME: TIME;
    END_TIME: TIME;
    A_VALUE: INTEGER := 12;
begin
    START_TIME := CLOCK;
    for INDEX in 1..LOOP_REPETITIONS loop
        PROC(A_VALUE);
    end loop;
    END_TIME := CLOCK;
    return END_TIME - START_TIME;
end LOOP_5;

begin
for CURRENT_TEST in 1..TEST_REPETITIONS loop
    -- Calling sequence one:
    CALLING_SEQUENCE(CURRENT_TEST, 1) := "1-2-3-4-5";
    LOOP_TURNS(CURRENT_TEST, 1, 1) := LOOP_1;
    LOOP_TURNS(CURRENT_TEST, 1, 2) := LOOP_2;
    LOOP_TURNS(CURRENT_TEST, 1, 3) := LOOP_3;
    LOOP_TURNS(CURRENT_TEST, 1, 4) := LOOP_4;
    LOOP_TURNS(CURRENT_TEST, 1, 5) := LOOP_5;

    -- Calling sequence two:
    CALLING_SEQUENCE(CURRENT_TEST, 2) := "5-4-3-2-1";
    LOOP_TURNS(CURRENT_TEST, 2, 5) := LOOP_5;
    LOOP_TURNS(CURRENT_TEST, 2, 4) := LOOP_4;
    LOOP_TURNS(CURRENT_TEST, 2, 3) := LOOP_3;
    LOOP_TURNS(CURRENT_TEST, 2, 2) := LOOP_2;
    LOOP_TURNS(CURRENT_TEST, 2, 1) := LOOP_1;

    -- Calling sequence three:
    CALLING_SEQUENCE(CURRENT_TEST, 3) := "2-5-1-3-4";
    LOOP_TURNS(CURRENT_TEST, 3, 2) := LOOP_2;
    LOOP_TURNS(CURRENT_TEST, 3, 5) := LOOP_5;
    LOOP_TURNS(CURRENT_TEST, 3, 1) := LOOP_1;
    LOOP_TURNS(CURRENT_TEST, 3, 3) := LOOP_3;
    LOOP_TURNS(CURRENT_TEST, 3, 4) := LOOP_4;

    -- Calling sequence four:
    CALLING_SEQUENCE(CURRENT_TEST, 4) := "4-1-5-2-3";
    LOOP_TURNS(CURRENT_TEST, 4, 4) := LOOP_4;
    LOOP_TURNS(CURRENT_TEST, 4, 1) := LOOP_1;
    LOOP_TURNS(CURRENT_TEST, 4, 5) := LOOP_5;
    LOOP_TURNS(CURRENT_TEST, 4, 2) := LOOP_2;
    LOOP_TURNS(CURRENT_TEST, 4, 3) := LOOP_3;
end loop;

PUT_LINE("CAL2--Multiple executions of identical loops--time in seconds:");
NEW_LINE;
PUT_LINE("Test # LOOP_1 LOOP_2 LOOP_3 LOOP_4 LOOP_5 Calling Order");
for INDEX_1 in 1..TEST REPETITIONS loop
  for INDEX_2 in 1..SEQUENCE_COUNT loop
    PUT(((INDEX_1 - 1) * SEQUENCE_COUNT) + INDEX_2), 6);
  end loop;
  PUT(" ");
end loop;
new_line;
end loop;
end loop;
end CAL2;

package body T_ROUTINE is

procedure PROC(ARG: in out INTEGER) is
begin
  ARG := 42;
end PROC;

end T_ROUTINE;

C.b. CAL2 Source Code for the MC68020/SD-Ada

--
-- CAL2 is a benchmark calibration routine intended to test the assumption
-- that textually identical loops will take (approximately) the same amount
-- of time to execute.
--
-- CAL2_SD is a modified version which uses the restricted I/O facilities
-- provided by the SD compiler (Ver. 2B01).
--
-- The routine was devised to verify that benchmarks which depend on a
-- dual test and control loop structure will execute correctly on the
-- target system.
--
-- Test format is to call five functions (LOOP_1..LOOP_5) executed in
-- succession. Each function returns a DURATION value, obtained using
-- the Ada CALENDAR.CLOCK routine. The time is obtained by subtracting
-- the time as the routine is entered from the time just
-- prior to the return to caller. Between the two calls, a tight loop is
-- executed LOOP REPETITIONS times. The loop contains a single call to
-- procedure PROC. PROC simply serves to place a light load in each
-- of the timing loops.
--
-- The test calls are made in a number of arbitrary orders to allow
-- detection of any effects relating to the total number of machine
-- cycles, as opposed to the ordering of the LOOP routines.
--
-- The test sequence is executed TEST REPETITIONS times to allow for system
-- initialization effects (and possibly interruptions during execution).
--
-- Results are output at the conclusion of all tests.
--
-- Programming notes:
-- o The package T_ROUTINE contains a small routine PROC, which simply
-- assigns a fixed value to the single integer argument, ARG. It is
-- isolated in a package to prevent its being optimized to an inline
-- assignment.
--
-- Known bugs:
-- <none>
package T_ROUTINE is
  procedure PROC(ARG: in out INTEGER);
end T_ROUTINE;

type INTEGER is ...

procedure CAL2_SD is
  LOOP_REPETITIONS: constant INTEGER := 100000;
  TEST_REPETITIONS: constant INTEGER := 5;
  SEQUENCE_COUNT: constant INTEGER := 4;
  LOOP_COUNT: constant INTEGER := 5;
  LOOP_TIMES: array (1..TEST_REPETITIONS, 1..SEQUENCE_COUNT, 1..LOOP_COUNT) of DURATION;
  SEQUENCE_LENGTH: constant INTEGER := (LOOP_COUNT * 2) - 1;
  CALLING_SEQUENCE: array (1..TEST_REPETITIONS, 1..SEQUENCE_COUNT) of STRING(4..SEQUENCE_LENGTH);
  TEMP_FLOAT: FLOAT;
  TEST_NUMBER: INTEGER;
  T_VALUE_INT_PART: INTEGER;
  T_VALUE_FRAC_PART: INTEGER;

function LOOP_1 return DURATION is
  START_TIME: TIME;
  END_TIME: TIME;
  A_VALUE: INTEGER := 12;
  begin
    START_TIME := CLOCK;
    for INDEX in 1..LOOP_REPETITIONS loop
      PROC(A_VALUE);
    end loop;
    END_TIME := CLOCK;
    return END_TIME - START_TIME;
  end LOOP_1;

function LOOP_2 return DURATION is
  START_TIME: TIME;
  END_TIME: TIME;
  A_VALUE: INTEGER := 12;
  begin
    START_TIME := CLOCK;
    for INDEX in 1..LOOP_REPETITIONS loop
      PROC(A_VALUE);
    end loop;
function LOOP_3 return DURATION is
    START_TIME: TIME;
    END_TIME: TIME;
    A_VALUE: INTEGER := 12;
begin
    START_TIME := CLOCK;
    for INDEX in 1..LOOP_REPETITIONS loop
        PROC(A_VALUE);
        end loop;
    END_TIME := CLOCK;
    return END_TIME - START_TIME;
end LOOP_3;

function LOOP_4 return DURATION is
    START_TIME: TIME;
    END_TIME: TIME;
    A_VALUE: INTEGER := 12;
begin
    START_TIME := CLOCK;
    for INDEX in 1..LOOP_REPETITIONS loop
        PROC(A_VALUE);
        end loop;
    END_TIME := CLOCK;
    return END_TIME - START_TIME;
end LOOP_4;

function LOOP_5 return DURATION is
    START_TIME: TIME;
    END_TIME: TIME;
    A_VALUE: INTEGER := 12;
begin
    START_TIME := CLOCK;
    for INDEX in 1..LOOP_REPETITIONS loop
        PROC(A_VALUE);
        end loop;
    END_TIME := CLOCK;
    return END_TIME - START_TIME;
end LOOP_5;

begin
    for CURRENT_TEST in 1..TEST_REPETITIONS loop
        -- Calling sequence one:
        CALLING_SEQUENCE(CURRENT_TEST, 1) := "1-2-3-4-5";
        LOOP_TIMES(CURRENT_TEST, 1, 1) := LOOP_1;
        LOOP_TIMES(CURRENT_TEST, 1, 2) := LOOP_2;
        LOOP_TIMES(CURRENT_TEST, 1, 3) := LOOP_3;
        LOOP_TIMES(CURRENT_TEST, 1, 4) := LOOP_4;
        LOOP_TIMES(CURRENT_TEST, 1, 5) := LOOP_5;
    end loop;
end.
Calling sequence two:

```
CALLING_SEQUENCE(CURRENT_TEST, 2) := "5-4-3-2-1";
LOOP_TIMES(CURRENT_TEST, 2, 5) := LOOP_5;
LOOP_TIMES(CURRENT_TEST, 2, 4) := LOOP_4;
LOOP_TIMES(CURRENT_TEST, 2, 3) := LOOP_3;
LOOP_TIMES(CURRENT_TEST, 2, 2) := LOOP_2;
LOOP_TIMES(CURRENT_TEST, 2, 1) := LOOP_1;
```

Calling sequence three:

```
CALLING_SEQUENCE(CURRENT_TEST, 3) := "2-5-1-3-4";
LOOP_TIMES(CURRENT_TEST, 3, 2) := LOOP_2;
LOOP_TIMES(CURRENT_TEST, 3, 5) := LOOP_5;
LOOP_TIMES(CURRENT_TEST, 3, 1) := LOOP_1;
LOOP_TIMES(CURRENT_TEST, 3, 3) := LOOP_3;
LOOP_TIMES(CURRENT_TEST, 3, 4) := LOOP_4;
```

Calling sequence four:

```
CALLING_SEQUENCE(CURRENT_TEST, 4) := "4-1-5-2-3";
LOOP_TIMES(CURRENT_TEST, 4, 4) := LOOP_4;
LOOP_TIMES(CURRENT_TEST, 4, 1) := LOOP_1;
LOOP_TIMES(CURRENT_TEST, 4, 5) := LOOP_5;
LOOP_TIMES(CURRENT_TEST, 4, 2) := LOOP_2;
LOOP_TIMES(CURRENT_TEST, 4, 3) := LOOP_3;
```

end loop;

```
OUT_STRING(VDU_PORT, "CAL2_SD--Multiple executions of identical loops--time in seconds:");
NEW_LINE(VDU_PORT);
OUT_STRING(VDU_PORT, "Test # LOOP_1 LOOP_2 LOOP_3 LOOP_4 LOOP_5 Calling Order");
NEW_LINE(VDU_PORT);
for INDEX_1 in 1..TEST REPETITIONS loop
  for INDEX_2 in 1..SEQUENCE_COUNT loop
    TEST_NUMBER := (INDEX_1 - 1) * SEQUENCE_COUNT + INDEX_2;
    OUT_DECIMAL_INTEGER(VDU_PORT, TEST_NUMBER, 6);
    for INDEX_3 in 1..LOOP_COUNT loop
      TEMP_FLOAT := FLOAT(LOOP_TIMES(INDEX_1, INDEX_2, INDEX_3));
      T_VALUE_INT_PART := INTEGER(TEMP_FLOAT);
      TEMP_FLOAT := FLOAT(LOOP_TIMES(INDEX_1, INDEX_2, INDEX_3)) * 100.0;
      T_VALUE_FRAC_PART := INTEGER(TEMP_FLOAT) rem 100;
      OUT_DECIMAL_INTEGER(VDU_PORT, T_VALUE_INT_PART, 2);
      OUT_STRING(VDU_PORT, ".");
      OUT_DECIMAL_INTEGER(VDU_PORT, T_VALUE_FRAC_PART, 2);
    end loop;
    OUT_STRING(VDU_PORT, ");
    OUT_STRING(VDU_PORT, CALLING_SEQUENCE(INDEX_1, INDEX_2));
    NEW_LINE(VDU_PORT);
  end loop;
end loop;
end CAL2_SD;
```

```
package body T_ROUTINE is
  procedure PROC(ARG: in out INTEGER) is
  begin
    ARG := 42;
    end PROC;
  end T_ROUTINE;
```
The text describes the timing variation in dual loop benchmarks.

Benchmarks that measure time values using a standard system clock often employ a dual loop design. One of the important assumptions of this design is that textually identical loop statements will take the same amount of time to execute. This assumption has been tested on two bare computers with ADA test programs and has been demonstrated to be inaccurate in these specific test cases.
END
12-87
DTIC