MICROCOMPUTER ARRAY PROCESSOR SYSTEM

Kenneth D. Slezak
Goodyear Aerospace Corporation
Akron, Ohio

The Microcomputer Array Processor System (MAPS) is a programmable multiprocessor computer system designed for Electronic Warfare applications for the Air Force Avionics Laboratory (AFAL). The system architecture retains many of the classic multiprocessor design concepts including a master-slave relationship among its microprocessors under the control of a single operating system in a tightly coupled structure. Each processor is a 32-bit programmable computer with its own dedicated memory and a capability to execute approximately 4 million instructions a second. In addition to the dedicated memory, each processor can communicate with numerous banks of common memory (referred to as global memory). The various global memory modules and their communication structure serve to tie the individual processors together in a symmetrical multiprocessor computer architecture. The multiprocessor system is modular and can contain as few as 2 and as many as 8 processors coupled with from 1 to 16 banks of global memory and executes 32 million instructions per second. Expansions beyond these limits are possible if every processor does not have to have access to every global memory module. Currently, a 4 processor system (with 3 banks of global memory) is installed at Wright Patterson Air Force Base for use by AFAL. This system will be expanded to 6 processors during 1980. This multiprocessor subsystem is approximately 1.6 cubic feet and consumes under 400 watts of power.
MULTIPROCESSOR SYSTEM ATTRIBUTES

- TASK
- SYMMETRY
- COMMUNICATION
- PROCESSOR INTELLIGENCE
FAULT TOLERANT MAP ARCHITECTURE

MICROPROCESSOR-1

PROGRAM MEMORY  CPU

PROGRAM MEMORY  CPU

PROGRAM MEMORY  CPU

PROGRAM MEMORY  CPU

PORT

PORT

PORT

PORT

PORT

PORT

GLOBAL MEMORY

BANK-1

2Kx32

BANK-2

2Kx32

...
FAULT TOLERANT MAP ARCHITECTURE

MICROPROCESSOR-1

PROGRAM MEMORY → CPU

PROGRAM MEMORY → CPU

PROGRAM MEMORY → CPU

PROGRAM MEMORY → CPU

...

PROGRAM MEMORY → CPU

SPARES

PROGRAM MEMORY → CPU

GLOBAL MEMORY

BANK-1 2Kx32

BANK-2 2Kx32

SPARE MEMORY

BANK-3
MAP PROCESSING FUNCTIONS

- Establishes file of active emitters
  - Determines PRI
  - Reports presence of new emitters.
- Tracks established emitters
  - Tracks in time and angle
- Deletes inactive emitters
- Capability for
  - Scan rate determination
  - Emitter type identification
  - Receiver control
  - Power management

PDS SYSTEM

0.1 - 19 GHz

PROCESSING SYSTEM

RECEIVER
DIGITIZER
PRE PROCESSOR
MAP
DISPLAY CONTROL
DISPLAY

INTERCEPT PROCESSING
EMITTER ESTABLISHMENT
SYSTEM PROCESSING

RECEIVER CONTROL

265
PROCESSOR

TIMING & CONTROL

INTERRUPTS

PM

Pipel ine

4K x 32

ALU

EXTERNAL DEVICES

BUS TRANSCEIVER

PDP11

BUS TRANSCEIVER

PCU

PCU (PROGRAM CONTROL UNIT)

PC STACK

PGM CTR

PMAR

INTERRUPT CONTROL UNIT

STATUS REGISTER

MASK REGISTER

INTERRUPTS

INSTRUCTION CONTROL

NEXT

REPEAT COUNTER

CONDITION DECODE

OPCODE DECODE

BRANCH ADDRESS

PIPELINE

PM ADDR
MICROPROGRAM SEQUENCER
BLOCK DIAGRAM

ADDRESS REGISTER

STACK POINTER

4 X 4 FILE

MICROPROGRAM COUNTER REGISTER

MULTIPLEXER

INCREMERTER

DIRECT INPUTS
D
S₀
S₁
OR₃
OR₂
OR₁
OR₀
ZERO

OUTPUT CONTROL
GE
Y₀
Y₁
Y₂
Y₃
Cₙ
Cₙ₊₁

REGISTER ENABLE
RE

PUSH/POP

FILE ENABLE

CLOCK
MICROPROCESSOR SLICE BLOCK DIAGRAM

CLOCK

RAM SHIFT

Q SHIFT

Q REGISTER

16 X 4 RAM READ A & B WRITE B

A ADDRESS

B ADDRESS

DIRECT INPUT

MICRO-CODE

MICRO-INSTRUCTION DECODE

SELECTOR

ALU

MULTIPLEXER

OUTPUT CONTROL

OUTPUT
<table>
<thead>
<tr>
<th>TYPE</th>
<th>INSTRUCTION</th>
<th>EXECUTION (nSec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>REGISTER/REGISTER</td>
<td>.250 or 325</td>
</tr>
<tr>
<td>1</td>
<td>INPUT/OUTPUT</td>
<td>350 OUTPUT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>400 INPUT</td>
</tr>
<tr>
<td>2</td>
<td>REGISTER/IMMEDIATE</td>
<td>350</td>
</tr>
<tr>
<td>3</td>
<td>READ/WRITE PROGRAM MEMORY</td>
<td>525 READ</td>
</tr>
<tr>
<td></td>
<td></td>
<td>650 WRITE</td>
</tr>
<tr>
<td>4</td>
<td>EXTERNAL FUNCTION CONTROL</td>
<td>350</td>
</tr>
<tr>
<td>5</td>
<td>INTERRUPT CONTROL</td>
<td>400</td>
</tr>
<tr>
<td>6</td>
<td>PC STACK CONTROL</td>
<td>300</td>
</tr>
<tr>
<td>7</td>
<td>CONDITIONAL BRANCH</td>
<td>200 NO BRANCH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>300 BRANCH</td>
</tr>
</tbody>
</table>
## COMPARISON OF \( \mu \)PROCESSORS

<table>
<thead>
<tr>
<th></th>
<th>AMD AM2901</th>
<th>MMI MM6701</th>
<th>Intel 3002</th>
<th>TI SBP0400</th>
<th>Motorola M10800</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Slice Width</strong></td>
<td>4 bits</td>
<td>4-bits</td>
<td>2-bits</td>
<td>4-bits</td>
<td>4-bits</td>
</tr>
<tr>
<td><strong>Cycle Time</strong></td>
<td>100ns</td>
<td>200ns</td>
<td>150ns</td>
<td>1000ns</td>
<td>55ns</td>
</tr>
<tr>
<td>(Register to</td>
<td>(Register</td>
<td>(Register</td>
<td>(Register</td>
<td>(Register</td>
<td>(Register</td>
</tr>
<tr>
<td>register; Read,</td>
<td>read; Read</td>
<td>modify;</td>
<td>read; Modify;</td>
<td>write)</td>
<td>write)</td>
</tr>
<tr>
<td><strong>Power Dissipation</strong></td>
<td>0.92W</td>
<td>1.12W</td>
<td>1.45W</td>
<td>0.13W</td>
<td>1.3W</td>
</tr>
<tr>
<td>(4 bits)</td>
<td></td>
<td></td>
<td>(2 x 0.73)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Addressable</strong></td>
<td>16</td>
<td>16</td>
<td>11</td>
<td>8</td>
<td>1 (External</td>
</tr>
<tr>
<td>Registers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4-256)</td>
</tr>
<tr>
<td><strong>Register</strong></td>
<td>Two-</td>
<td>Two-</td>
<td>Single-</td>
<td>Single-</td>
<td>Single-</td>
</tr>
<tr>
<td><strong>Addressing</strong></td>
<td>Address</td>
<td>Address</td>
<td>Address</td>
<td>Address</td>
<td>Address</td>
</tr>
<tr>
<td><strong>Mode</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Number of</strong></td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>9</td>
<td>16</td>
</tr>
<tr>
<td>Microcode</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Control Inputs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Primary</strong></td>
<td>R + S</td>
<td>R + S</td>
<td>R + S</td>
<td>R + S</td>
<td>R + S</td>
</tr>
<tr>
<td><strong>Arithmetic</strong></td>
<td>R - S</td>
<td>R - S</td>
<td>R - S</td>
<td>R - S</td>
<td>R - S</td>
</tr>
<tr>
<td><strong>Functions</strong></td>
<td>S - R</td>
<td>S - R</td>
<td>S - R</td>
<td>S - R</td>
<td>S - R</td>
</tr>
<tr>
<td><strong>Primary</strong></td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>8</td>
<td>6 - BCD</td>
</tr>
<tr>
<td><strong>Logic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8 - Binary</td>
</tr>
<tr>
<td><strong>Functions</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Possible Source</strong></td>
<td>203</td>
<td>203*</td>
<td>24*</td>
<td>33*</td>
<td>6 - 262</td>
</tr>
<tr>
<td><strong>operand</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Combination to</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ALU</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Possible</strong></td>
<td>17</td>
<td>17</td>
<td>12</td>
<td>10</td>
<td>2 - 258</td>
</tr>
<tr>
<td><strong>ALU Destination</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Registers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Flags</strong></td>
<td>Carry</td>
<td>Carry</td>
<td>Carry</td>
<td>Carry</td>
<td>Carry</td>
</tr>
<tr>
<td></td>
<td>Overflow</td>
<td>Overflow</td>
<td>Overflow</td>
<td>Overflow</td>
<td>Overflow</td>
</tr>
<tr>
<td></td>
<td>Zero</td>
<td>Zero</td>
<td>F=1111</td>
<td>Zero</td>
<td></td>
</tr>
</tbody>
</table>

*Not all functions can be performed on all operand pairs.*
DISTINCTIVE CHARACTERISTICS

- Two-address architecture — Independent simultaneous access to two working registers saves machine cycles.
- Eight-function ALU — Performs addition, two subtraction operations, and five logic functions on two source operands.
- Flexible data source selection — ALU data is selected from five source ports for a total of 203 source operand pairs for every ALU function.
- Left/right shift independent of ALU — Add and shift operations take only one cycle.
- Four status flags — Carry, overflow, zero, and negative.
- Expandable — Connect any number of Am2901's together for longer word lengths.
- Microprogrammable — Three groups of three bits each for source operand, ALU function, and destination control.

MAP PERFORMANCE
(42 Emitter Environment)

PULSE RATE = 31,800