A-LEVEL COMPUTER SCIENCE • EXERCISE SHEET

4.3.1 Arithmetic and cyclic shifts, and when a shift stops being a multiply or a divide

Name: _____ Class: _____ Date: _____ **Total: 29 marks**

KEY WORDS logical shift 逻辑移位 • arithmetic 算术移位 • binary shift 二进制移位 • cyclic 循环移位 • mask 掩码

Objective

Build the skills to answer the **binary shift** 二进制移位 questions that sheet 4.3 does not reach. That sheet performs **logical** shifts and uses a **mask** 掩码 to set, clear, toggle and test a bit; this one is about the other two shifts the syllabus names and that sheet only mentions – the **arithmetic** 算术移位 and the **cyclic** 循环移位 shift – what each one does to the **value**, and when a shift stops being a multiplication or a division.

You must be able to:

- perform a **logical**, an **arithmetic** and a **cyclic** shift, left and right, by any number of places
- state the effect of each shift on the value, and say which reading of the bits it is correct for
- say when a shift is no longer a multiplication or a division, and why
- extract a field from a register by combining a shift with a mask

1 Worked examples

Study these first. Each one shows a **method** that a question later on this sheet needs.

■ The three shifts, on one byte

A shift question gives you a bit pattern and a number of places. What differs between the three kinds is only **what enters the vacated end**.

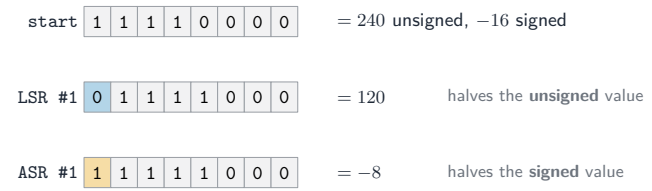
Shift	What enters	What leaves
logical (`LSL`, `LSR`)	a **0**, at either end	falls off and is **lost**
arithmetic right (`ASR`)	a copy of the **sign bit**	falls off and is lost
cyclic (rotate)	the bit that just **left the other end**	comes back round – **nothing is lost**

Worked example. *Shift `10110100` by two places.*

	Result	Unsigned	Signed
`LSL #2`	`11010000`	208	−48
`LSR #2`	`00101101`	45	45
`ASR #2`	`11101101`	237	−19

- Only the **arithmetic** right shift keeps the number negative. `10110100` is −76 signed, and $-76 \div 4 = -19$, which is what `ASR #2` gives.

■ Why there are two right shifts



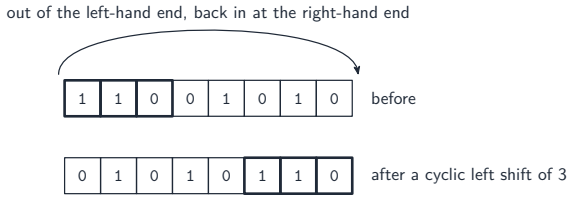
The two results differ in **one bit** — the one that entered on the left. **LSR** always brings in a 0; **ASR** copies the sign bit, so a negative number stays negative and $-16 \div 2$ comes out right.

The same byte reads as two different numbers, and each right shift halves one of them.

`11110000` is **240** read as unsigned and **−16** read as two's complement.

- `LSR #1` brings in a 0: `01111000` = 120, which is half of 240.
- `ASR #1` copies the sign bit: `11111000` = −8, which is half of −16.
- **Neither is wrong.** The question tells you which reading applies, and that chooses the shift. Signed data takes the arithmetic shift; unsigned data takes the logical one.

■ The cyclic shift loses nothing



A cyclic left shift of 3 on `11001010` takes the leading `110` off the left and puts it back on the right, giving `01010110`.

- Because nothing is lost, a cyclic shift is **reversible**: a cyclic shift of 8 places on an 8-bit register returns the original pattern exactly.
- That is what it is used for: rotate a register one place at a time, testing the same single bit each time, and you can inspect all 8 bits without ever destroying the data.
- A cyclic shift is **not** a multiplication or a division. `11001010` is 202, and the rotated `01010110` is 86.

A shift is only a multiply or a divide while nothing important falls off

- `LSL #n` multiplies an unsigned value by 2^n – but only while the bits leaving the left are **zeros**. `00001101` is 13, and `LSL #3` gives `01101000` $= 104 = 13 \times 8$, correct because only 0s left.
- The same shift on `10110100` (180) should give $180 \times 4 = 720$, which needs ten bits. `LSL #2` gives `11010000` $= 208$: the two 1s that fell off the left are gone, the sign bit has changed, and the answer is simply wrong. **Overflow.**
- `ASR #n` divides a signed value by 2^n, but it rounds **down**, towards the more negative number, not towards zero. -9 is `11110111`; `ASR #1` gives `11111011` $= -5$, not -4.

Shift and mask together

To pull one **field** out of a register, shift it down to the bottom and mask off what is left.

With `ACC` holding `10110100`, where the top four bits are a sensor number and the bottom four a reading:

- the **sensor number**: `LSR #4` gives `00001011` $= 11$. No mask is needed, because a logical shift brings 0s in on the left.
- the **reading**: `AND B00001111` gives `00000100` $= 4$. No shift is needed, because the field is already at the bottom.

2 Practice

Now use the methods above.

2.1 A register holds `10110100`. Give the contents after each of these shifts. [3]

(a) `LSL #2`

(b) `LSR #2`

(c) `ASR #2`

2.2 Perform a **cyclic left shift of 3 places** on `11001010`. [2]

2.3 A register holds `11110000`.

Give the result of `LSR #1` and of `ASR #1`, and state the denary value each one is the correct half of. [3]

2.4 State the contents of an 8-bit register after a **cyclic shift of 8 places**, and explain your answer. [1]

2.5 A register holds `00001101`. Perform `LSL #3` and state whether the result is still eight times the original. [2]

3 Exam-style questions

3.1 A register holds the 8-bit two's complement integer `10110100`.

(a) State its denary value. [1]

(b) Give the contents of the register after `ASR #2`, and show that the result is the correct value. [2]

(c) State why `LSR #2` would **not** give the correct answer here. [1]

3.2 A programmer halves a signed integer by performing an arithmetic right shift of one place.

The register holds `11110111`.

(a) State the denary value before and after the shift. [2]

(b) The programmer expected -4. Explain why the answer is different. [1]

3.3 A microcontroller must test each of the 8 bits of a register in turn, and must still hold the original value when it has finished.

(a) Name the type of shift that makes this possible, and explain why the other two cannot be used. [3]

(b) State how many shifts return the register to its starting contents. [1]

3.4 For each task, name the shift to use and give one reason. [3]

(a) multiply an unsigned counter by 4

(b) halve a signed temperature reading that may be negative

(c) move every bit one place left without losing the bit at the far end

3.5 An 8-bit accumulator holds `10110100`. The top four bits are a sensor number and the bottom four bits are that sensor's reading.

Write the instruction, or instructions, that leave **only** the sensor number in the accumulator, and state the denary value that results. Then do the same for the reading. [4]