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| **Instruction Type** | **Instructions** | **Description** |
| Matrix Ops | VMMUL rd, rs1, rs2, rs3 | **Vector-Matrix Multiply:** Multiply a vector in rs1 by a matrix in rs2 and store the result in rd |
|  | VDOT rd, rs1, rs2 | **Vector Dot Product:** Compute the dot product of two vectors. |
|  | MATMUL rd, rs1, rs2 | **Matrix Multiply**: compute matrix multiplication of two matrices |
| FFT / STFT Acceleration | FFT rd, rs1 | Compute **Fast Fourier Transform (FFT)** on the input signal. |
|  | IFFT rd, rs1 | Compute **Inverse FFT** |
|  | MELFILTER rd, rs1 | Apply **Mel filter bank** (log scaling & filtering) |
| LSTM/GRU layers | LSTM\_GATE rd, rs1, rs2, rs3 | **Compute sigmoid** (Wx + Uh + b) for input, forget, and output gates. |
|  | LSTM\_UPDATE rd, rs1, rs2 | **Compute new cell** state: c\_t = f\_t \* c\_t-1 + i\_t \* g\_t |
|  | TANH rd, rs1 | Efficient **Tanh activation** (used in LSTMs) |
|  | SIGMOID rd, rs1 | Efficient **Sigmoid activation** |
| Batch Normalization & Activation | BATCHNORM rd, rs1, rs2, rs3 | **Normalize input** x using mean and variance |
|  | RELU rd, rs1 | Apply **ReLU activation** |
|  | LOGSOFTMAX rd, rs1 | Compute **log-softmax** for CTC loss. |
| Memory & Data Movement | LDV rd, [rs1] | **Load a vector** from memory into register rd |
|  | STV rs1, [rd] | **Store a vector** back to memory |
|  | PREFETCH rs1 | **Prefetch a block of memory** into local buffer. |
|  | DMA\_MOVE rs1, rs2, rs3 | **Move data** asynchronously from DRAM to accelerator |
|  | DMA\_CONFIG rs1, rs2, rs3 | **Configure DMA** (sets source, destination, and transfer size before calling DMA\_MOVE). |
|  | DMA\_STATUS rd | **Check if DMA transfer is done** (reads completion status). |

ARM HPS Memory

**Audio Codec**

Accelerator/TPU

DMA Controller

**SPART**

RISC-V Processor