Hinweise – Dekodierung

Dr.-Ing. Volkmar Sieh

Department Informatik 4
Verteilte Systeme und Betriebssysteme
Friedrich-Alexander-Universität Erlangen-Nürnberg

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Dekodierung

Beispiel CPU 6510 (Prozessor Commodore-64):

		0	1	2	3	4	5	6	L 7
	0	BRK	ORA(z,x)	JAM i	SLO(z,x)	NOP z	ORA z	ASL z	SLO z
	1	BPL r	ORA(z),y	JAM i	SLO(z),y	NOP z,x	ORA z,x	ASL z,x	SLO z,x
	2	JSR a	AND(z,x)	JAM i	RLA(z,x)	BIT z	AND z	ROL z	RLA z
	3	BMI r	AND(z),y	JAM i	RLA(z),y	NOP z,x	AND z,x	ROL z,x	RLA z,x
	4	RTI s	EOR(z,x)	JAM i	SRE(z,x)	NOP z	EOR z	LSR z	SRE z
	5	BVC r	EOR(z),y	JAM i	SRE(z),y	NOP z,x	EOR z,x	LSR z,x	SRE z,x
	6	RTS s	ADC(z,x)	JAM i	RRA(z,x)	NOP z	ADC z	ROR z	RRA z
	7	BVS r	ADC(z),y	JAM i	RRA(z),y	NOP z,x	ADC z,x	ROR z,x	RRA z,x
	8	NOP #	STA(z,x)	NOP #	SAX(z,x)	STY z	STA z	STX z	SAX z
	9	BCC r	STA(z),y	JAM i	SHA a,x	STYz,x	STA z,x	STX z,y	SAX z,y
	A	LDY #	LDA(z,x)	LDX #	LAX(z,x)	LDY z	LDA z	LDX z	LAX z
	B	BCS r	LDA(z),y	JAM i	LAX(z),y	LDY z,x	LDA z,x	LDX z,y	LAX z,y
	C	CPY #	CMP(z,x)	NOP #	DCP(z,x)	CPY z	CMP z	DEC z	DCP z
	D	BNE r	CMP(z),y	JAM i	DCP(z),y	NOP z,x	CMP z,x	DEC z,x	DCP z,x
	E	CPX #	SBC(z,x)	NOP #	ISB(z,x)	CPX z	SBC z	INC z	ISB z
H	F	BEQ r	SBC(z),y	JAM i	ISB(z),y	NOP z,x	SBC z,x	INC z,x	ISB z,x

Dekodierung

		8	9	A	B	C	D	E	L F
	0	PHP s	ORA #	ASL A	ANC #	NOP a	ORA a	ASL a	SLO a
	1	CLC i	ORA a,y	NOP i	SLO a,y	NOP a,x	ORA a,x	ASL a,x	SLO a,x
	2	PLP s	AND #	ROL A	ANC #	BIT a	AND a	ROL a	RLA a
	3	SEC i	AND a,y	NOP i	RLA a,y	NOP a,x	AND a,x	ROL a,x	RLA a,x
	4	PHA s	EOR #	LSR A	ASR #	JMP a	EOR a	LSR a	SRE a
	5	CLI i	EOR a,y	NOP i	SRE a,y	NOP a,x	EOR a,x	LSR a,x	SRE a,x
	6	PLA s	ADC #	ROR A	ARR #	JMP (a)	ADC a	ROR a	RRA a
	7	SEI i	ADC a,y	NOP i	RRA a,y	NOP a,x	ADC a,x	ROR a,x	RRA a,x
	8	DEY i	NOP #	TXA i	ANE #	STY a	STA a	STX a	SAX a
	9	TYA i	STA a,y	TXS i	SHS a,x	SHY a,y	STA a,x	SHX a,y	SHA a,y
	A	TAY i	LDA #	TAX i	LXA #	LDY a	LDA a	LDX a	LAX a
	B	CLV i	LDA a,y	TSX i	LAE a,y	LDY a,x	LDA a,x	LDX a,y	LAX a,y
	C	INY i	CMP #	DEX i	SBX #	CPY a	CMP a	DEC a	DCP a
	D	CLD i	CMP a,y	NOP i	DCP a,y	NOP a,x	CMP a,x	DEC a,x	DCP a,x
	E	INX i	SBC #	NOP i	SBC #	CPX a	SBC a	INC a	ISB a
H	F	SED i	SBC a,y	NOP i	ISB a,y	NOP a,x	SBC a,x	INC a,x	ISB a,x

Dekodierung

Beispiel CPU 6510 (Prozessor Commodore-64):

		0	1	2	3	4	5	6	L 7
	0	BRK	ORA(z,x)	JAM i	SLO(z,x)	NOP z	ORA z	ASL z	SLO z
	1	BPL r	ORA(z),y	JAM i	SLO(z),y	NOP z,x	ORA z,x	ASL z,x	SLO z,x
	2	JSR a	AND(z,x)	JAM i	RLA(z,x)	BIT z	AND z	ROL z	RLA z
	3	BMI r	AND(z),y	JAM i	RLA(z),y	NOP z,x	AND z,x	ROL z,x	RLA z,x
	4	RTI s	EOR(z,x)	JAM i	SRE(z,x)	NOP z	EOR z	LSR z	SRE z
	5	BVC r	EOR(z),y	JAM i	SRE(z),y	NOP z,x	EOR z,x	LSR z,x	SRE z,x
	6	RTS s	ADC(z,x)	JAM i	RRA(z,x)	NOP z	ADC z	ROR z	RRA z
	7	BVS r	ADC(z),y	JAM i	RRA(z),y	NOP z,x	ADC z,x	ROR z,x	RRA z,x
	8	NOP #	STA(z,x)	NOP #	SAX(z,x)	STY z	STA z	STX z	SAX z
	9	BCC r	STA(z),y	JAM i	SHA a,x	STYz,x	STA z,x	STX z,y	SAX z,y
	A	LDY #	LDA(z,x)	LDX #	LAX(z,x)	LDY z	LDA z	LDX z	LAX z
	B	BCS r	LDA(z),y	JAM i	LAX(z),y	LDY z,x	LDA z,x	LDX z,y	LAX z,y
	C	CPY #	CMP(z,x)	NOP #	DCP(z,x)	CPY z	CMP z	DEC z	DCP z
	D	BNE r	CMP(z),y	JAM i	DCP(z),y	NOP z,x	CMP z,x	DEC z,x	DCP z,x
	E	CPX #	SBC(z,x)	NOP #	ISB(z,x)	CPX z	SBC z	INC z	ISB z
H	F	BEQ r	SBC(z),y	JAM i	ISB(z),y	NOP z,x	SBC z,x	INC z,x	ISB z,x

Dekodierung

		8	9	A	B	C	D	E	L F
	0	PHP s	ORA #	ASL A	ANC #	NOP a	ORA a	ASL a	SLO a
	1	CLC i	ORA a,y	NOP i	SLO a,y	NOP a,x	ORA a,x	ASL a,x	SLO a,x
	2	PLP s	AND #	ROL A	ANC #	BIT a	AND a	ROL a	RLA a
	3	SEC i	AND a,y	NOP i	RLA a,y	NOP a,x	AND a,x	ROL a,x	RLA a,x
	4	PHA s	EOR #	LSR A	ASR #	JMP a	EOR a	LSR a	SRE a
	5	CLI i	EOR a,y	NOP i	SRE a,y	NOP a,x	EOR a,x	LSR a,x	SRE a,x
	6	PLA s	ADC #	ROR A	ARR #	JMP (a)	ADC a	ROR a	RRA a
	7	SEI i	ADC a,y	NOP i	RRA a,y	NOP a,x	ADC a,x	ROR a,x	RRA a,x
	8	DEY i	NOP #	TXA i	ANE #	STY a	STA a	STX a	SAX a
	9	TYA i	STA a,y	TXS i	SHS a,x	SHY a,y	STA a,x	SHX a,y	SHA a,y
	A	TAY i	LDA #	TAX i	LXA #	LDY a	LDA a	LDX a	LAX a
	B	CLV i	LDA a,y	TSX i	LAE a,y	LDY a,x	LDA a,x	LDX a,y	LAX a,y
	C	INY i	CMP #	DEX i	SBX #	CPY a	CMP a	DEC a	DCP a
	D	CLD i	CMP a,y	NOP i	DCP a,y	NOP a,x	CMP a,x	DEC a,x	DCP a,x
	E	INX i	SBC #	NOP i	SBC #	CPX a	SBC a	INC a	ISB a
H	F	SED i	SBC a,y	NOP i	ISB a,y	NOP a,x	SBC a,x	INC a,x	ISB a,x

Dekodierung

Beispiel CPU 6510 (Prozessor Commodore-64):

		0	1	2	3	4	5	6	L 7
	0	BRK	ORA(z,x)	JAM i	SLO(z,x)	NOP z	ORA z	ASL z	SLO
	1	BPL r	ORA(z),y	JAM i	SLO(z),y	NOP z,x	ORA z,x	ASL z,x	SLO
	2	JSR a	AND(z,x)	JAM i	RLA(z,x)	BIT z	AND z	ROL z	RLA
	3	BMI r	AND(z),y	JAM i	RLA(z),y	NOP z,x	AND z,x	ROL z,x	RLA
	4	RTI s	EOR(z,x)	JAM i	SRE(z,x)	NOP z	EOR z	LSR z	SRE
	5	BVC r	EOR(z),y	JAM i	SRE(z),y	NOP z,x	EOR z,x	LSR z,x	SRE
	6	RTS s	ADC(z,x)	JAM i	RRA(z,x)	NOP z	ADC z	ROR z	RRA
	7	BVS r	ADC(z),y	JAM i	RRA(z),y	NOP z,x	ADC z,x	ROR z,x	RRA
	8	NOP #	STA(z,x)	NOP #	SAX(z,x)	STY z	STA z	STX z	SAX
	9	BCC r	STA(z),y	JAM i	SHA a,x	STY z,x	STA z,x	STX z,y	SAX
	A	LDY #	LDA(z,x)	LDX #	LAX(z,x)	LDY z	LDA z	LDX z	LAX
	B	BCS r	LDA(z),y	JAM i	LAX(z),y	LDY z,x	LDA z,x	LDX z,y	LAX
	C	CPY #	CMP(z,x)	NOP #	DCP(z,x)	CPY z	CMP z	DEC z	DCP
	D	BNE r	CMP(z),y	JAM i	DCP(z),y	NOP z,x	CMP z,x	DEC z,x	DCP
	E	CPX #	SBC(z,x)	NOP #	ISB(z,x)	CPX z	SBC z	INC z	ISB
H	F	BEQ r	SBC(z),y	JAM i	ISB(z),y	NOP z,x	SBC z,x	INC z,x	ISB z

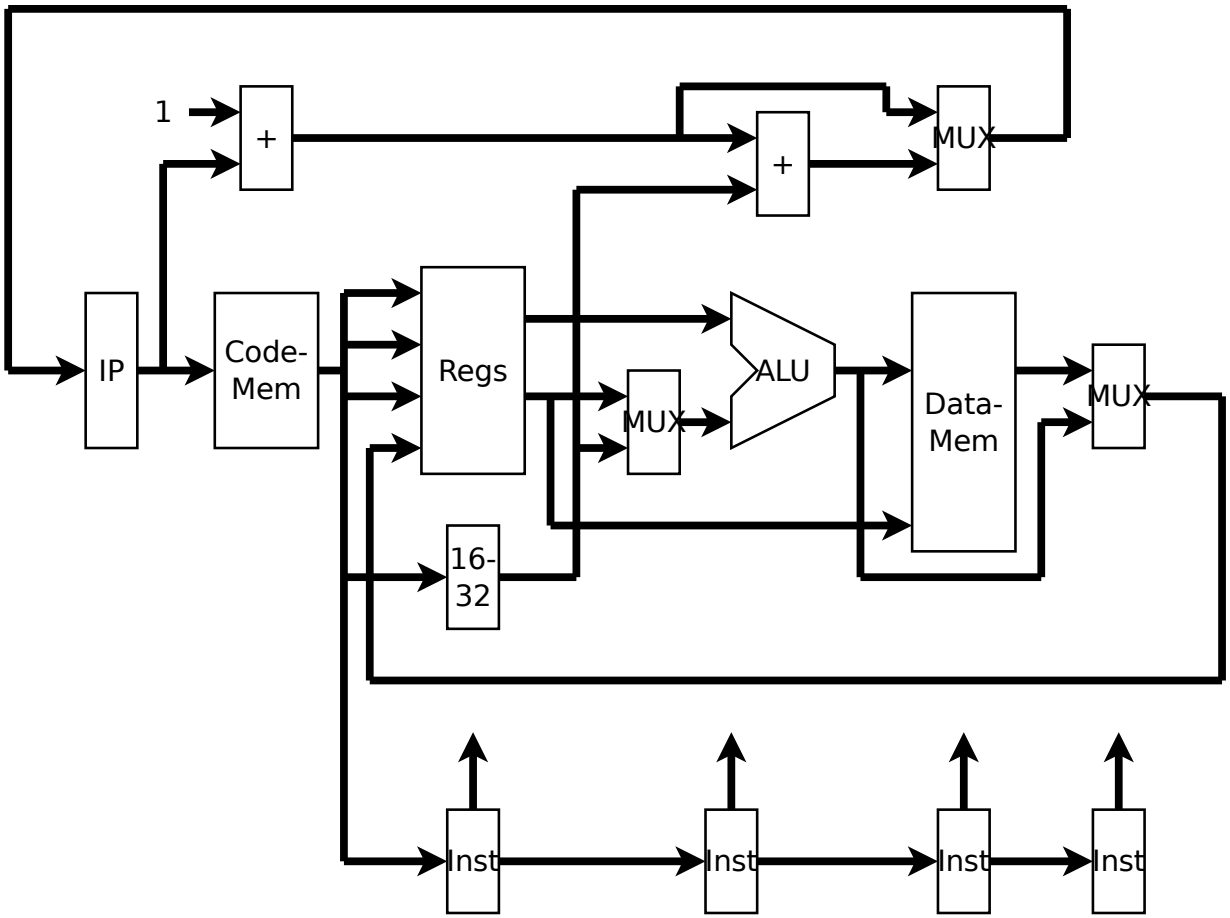
Dekodierung

H	L	8	9	A	B	C	D	E	F
	0	PHP s	ORA #	ASL A	ANC #	NOP a	ORA a	ASL a	SLO a
	1	CLC i	ORA a,y	NOP i	SLO a,y	NOP a,x	ORA a,x	ASL a,x	SLO a,x
	2	PLP s	AND #	ROL A	ANC #	BIT a	AND a	ROL a	RLA a
	3	SEC i	AND a,y	NOP i	RLA a,y	NOP a,x	AND a,x	ROL a,x	RLA a,x
	4	PHA s	EOR #	LSR A	ASR #	JMP a	EOR a	LSR a	SRE a
	5	CLI i	EOR a,y	NOP i	SRE a,y	NOP a,x	EOR a,x	LSR a,x	SRE a,x
	6	PLA s	ADC #	ROR A	ARR #	JMP (a)	ADC a	ROR a	RRA a
	7	SEI i	ADC a,y	NOP i	RRA a,y	NOP a,x	ADC a,x	ROR a,x	RRA a,x
	8	DEY i	NOP #	TXA i	ANE #	STY a	STA a	STX a	SAX a
	9	TYA i	STA a,y	TXS i	SHS a,x	SHY a,y	STA a,x	SHX a,y	SHA a,y
	A	TAY i	LDA #	TAX i	LXA #	LDY a	LDA a	LDX a	LAX a
	B	CLV i	LDA a,y	TSX i	LAE a,y	LDY a,x	LDA a,x	LDX a,y	LAX a,y
	C	INY i	CMP #	DEX i	SBX #	CPY a	CMP a	DEC a	DCP a
	D	CLD i	CMP a,y	NOP i	DCP a,y	NOP a,x	CMP a,x	DEC a,x	DCP a,x
	E	INX i	SBC #	NOP i	SBC #	CPX a	SBC a	INC a	ISB a
H	F	SED i	SBC a,y	NOP i	ISB a,y	NOP a,x	SBC a,x	INC a,x	ISB a,x

Dekodierung

Woher kommen diese Muster...?

Dekodierung – Pipelining



Dekodierung – Pipelining

Einfachste Pipeline-Realisierung:

Jede Pipeline-Stufe verwendet jeweils für sie bestimmte Bits einer Instruktion:

Register-File: Bits für Register-Nummern

ALU: Bits für Operation (+, -, ...)

Multiplexer: Bits für Auswahl

...: Bits für ...

Weitergegebene Instruktion vermindert sich jeweils um die bereits ausgewerteten Bits.

Dekodierung

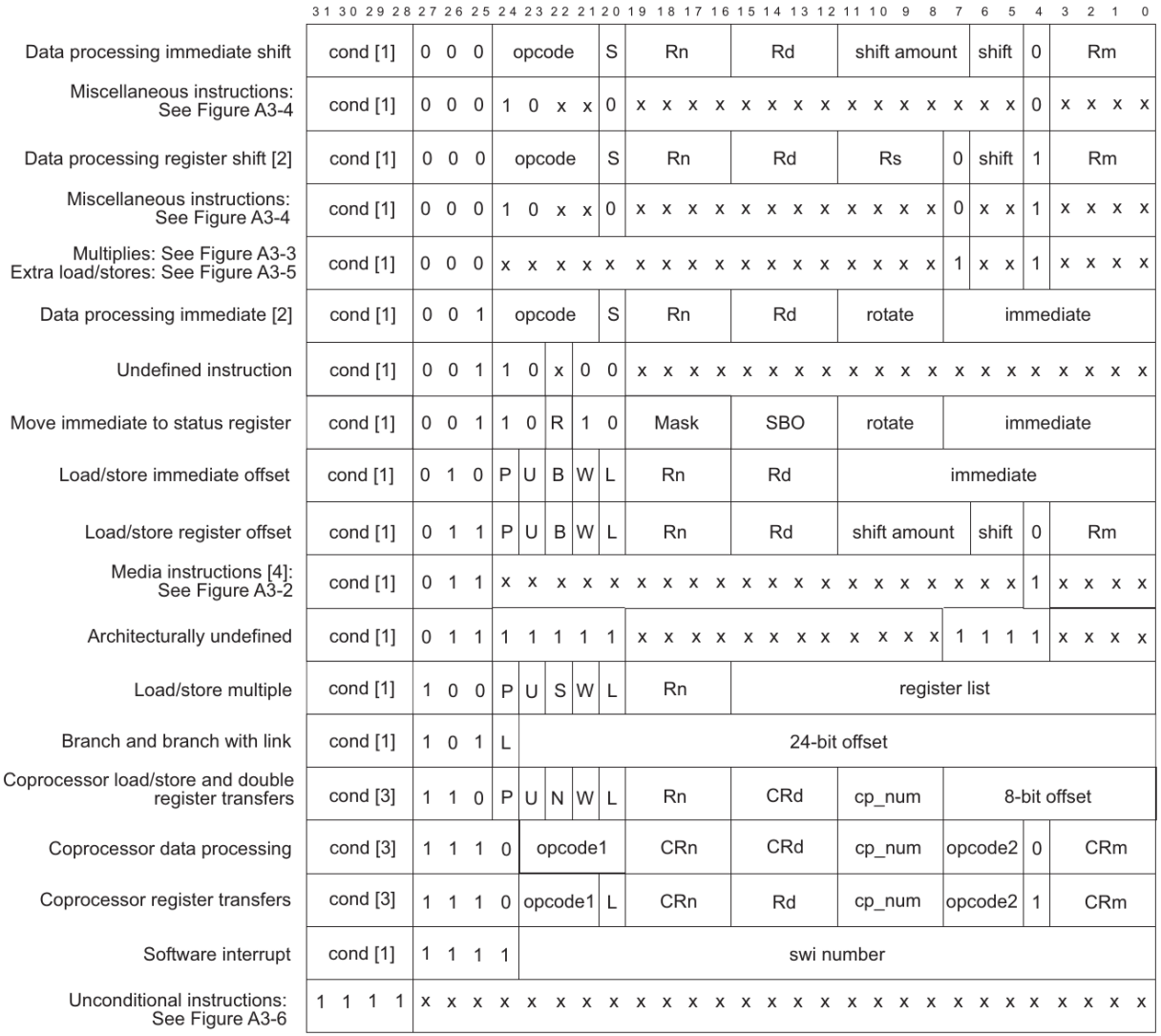
Was heißt das für eine VM?

Dekodierung

```
step() {
    /* 1. Pipeline-Stufe: Instruktion holen */
    inst = fetch(ip++);

    /* 2. Pipeline-Stufe: Operanden holen */
    op1 = reg_read((inst >> 0) & 7);
    op2 = reg_read((inst >> 3) & 7);

    /* 3. Pipeline-Stufe: Rechnen */
    switch ((inst >> 6) & 7) {
    case 0: res = op1 + op2; break;
    case 1: res = op1 - op2; break;
    case 2: res = op1 & op2; break;
    ...
    }

    /* 4. Pipeline-Stufe: Ergebnis speichern */
    reg_write((inst >> 9) & 7, res);
}
```

Dekodierung

In der Praxis: mehrere Instruktionsformate. Beispiel ARM:



Dekodierung

Grund für verschiedene Instruktions-Formate:

Unterschiedliche Befehle brauchen unterschiedliche Parameter.

Beispiele:

- Sprünge brauchen
  - einen (großen) Offset
- bedingte Sprünge brauchen
  - eine Bedingung
  - einen (nicht ganz so großen) Offset
- ALU-Operationen brauchen
  - drei Register-Nummern

  oder
  - zwei Register-Nummern
  - einen (größeren) Immediate-Wert

...

Dekodierung

```
step() {
    /* 1. Pipeline-Stufe: Instruktion holen */
    inst = fetch(ip++);

    switch (inst_format(inst) {
    case ALU_REG_REG:
        /* 2. Pipeline-Stufe: Operanden holen */
        op1 = reg_read((inst >> 0) & 0xf);
        op2 = reg_read((inst >> 4) & 0xf);

        /* 3. Pipeline-Stufe: Rechnen */
        res = alu((inst >> 24) & 0xf, op1, op2);

        /* 4. Pipeline-Stufe: Ergebnis speichern */
        reg_write((inst >> 20) & 0xf, res);
        break;

    case ALU_REG_IMM:
        /* 2. Pipeline-Stufe: Operanden holen */
        op1 = reg_read((inst >> 0) & 0xf);
        op2 = (inst >> 4) & 0xffff;

        /* 3. Pipeline-Stufe: Rechnen */
        res = alu((inst >> 24) & 0xf, op1, op2);

        /* 4. Pipeline-Stufe: Ergebnis speichern */
        reg_write((inst >> 20) & 0xf, res);
        break;

    case ...
        ...
    }
}
```