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
GLOBAL MEMORY

MEMORY BANK-0

MEMORY BANK-1

MEMORY BANK-N

MEMORY PORT CONTROLLER

MEMORY PORT CONTROLLER

MEMORY PORT CONTROLLER

PORT

PORT

PORT

PORT

PORT

PORT

MICROPROCESSOR 1

MICROPROCESSOR 2

MICROPROCESSOR 3
MULTI-PROCESSOR PERFORMANCE

IMPROVEMENT RATIO

THEORETICAL PERFORMANCE LIMIT

ACTUAL SPEEDUP

NUMBER OF MICROPROCESSORS
FAULT TOLERANT MAP ARCHITECTURE

MICROPROCESSOR-1

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
MICROCOMPUTER ARRAY PROCESSOR

RCVR

DATA BUFFER

INPUT REGISTER

COMPARATORS

TRANSFORM

EMITTER FILE

PREPROCESSOR

MEMORY REQUEST LOGIC

MEMORY BANK-0
INTERCEPT BUFFER-0
2K x 32

MEMORY BANK-1
INTERCEPT BUFFER-1
2K x 32

MEMORY BANK-N

LOCAL MEMORY

LOCAL MEMORY

LOCAL MEMORY

LOCAL MEMORY

LOCAL MEMORY

LOCAL MEMORY

GLOBAL MEMORY

TO SYSTEM COMPUTER
MICROPROGRAM SEQUENCER BLOCK DIAGRAM

- **REGISTER ENABLE**
  - **RE**

- **ADDRESS REGISTER**

- **STACK POINTER**

- **4 X 4 FILE**

- **FILE ENABLE**

- **CLOCK**

- **DIRECT INPUTS**
  - **D**
  - **S_0**
  - **S_1**
  - **OR_3**
  - **OR_2**
  - **OR_1**
  - **OR_0**

- **MULTIPLEXER**
  - **X_0**
  - **X_1**
  - **X_2**
  - **X_3**

- **MICROPROGRAM COUNTER REGISTER**

- **INCREMENTER**

- **PUSH/POP**

- **OUTPUT CONTROL**
  - **GE**
  - **Y_0**
  - **Y_1**
  - **Y_2**
  - **Y_3**
  - **C_n**
  - **C_n+1**
MICROPROCESSOR SLICE BLOCK DIAGRAM

- **CLOCK**
- **RAM SHIFT**
- **Q SHIFT**
- **16 X 4 RAM READ A & B WRITE B**
- **Q REGISTER**
- **SELECTOR**
- **ALU**
- **MICRO-INSTRUCTION DECODE**
- **MULTIPLEXER**

**Inputs:**
- A ADDRESS
- B ADDRESS
- DIRECT INPUT
- MICRO-CODE

**Outputs:**
- OUTPUT
- CONTROL
- Q

**Connections:**
- LO/RI
- RO/LI
- 0 REGISTER
- 16X4 RAM
<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>0.250 or 0.325</td>
</tr>
<tr>
<td>1</td>
<td>INPUT/OUTPUT</td>
<td>0.350 OUTPUT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.400 INPUT</td>
</tr>
<tr>
<td>2</td>
<td>REGISTER/IMMEDIATE</td>
<td>0.350</td>
</tr>
<tr>
<td>3</td>
<td>READ/WRITE PROGRAM MEMORY</td>
<td>0.525 READ</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.650 WRITE</td>
</tr>
<tr>
<td>4</td>
<td>EXTERNAL FUNCTION CONTROL</td>
<td>0.350</td>
</tr>
<tr>
<td>5</td>
<td>INTERRUPT CONTROL</td>
<td>0.400</td>
</tr>
<tr>
<td>6</td>
<td>PC STACK CONTROL</td>
<td>0.300</td>
</tr>
<tr>
<td>7</td>
<td>CONDITIONAL BRANCH</td>
<td>0.200 NO BRANCH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.300 BRANCH</td>
</tr>
</tbody>
</table>
## COMPARISON OF \( \mu \)PROCESSORS

<table>
<thead>
<tr>
<th></th>
<th>AMD AM2916</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></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>register; Read,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modify, Write)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>**Power</td>
<td>0.92W</td>
<td>1.12W</td>
<td>1.45W (2 x 0.73)</td>
<td>0.13W</td>
<td>1.3W</td>
</tr>
<tr>
<td>Dissipation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4 bits)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>**Addressable</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>**Register</td>
<td>Two-</td>
<td>Two-</td>
<td>Single-</td>
<td>Single-</td>
<td>Single-</td>
</tr>
<tr>
<td>Addressing</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>**Number of</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>**Primary</td>
<td>R + S</td>
<td>R + S</td>
<td>R + S</td>
<td>R + S</td>
<td>R + S</td>
</tr>
<tr>
<td>Arithmetic</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>**Primary</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>8</td>
<td>6 - BCD</td>
</tr>
<tr>
<td>Logic Functions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8 - Binary</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>operand</td>
<td>Combination</td>
<td>to ALU</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Possible ALU</strong></td>
<td>17</td>
<td>17</td>
<td>12</td>
<td>10</td>
<td>2 - 258</td>
</tr>
<tr>
<td><strong>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></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