

bso2 Monitor Reference

Target: W65C02EDU | Source: SRC/bso2.asm | Generated: 2026-02-14

0) Naming

`bso2` is the preferred written form in this manual.

It is intentionally dual-meaning and retro-styled:

- `b` = Basic
- `s` = System
- `0` = Operations (also read as letter `O`)
- `2` = `/2` and 6502 lineage

Stylized-glyph note: `6` can stand in for lowercase `b`, and `5` can stand in for lowercase `s`.

That makes `6502` a visual shorthand for `bso2` (`6=b`, `5=s`, `0=o`, `2=/2`).

Expanded meaning: `Basic System Operations/2`.

1) Startup / Prompt Behavior

On reset with valid reset cookie, boot choices are `C/W/M`:

`C` = clear RAM (confirm Y/N)

`W` = warm start

`M` = enter monitor

A terminal-width prompt follows boot selection: `TERM WIDTH 4=40 8=80 1=132 [8]? .`

Width persistence policy: `W/M` restore prior width before prompting; `C` starts from default 80 before prompting.

After clear/startup, the sign-on banner (`BS02_INIT`) is printed:

```
**** basic system operations/2 ****
****      b s o / 2 v0 . 9      ****
****      6 5 0 2              ****
```

Monitor prompt is a single `-` character on a new line.

2) Command Summary

Cmd	Syntax	Behavior / Output	Flags / Notes
<code>?</code>	<code>?</code>	Short help line.	Quick command list only.
<code>H</code>	<code>H [A P M S]</code>	Help index or scoped help sections.	<code>H=index</code> , <code>H</code> <code>A=all</code> , <code>H</code> <code>P=protection</code> , <code>H</code> <code>M=memory/tools</code> , <code>H</code> <code>S=steering</code> .
<code>Z</code>	<code>Z</code>	Clear RAM after Y/N confirmation.	Zeroes <code>\$0200-\$7EFF</code> . Does not zero <code>\$0000-\$01FF</code> (ZP/stack) or <code>\$7F00-\$7FFF</code> (I/O area).

W	W	Warm start back into monitor.	No args.
D	D [START [END]]	Hex+ASCII dump. END is inclusive.	D alone repeats last span from next address. Hex/ASCII fields show an 8+8 split.
U	U [START END]	Disassemble as 65C02 mnemonics and operands.	END is inclusive. Bare U repeats from saved next-instruction address. Emits ADDR: MNM OPERAND .
A	A START [INSN]	Tiny 65C02 assembler, interactive at next address.	Example: A 1000 LDA #FF then prompt A 1002: . exits. No labels/forward refs. Relative branches accept absolute hex targets and are range-checked. Explicit accumulator form like INC A is supported.
X	X START	Execute from absolute address.	Transfers control via RTS trampoline. NMI while running under X breaks back to monitor; target RTS also returns to monitor.
R	R [A=HH] [X=HH] [Y=HH]	Resume last debug context.	Restores A/X/Y/P/SP/PC from latest debug snapshot and resumes via RTI. Optional A/X/Y overrides are applied first. Up-arrow repeat is useful for single-step resume loops.
N	N	Run to next sequential instruction.	Implements next-stop by patching a temporary BRK at PC+len(opcode) . RAM only; ROM/I/O patch targets are rejected. Debug output restores

			and displays the original stepped-to instruction in CURR: .
M	M [START [B0..B15]]	Modify/deposit memory. Inline deposit supports up to 16 bytes.	Interactive mode: CR/LF = next, . ends. CRLF pair counts as one next.
F	F START END B0..B15	Fill inclusive range with repeating 1..16 byte pattern.	No interactive mode. Verifies each write.
C	C SRC_START SRC_END DST_START	Copy inclusive source range to destination.	Overlap-safe (forward/backward selection). Verifies each write.
!	!F ..., !M ..., !C ..., !A ..., !N	Force-prefix for protected commands.	Allows access to protected low RAM (\$0000-\$03FF).
Q	Q	Enter WAI halt loop.	IRQ masked. Resume by NMI (or Reset). NMI latch returns cleanly to monitor.
V	V	Show vector jump chains.	Spaced format: RST: FFFC > F818 > 8004 > 9F31 > [0089] > 800D. Bracketed links use [addr16] and indicate a patchable 16-bit RAM trampoline address.

3) Interactive Caveats

- M interactive: two hex digits are required per byte write (00..FF).
- A interactive: type one mnemonic/operand per prompt, . exits assembler mode.
- . exits interactive modify and retains next-address state for subsequent M.
- CR or lone LF advances to next address.
- CRLF pair is consumed as a single next-step.
- F does not support interactive mode.
- At an empty monitor prompt, Up Arrow (ESC [A) repeats and executes the previous command.
- Special repeat behavior: if the previous command was a D ... or U ... form, up-arrow replays bare D/U; D continues by saved span, U by saved next-instruction address.
- F/M/C/A/N block access to \$0000-\$03FF unless prefixed with !. D is always allowed.
- Direct vector-hook edits with !M are non-atomic and debug-only. Writing live bytes at \$0089-\$0091 (especially \$008C-\$008E) can produce mixed-byte jumps, wrong dispatch, hangs/crashes, or temporary vector-name mismatch while patching.
- Game ask hook (GAME ASK, older text: POST ASK) is one-shot: it is set on Reset and when NMI returns to monitor, then cleared after first use.
- Hook flag is fixed/reserved at \$0088 (GAMEASK_PENDING). Manual control: !M 88 01 sets pending; !M 88 00 clears pending.

- Terminal width byte is fixed/reserved at \$0093 (TERM_COLS): 28/50/84 for 40/80/132 columns.

4) Verify / Error Outputs

Operation	Message / Behavior
Modify verify fail	M VERIFY FAILED AT ADDR + failing address.
Fill verify fail	F VERIFY FAILED AT ADDR + failing address.
Copy verify fail	C VERIFY FAILED AT ADDR + failing address.
Dump range error	D RANGE ERROR .
Unassemble range error	U RANGE ERROR .
Assembler branch range error	A BRANCH RANGE ERROR .
BRK debug context	Printed as two lines: CURR: and NEXT: on one line, then STATE: on the next line. For N-generated temporary breaks, CURR: shows the restored original instruction.
Bad syntax	Per-command usage lines (e.g. USAGE: M [START [B0..B15]]).

5) API Reference (Macros and Functions)

Use this section when calling monitor functionality from your own assembly code.

5.1) Macro Reference (macros.inc)

Macro	Parameters	Behavior / Notes
PUSH	PUSH p1 [,p2] [,p3] [,p4]	Pushes listed registers in given order. Supported tokens: A/X/Y/P (case-insensitive).
PULL	PULL p1 [,p2] [,p3] [,p4]	Pops listed registers in given order. Keep ordering compatible with prior PUSH.
REPEAT	REPEAT Routine, Count	Calls JSR Routine repeatedly Count times. Preserves X via push/pull.
PRT_CSTRING	PRT_CSTRING Label	Prints null-terminated string at Label via PRT_C_STRING.
DUMP	DUMP Start, EndExclusive	Convenience wrapper for MEM_DUMP with explicit exclusive end.
FILL	FILL Start, EndInclusive, B0 [,B1] [,B2] [,B3] [,B4]	Loads pattern bytes (1..5) and calls MEM_FILL_PATTERN. End is inclusive in macro syntax.
COPY	COPY SrcStart, SrcEndInclusive, DstStart	Calls overlap-safe MEM_COPY_RANGE. Source end is inclusive in macro syntax.
COPY_BLOCK	COPY_BLOCK SrcStart, Length, DstStart	Compatibility wrapper that expands to COPY SrcStart,(SrcStart+Length-1),DstStart .
CMP_CSTRING	CMP_CSTRING AddrA, AddrB	Wrapper for project-specific string compare symbols/routine (STRCMP_PTR_* , STR_COMPARE). Use only when those symbols are provided by your build.

5.2) Callable Function Reference

Practical entry points for extensions and integration.

Routine	Input	Output	Flags	ZP / Memory Use
INIT_SERIAL	None	UART initialized	Unchanged	None
WRITE_BYTE	A=char	Char sent to UART, LED updated	Unchanged	None
READ_BYTE	None	A=received char (ROM read)	ROM-defined	None
CHECK_BYTE	None	A=status	C=1 if RX empty	None
RBUF_INIT	None	Input ring reset	Unchanged	Uses generic buffer descriptor core
BUF_INIT	Active descriptor pointers set	Head/Tail/Count zeroed	Unchanged	Uses BUF_*_PTR
BUF_PUT_A	A=byte	Byte queued	C=0 stored, C=1 full	Uses BUF_*_PTR , BUF_SIZE
BUF_GET_A	None	A=byte	C=0 byte, C=1 empty	Uses BUF_*_PTR , BUF_SIZE
CMD_DISPATCH	A=command letter	Handler called from table	C=0 handled, C=1 unknown	Uses CMD_TABLE , CMD_POST_ACTI ON
MEM_DUMP	PTR_DUMP_CUR=start (inc), PTR_TEMP=end (exc)	Formatted hex+ASCII dump with 8+8 separator	Unchanged	Uses PTR_DUMP_CUR , PTR_DUMP_END , PTR_LEG , MEM_DUMP_CNT
MEM_DISASM_65C 02	PTR_DUMP_CUR=start (inc), PTR_TEMP=end (inc)	65C02 disassembly output (ADDR: MNM OPERAND)	Unchanged	Uses PTR_DUMP_CUR , PTR_DUMP_END , PTR_TEMP , PTR_LEG , DIS_*
MEM_FILL_PATTE RN	PTR_DUMP_CUR=start (inc), PTR_DUMP_END=end (exc), F_COUNT=pattern length, F_PATTERN=pattern bytes	Fills range with repeating pattern	C=0 complete, C=1 aborted (verify/protect)	Uses PTR_DUMP_CUR , PTR_DUMP_END , F_COUNT , F_PATTERN , F_PAT_IDX
MEM_COPY_RANGE	PTR_LEG=src start (inc), PTR_DUMP_END=src end (exc), PTR_TEMP=dst start	Copies source to destination (overlap-safe)	C=0 complete, C=1 aborted (verify/protect)	Uses PTR_LEG , PTR_DUMP_CUR , PTR_DUMP_END ,

				PTR_TEMP , CMD_PARSE_VAL
CMD_DO_ASM	CMD_LINE = A START [INSN]	Interactive tiny assembler	. exits	Uses CMD_LINE , PTR_TEMP , opcode tables, and ASM_* / DIS_* scratch

6) Parser and Buffer Limits

- CMD_MAX_LEN = 31 characters (excluding null terminator).
- RBUF_SIZE = 32 bytes.
- One-command history is kept for up-arrow repeat (CMD_LAST_LINE).
- Hex token parser accepts 1..4 hex digits, optional \$ prefix.
- M and F inline byte lists: max 16 bytes each.
- ! is consumed as a command prefix, then normal parsing continues.

7) Memory Usage

Build Section Usage (current)

Section	ORG	Size (hex)	Size (dec)
PAGE0	\$0040	\$BF	191
CODE	\$8000	\$24A9	9385
KDATA	\$A4A9	\$1165	4453
UDATA	\$0200	\$7A	122
Total	-	\$3747	14151

RAM Layout Highlights

- PAGE0 starts at \$0040. Includes parser state, dump state, debug snapshot, vector hooks, and active buffer descriptor pointers.
- Guard policy reserves PAGE0 through \$00FE to enforce a hard ceiling for this monitor build.
- KDATA floats directly behind CODE (current build start: \$A4A9).
- Fixed/pinned bytes: GAME_ASK_PENDING=\$0088 , RST_HOOK=\$0089 , NMI_HOOK=\$008C , IRQ_HOOK=\$008F , BRK_FLAG=\$0092 , TERM_COLS=\$0093 .
- Hardware vectors are fixed at the top page: NMI=\$FFFA , RST=\$FFFC , IRQ/BRK=\$FFFF .
- UDATA starts at \$0200 :

```
RBUF_DATA    32 bytes
CMD_LINE     32 bytes (31 + NUL)
CMD_LAST_LINE 32 bytes (31 + NUL)
RESET_COOKIE  4 bytes
F_PATTERN    16 bytes
DBG_TAG_BUF   6 bytes
```

8) Notes for Integrators

- Command parser uppercases incoming command bytes before parse/dispatch.
- Command execution is table-driven via CMD_TABLE .
- Input buffering now uses a generic descriptor-based core bound to the ring buffer.

- Q path relies on NMI latch (SYSF_NMI_FLAG_M) and then re-enters monitor cleanly.

9) Planned Commands (Appendix, Provisional)

This appendix documents planned command architecture and roadmap intent only.

Proviso: change is constant. These plans are not stable API and may change before publish.

9.1) Grammar Direction

- Primary model: noun verb [args...] (namespace first, action second).
- Direct-action commands may still exist where practical (for example jump/execute style flow).
- Parser should accept both spaced and fused forms for operator speed.

9.2) Canonical Input Compatibility

- Parser policy: token 1 selects namespace and remains locked for that line (no cross-namespace fallback).
- X S and XS should map to the same internal command key.
- X R and XR should map to the same internal command key.
- M D and MD should map to the same internal command key.
- I O V and IOV should map to the same internal command key.
- I C and IC should map to the same internal command key.
- One canonical dispatch representation is preferred to avoid duplicate handlers.
- Aliases are spelling variants only (same meaning); command override behavior is intentionally avoided.

9.3) Namespace Plan

Root	Planned Role	Notes
B	Bank / FLASH	Reserved for FLASH-related operations (read/program/erase/verify family).
I	Info root	Carries nested subfamilies such as time and I/O.
I T	Time	Time moves under Info; top-level T is freed.
I C	Calculator	Planned calculator entry under Info; prefer RPN input style.
T	Terminal	Repurposed top-level namespace for terminal-related operations.
I O P	PIA	Top-level P is freed; PIA moves under Info/IO.
I O V	VIA	Top-level V is freed; VIA moves under Info/IO.
I O V T	VIA timers	Hardware timers are expected under VIA tree.
J	Jump / Execute	Preferred home for execute flow if top-level execute letter changes.
X	Transfer / XMODEM	At minimum: send and receive support.
S	Search	Text and binary search families.
M	Memory family	Supports compact forms such as MD / MM as aliases.
O	Deferred decision	Candidate: chained execution wrapper; decision postponed.

9.4) Search Family Detail

- Planned base forms: `S C START END <text>` and `S B START END <pattern...>`.
- `S C` mode: unquoted text stops at first whitespace.
- `S C` mode: quoted delimiters can include `"`, `'`, and ```.
- `S C` mode: delimiter escape by doubling delimiter character.
- `S C` mode wildcards: `?` matches exactly one character, `*` matches zero or more characters.
- `S C` mode literals: `??` matches literal `?`, and `**` matches literal `*`.
- `S B` mode tokens: `HH` byte, `HHHH` little-endian word, nibble wildcard (`?A / A? / ??`), and `*` byte wildcard.
- Candidate extensions: Pascal strings and high-bit-set text search modes.

9.5) XMODEM Requirement

- Before publish, provide both XMODEM receive and send paths.
- Preferred forms: `X R ...` and `X S ...` with fused aliases (`XR`, `XS`).

9.6) Vector + Safety Direction (Pre-Publish Requirement)

- Vector updates must support dynamic atomic update behavior.
- Handler-name contract direction: every patchable target exports `<HANDLER>` and `<HANDLER_NAME>` (`ASCIIIZ`); retarget operations update target address and name pointer together.
- Critical windows include vector commit and FLASH routines.
- During critical windows, all EDU LEDs should flash to signal that NMI should not be pressed.
- NMI path should be guarded/deferred during critical windows instead of normal debug flow.
- Staged-update plus atomic-commit behavior is the intended implementation pattern.
- NMI retargeting direction: patch inactive slot fully, then commit via single-byte active-slot selector flip (no in-place live NMI hook rewrite).
- Direct `!M` edits to live vector hook bytes are allowed for bring-up/debug but are intentionally outside the production-safe retarget path.
- Mandate (non-changing requirement): any operation that mutates FLASH state or vector state must assert critical indication/guard behavior, including module/transient load paths; implementation detail may change, requirement does not.

9.7) Deferred Item

- `O` command semantics are intentionally deferred.
- If adopted as an operation chain wrapper, error policy and guard policy must be defined explicitly.

9.8) Active TODO (Pressing)

Now

- TODO: wrap `WDCMONV2` FLASH routine calls behind `bso2` wrapper/trampoline entry points.
- TODO: extend `V` IRQ output to include sub-dispatch lines for `BRK` and `HW` targets (for example `IRQ: ... > DISPATCH`, then `BRK: XXXX <name>` and `HW: YYYY <name>`).
- TODO: add a post-link map check that enforces `END_KDATA < $F000`.

Before Publish

- TODO: provide XMODEM receive and send paths before publish (`X R / XR`, `X S / XS`).
- TODO: implement staged vector update plus atomic commit flow for runtime retargeting.
- TODO: enforce critical-window behavior for FLASH/vector mutation paths (LED warning plus NMI guard/defer).
- TODO: enforce dangerous `B` operation policy (! required, explicit confirmation, and fail-closed behavior without mutation).
- TODO: add deterministic status reporting for dangerous operations (status code byte plus `OK / ABORTED / VERIFY_FAIL / FLASH_FAIL / DENIED`).
- Deferred (not current TODO): text compression/decompression, tokenization/RLE, and TX ring architecture while 32K FLASH headroom is sufficient.

9.9) Flash / Bank Safety Policy (Critical, Non-Negotiable)

- `B` must not execute dangerous operations by default.
- bso2 plans to use WDCMONv2 FLASH routines through wrappers/trampolines.
- Integration intent is behavioral/protocol compatibility via wrapper entry points, not direct source-text copy.
- Any dangerous `B` operation requires both force-prefix `!` and explicit user confirmation.
- Dangerous operations include at minimum erase, program/write, monitor self-update, vector commit, and bank activation/commit transitions.
- If `!` is absent, dangerous operations fail closed with no side effects.
- Confirmation must be operation-specific (typed intent token), not an implicit continue.
- During dangerous operations: enter critical guard mode before mutation starts, flash all LEDs, and guard/defer NMI debug flow until critical mode exits.
- On verify/check failure: abort mutation, exit critical mode cleanly, and report explicit status.
- Required output for dangerous operations: status code byte plus textual result (`OK`, `ABORTED`, `VERIFY_FAIL`, `FLASH_FAIL`, `DENIED`).

9.10) Board Self-Update Policy

- Board self-update is always dangerous and always requires `!` plus explicit confirmation.
- Before final commit, display target region, byte count, and integrity value (checksum/hash when available).
- Preferred execution shape: preflight validation, stage payload, erase/program, verify, then commit/activate.
- Avoid in-place blind overwrite as the only strategy; preserve a recovery path.
- Self-update is fully covered by the non-changing mandate: any FLASH/vector mutation path (including module/transient load/activation) must assert critical indication and guard behavior.

9.11) Host Tooling Direction (Linux GNU C)

- Critical FLASH workflows are expected to have a Linux GNU C host path.
- Python helpers may exist for convenience, but they are not the required path for critical FLASH operations.
- Preferred host model: raw serial protocol wrappers in C with explicit timeout/error handling and deterministic status reporting.

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