

bso2 Monitor Reference

Target: W65C02EDU | Source: SRC/bso2.asm | Generated: 2026-02-20

0) Naming

bso2 is the preferred written form in this manual.

It is intentionally dual-meaning and retro-styled:

- b = 6 = Basic
- s = 5 = System
- o = 0 = Operations
- 2 = 2 = /2 (homage to IBM System/36)

That makes 6502 a visual shorthand for bso2.

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

Power-on prompt uses C/M with a 6-second wait and > tick markers; timeout defaults to C.

Reset-cookie prompt uses C/W/M with a 6-second wait and < tick markers; LEDs blink every ~333ms while waiting and timeout defaults to M.

Boot-choice and clear-confirm prompts echo keypresses in uppercase.

C/W/M Decision Truth Table

Condition	Input	Result
Power-on (no valid reset cookie)	C	Enter clear path.
Power-on (no valid reset cookie)	M	Enter monitor path.
Power-on (no valid reset cookie)	Timeout	Default to clear path (C).
Power-on (no valid reset cookie)	Invalid key	Ignored; prompt/countdown continues.
Reset with valid cookie	C	Enter clear confirmation prompt Y/N.
Clear confirmation	Y	Run clear-memory path.
Clear confirmation	N	Abort clear and continue warm path (W-equivalent branch).
Reset with valid cookie	W	Warm start path (no clear).
Reset with valid cookie	M	Monitor path.
Reset with valid cookie	Invalid key	Ignored; prompt/countdown continues.

Reset with valid cookie	Timeout	Default to monitor path (M).
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Note: this is the default behavior for the currently installed vector trampolines/handlers; future trampolines or handlers may implement different startup policy.

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

Width prompt timeout uses fixed byte `$007B` (`TERM_WIDTH_TIMEOUT`): `00`=wait forever, `01-FF`=seconds, default `08`.

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  R0M0V0I00  ****
****       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</code> =index, <code>H</code> <code>A</code> =all, <code>H</code> <code>P</code> =protection, <code>H</code> <code>M</code> =memory/tools, <code>H</code> <code>S</code> =steering.
<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).
<code>T</code>	<code>T</code>	Clear terminal viewport.	Emits <code>LF</code> 24 times, then one <code>CR</code> .
<code>W</code>	<code>W</code>	Warm start back into monitor.	No args.
<code>D</code>	<code>D [START [END]]</code>	Hex+ASCII dump. <code>END</code> is inclusive.	<code>D</code> alone repeats last span from next address. Hex/ASCII fields show an 8+8 split.
<code>U</code>	<code>U [START END]</code>	Disassemble as 65C02 mnemonics and operands.	<code>END</code> is inclusive. Bare <code>U</code> repeats from saved next-instruction address. Emits <code>ADDR: MNM OPERAND</code> .
<code>A</code>	<code>A START [INSN]</code>	Tiny 65C02 assembler, interactive at next address.	Example: <code>A 1000 LDA #FF</code> 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.
I	I C <RPN...> or IC <RPN...>	Evaluate 16-bit hex RPN expression.	Values are 1..4 hex digits (optional \$). Operators: + - * / & ^ ~ . Prints top-of-stack as I C = \$HHHH .
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.
S	S B START END ... or S C START END TEXT	Search memory for byte patterns or text.	Prints hit address plus aligned row base context.
L	L S L G S L B ADDR LEN	Load Motorola S-records or raw bytes.	L G S / LGS auto-jumps to the S7/S8/S9 start address after successful load.
!	! 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 > [0080] > 800D. IRQ now appends sub-dispatch lines: BRK: XXXX <name> and HW: YYYY <name>. 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 \$0080-\$0088 (especially \$0083-\$0085) 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 `$0078` (`GAME_ASK_PENDING`). Manual control: `!M 78 01` sets pending; `!M 78 00` clears pending.
- Terminal width byte is fixed/reserved at `$007A` (`TERM_COLS`): `28/50/84` for `40/80/132` columns.
- Terminal-width prompt timeout byte is fixed/reserved at `$007B` (`TERM_WIDTH_TIMEOUT`): `00`=wait forever , `01-FF`=seconds , default `08` .
- User ZP range is reserved at `$0090-$00FF` .
- User-program origin policy: avoid `$0000-$03FF` in normal operation (protected by default for write/execute-adjacent commands).
- Minimum practical user-program origin is `$0800` .
- Preferred default user-program origin is `$1000` (recommended for demos and monitor interoperability).

4) Verify / Error Outputs

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

5) API Reference (Macros and Functions)

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

Include model: prefer `INCLUDE EQUATES.INC` for monitor builds; `EQUATES.INC` automatically includes `MACROS.INC` .

5.1) Macro Reference (`macros.inc`)

Macro	Parameters	Behavior / Notes
<code>PUSH</code>	<code>PUSH p1 [,p2] [,p3] [,p4]</code>	Pushes listed registers in given order. Supported tokens: <code>A/X/Y/P</code> (case-insensitive).
<code>PULL</code>	<code>PULL p1 [,p2] [,p3] [,p4]</code>	Pops listed registers in given order. Keep ordering compatible with prior <code>PUSH</code> .
<code>REPEAT</code>	<code>REPEAT Routine, Count</code>	Calls <code>JSR Routine</code> repeatedly <code>Count</code> times. Preserves <code>X</code> via push/pull.
<code>PRT_CSTRING</code>	<code>PRT_CSTRING Label</code>	Prints null-terminated string at <code>Label</code> via <code>PRT_C_STRING</code> .

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_ACTION
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_65C02	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_PATTERN	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	\$0030	\$60	96
CODE	\$8000	\$2FA1	12193
KDATA	\$AFA1	\$1460	5216
UDATA	\$0200	\$9C	156
Total	-	\$44FD	17661

RAM Layout Highlights

- PAGE0 starts at \$0030. Includes parser state, dump state, debug snapshot, vector hooks, and active buffer descriptor pointers.
- Guard policy reserves monitor PAGE0 through \$008F; user ZP is reserved at \$0090-\$00FF.
- KDATA floats directly behind CODE (current build start: \$AFA1).

- Fixed/pinned bytes: `GAME_ASK_PENDING=$0078` , `BRK_FLAG=$0079` , `TERM_COLS=$007A` , `TERM_WIDTH_TIMEOUT=$007B` , `RST_HOOK=$0080` , `NMI_HOOK=$0083` , `IRQ_HOOK=$0086` , `BRK_HOOK=$0089` , `HW_HOOK=$008C` .
- Hardware vectors are fixed at the top page: `NMI=$FFFA` , `RST=$FFFC` , `IRQ/BRK=$FFFE` .
- Detailed zero-page map: [ZERO_PAGE_USAGE.md](#) and [ZERO_PAGE_USAGE.pdf](#) .
- 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
<code>B</code>	Bank / FLASH	Reserved for FLASH-related operations (read/program/erase/verify family).
<code>I</code>	Info root	Carries nested subfamilies such as time and I/O.
<code>I T</code>	Time	Time remains planned under Info; top-level <code>T</code> is now active for terminal clear.
<code>I C</code>	Calculator	Implemented baseline (<code>I C</code> / <code>IC</code>) with 16-bit hex RPN tokens; future expansion remains planned.

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...>.
- Current hit display format is <HIT_ADDR>{ |*}<ROW_BASE>: ...; HIT_ADDR is exact match start, and ROW_BASE = HIT_ADDR & \$FFF0.
- Separator marker: * means the match continues into the next 16-byte row (for example \$B8AF*\$B8A0 implies continuation at \$B8B0).
- 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

- `0` 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: add a post-link map check that enforces `END_KDATA < $F000`.

Soon

- TODO: get the ACIA port on the EDU board running.

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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