

Programming Quickies

KIM-1 Multiplication and Division

James C Couchman, General Dynamics Corp, Fort Worth
Division, POB 748, Fort Worth TX 76101

When I bought a MOS Technology KIM-1 microcomputer to use in a specific control function, it arrived with a set of comprehensive instruction, programming, and hardware books. As soon as I connected a 5 V power supply, I was able to interact with the machine through the hexadecimal keyboard and light-emitting diode (LED) display. It was a bit more difficult to get our Teletype to work with the KIM-1, but with a slight adjustment to the teleprinter timing, the problem was cured.

The KIM-1 is still a real bargain, with features including the 6502 microprocessor, 2 K bytes of read-only memory (containing the Keyboard Input Monitor from which the name is derived), an interval timer, fifteen input and output lines, 1 K bytes of programmable memory (with address logic for 16 K bytes), and probably some features I have not yet discovered.

Since the KIM-1 is programmed in machine language using a set of fifty-six instructions, I believe that the best way to learn to program it is to not just read about it, but do it. One should just start writing code, and, in time, the power of the basic instruction set will really be understood and appreciated.

Once the user is familiar with the capabilities of the KIM-1, he begins to wish that it could do more. One tool that provides more capability is a set of software routines that perform sixteen-bit multiplication and division on the 6502 processor. After I searched for a suitable set of routines, I concluded that I would have to write my own.

To prevent you from having to "reinvent the wheel," I am presenting these routines here. In developing these routines, I enlisted the invaluable assistance of my associates G R Arnett and J R Williamson. These routines should work without much difficulty on other 6502-based computers.

Sixteen-Bit Routines

These routines can multiply and divide two 16-bit signed quantities together and produce a signed 16-bit result. The routines are written as relocatable subroutines.

In multiplication, the high-order byte of the first multiplicand is loaded into hexadecimal location 0000, and the low-order byte into location 0001. The high-

order byte of the second multiplicand is put into location 0006, and the low-order byte into location 0007.

In division, the high-order byte of the divisor is loaded into hexadecimal location 0000; the low-order byte into location 0001. The high-order byte of the dividend is placed into location 0006, and the low-order byte is loaded into location 0007. If the value of the divisor is zero, the division routine will return control to the calling program.

For both the multiplication and the division routines, the answer is returned in hexadecimal locations 0002 (high-order) and 0003 (low-order byte). It should not be very hard to change this if need be.

An example of a simple calling routine is shown in listing 1. The calling sequence is essentially the same for both multiplication and for division; only the value contained in the two bytes that follow the jump-to-subroutine (JSR) instruction must be changed.

Listing 1a: Calling sequence for 16-bit multiply subroutine.

Address	Code
0007	20 (JSR)
0008	00
0009	01 (multiply)
000A	A9 (LDA)
000B	00
000C	F0
000D	FC

Listing 1b: Calling sequence for 16-bit divide subroutine.

Address	Code
0007	20 (JSR)
0008	30
0009	00 (divide)
000A	A9 (LDA)
000B	00
000C	F0
000D	FC

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The assembler mnemonics and hexadecimal code for the multiplication subroutine are given in listing 2. The division subroutine is given in similar form in listing 3. The multiplication subroutine is shown in hexadecimal memory-dump form in listing 4; the division code in that form in listing 5.

My colleagues and I hope that these programs will help other KIM-1 users. We know that having had them prepared for us would have saved us much time.

Listing 2: Relocatable subroutine to perform multiplication of 16-bit quantities on the 6502 microprocessor as used in the MOS Technology KIM-1. Both assembler mnemonics and hexadecimal code are given. Entry point is hexadecimal location 0100.

Address	Mnemonic	Hexadecimal Code
0100	CLC	18
0101	CLD	D8
0102	LDA #0	A9 00
0104	TAX	AA
0105	STA 0002	85 02
0107	STA 0003	85 03
0109	LDA 0000	A5 00
010B	BNE	D0 11
010D	LDA 0001	A5 01
010F	BEQ	F0 0C
0111	CMP #1	C9 01
0113	BNE	D0 1D
0115	LDA 0006	A5 06
0117	STA 0002	85 02
0119	LDA 0007	A5 07
011B	STA 0003	85 03
011D	RTS	60
011E	BPL	10 12
0120	INX	E8
0121	LDA 0001	A5 01
0123	CLC	18
0124	EOR FF	49 FF
0126	ADC #1	69 01
0128	STA 0001	85 01
012A	LDA 0000	A5 00
012C	EOR FF	49 FF
012E	ADC #0	69 00
0130	STA 0000	85 00
0132	LDA 0006	A5 06
0134	BNE	D0 26
0136	LDA 0007	A5 07
0138	BEQ	F0 18
013A	CMP #1	C9 01
013C	BNE	D0 32
013E	DEX	CA
013F	BNE	D0 12
0141	LDA 0001	A5 01
0143	CLC	18
0144	EOR FF	49 FF
0146	ADC #1	69 01
0148	STA 0003	85 03
014A	CDA 0000	A5 00
014C	EOR FF	49 FF
014E	ADC #0	69 00
0150	STA 0002	85 02
0152	RTS	60
0153	LDA 0001	A5 01
0155	STA 0003	85 03
0157	LDA 0000	A5 00
0159	STA 0002	85 02
015B	RTS	60
015C	BPL	10 12
015E	INX	E8
015F	LDA 0007	A5 07

Listing 2 continued on page 215

Listing 2 continued:

0161	CLC	18
0162	EOR FF	49 FF
0164	ADC #1	69 01
0166	STA 0007	85 07
0168	LDA 0006	A5 06
016A	EOR FF	49 FF
016C	ADC #0	69 00
016E	STA 0006	85 06
0170	LDA 0000	A5 00
0172	STA 0004	85 04
0174	LDA 0001	A5 01
0176	STA 0005	85 05
0178	LDA 0003	A5 03
017A	CLC	18
017B	ADC 0001	69 01
017D	STA 0003	85 03
017F	LDA 0002	A5 02
0181	ADC 0000	69 00
0183	STA 0002	85 02
0185	SEC	38
0186	LDA 0007	A5 07
0188	SBC #1	E9 01
018A	STA 0007	85 07
018C	LDA 0006	A5 06
018E	SBC #0	E9 00
0190	STA 0006	85 06
0192	CMP #0	C9 00
0194	BNE	D0 E2
0196	LDA 0007	A5 07
0198	CMP #0	C9 00
019A	BNE	D0 DC
019C	DEX	CA
019D	BNE	D0 15
019F	LDA 0002	A5 02
01A1	EOR FF	49 FF
01A3	STA 0002	85 02
01A5	LDA 0003	A5 03
01A7	EOR FF	49 FF
01A9	CLC	18
01AA	ADC #1	69 01
01AC	STA 0003	85 03
01AE	LDA 0002	A5 02
01B0	ADC #0	69 00
01B2	STA 0002	85 02
01B4	RTS	60

Listing 3: Relocatable subroutine to perform division of 16-bit quantities on the 6502 microprocessor of the KIM-1, with assembler mnemonics. Entry point is hexadecimal location 0030.

Address	Mnemonic	Hexadecimal Code
0030	CLC	18
0031	CLD	D8
0032	LDA #0	A9 00
0034	TAX	AA
0035	STA 02	85 02
0037	STA 03	85 03
0039	LDA 00	A5 00
003B	BNE	D0 05
003D	LDA 01	A5 01
003F	BNE	D0 15
0041	RTS	60
0042	BPL	10 12
0044	INX	E8
0045	LDA 01	A5 01
0047	CLC	18
0048	EOR FF	49 FF
004A	ADC #1	69 01
004C	STA 01	85 01
004E	LDA 00	A5 00
0050	EOR FF	49 FF

Listing 3 continued on page 216

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Listing 3 continued:

```

0052      ADC #0      69 00
0054      STA 00      85 00
0056      LDA 06      A5 06
0058      BNE        D0 26
005A      LDA 07      A5 07
005C      BEQ        F0 18
005E      CMP #1      C9 01
0060      BNE        D0 32
0062      DEX        CA
0063      BNE        D0 12
0065      LDA 01      A5 01
0067      CLC        18
0068      EOR FF      49 FF
006A      ADC #1      69 01
006C      STA 03      85 03
006E      LDA 00      A5 00
0070      EOR FF      49 FF
0072      ADC #0      69 00
0074      STA 02      85 02
0076      RTS        60
0077      LDA 01      A5 01
0079      STA 03      85 03
007B      LDA 00      A5 00
007D      STA 02      85 02
007F      RTS        60
0080      BPL        10 12
0082      INX        E8
0083      LDA 07      A5 07
0085      CLC        18
0086      EOR FF      49 FF
0088      ADC #1      69 01
008A      STA 07      85 07
008C      LDA 06      A5 06
008E      EOR FF      49 FF
0090      ADC #0      69 00
0092      STA 06      85 06
0094      LDA 03      A5 03
0096      CLC        18
0097      ADC #1      69 01
0099      STA 03      85 03
009B      LDA 02      A5 02
009D      ADC #0      69 00
009F      STA 02      85 02
00A1      SEC        38
00A2      LDA 01      A5 01
00A4      SBC 07      E5 07
00A6      STA 01      85 01
00A8      LDA 00      A5 00
00AA      SBC 06      E5 06
00AC      STA 00      85 00
00AE      LDA 00      A5 00
00B0      BMI        30 08
00B2      BNE        D0 E0

```

```

00B4      LDA 01      A5 01
00B6      BNE        D0 DC
00B8      BEQ        F0 0D
00BA      SEC        38
00BB      LDA 03      A5 03
00BD      SBC #1      E9 01
00BF      STA 03      85 03
00C1      LDA 02      A5 02
00C3      SBC #0      E9 00
00C5      STA 02      85 02
00C7      DEX        CA
00C8      BNE        D0 15
00CA      LDA 02      A5 02
00CC      EOR FF      49 FF
00CE      STA 02      85 02
00D0      LDA 03      A5 03
00D2      EOR FF      49 FF
00D4      CLC        18
00D5      ADC #1      69 01
00D7      STA 03      85 03
00D9      LDA 02      A5 02
00DB      ADC #0      69 00
00DD      STA 02      85 02
00DF      RTS        60

```

Listing 4: Multiplication subroutine in hexadecimal memory-dump form.

```

J 18010018D8A900AA85028503A500D011A501F00CC901D01DA50685097A
J 18011802A5078503601012E8A5011849FF69018501A50049FF69000E1D
J 1801308500A506D026A507F018C901D032CAD012A5011849FF6901DA0B
J 1801488503A50049FF6900850260A5018503A5008502601012E8A508EF
J 180160071849FF69018507A50649FF69008506A5008504A50185050E1B
J 180178A5031865018503A5026500850238A507E9018507A506E90007C0
J 1801908506C900D0E2A507C900D0DCCAD015A50249FF6902A503490BE6
J 1801A8FF1869018503A5026900850260E9008D060C900D0D8AD070968
J 0000080008 0

```

Listing 5: Division subroutine in hexadecimal memory-dump form.

```

J 18003018D8A900AA85028503A500D005A501D015601012E8A5011808C7
J 18004849FF69018501A50049FF69008500A506D026A507F018C9010992
J 180060D032CAD012A5011849FF69018503A50049FF6900850260A50A00
J 180078018503A5008502601012E8A5071849FF69018507A50649FF08A4
J 18009069008506A5031869018503A5026900850238A501E50785010735
J 1800A8A500E5068500A5003008D02A501D0DCP00D36A503E901850B00
J 1800C003A502E9008502CAD015A50249FF6902A50349FF186901850A0E
J 1800D803A5026900850260002A3FC3B3F1E3E3E3E7E7A7F07BE
J 0000080008 ■

```

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