# BNB Accelerator Timing Signals

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Fermilab has hosted 8 GeV neutrino experiments fed by the Booster Neutrino Beamline since 2002, starting with the commissioning of MiniBooNE. These experiments have made use of several accelerator timing signals in their data acquisition systems to determine when and how to measure beam in their detectors. Accelerator Division supports delivery of raw, generally unprocessed copies of these signals but can only do so with AD-supported hardware. Signals available downstream of the MI-12 service building can be manipulated by an individual experiment.

This document describes where signals are terminated and available for use as of the date of this publication, as well as how each signal is generated. This document also describes where AD plans to support signals in the future, as the installation of these pathways is not yet complete.

## Signal Availability

Presently, the AD-supported signals common to LArTF, SciBooNE, and SBN Near and Far Detector buildings are the Booster extraction sync (BES), Booster RF (BRF), Tevatron clock (TCLK) and Main Injector beam sync clock (MIBS). BES and BRF are broadcast from a Copper to Fiber Transmitter in MI-12 over multimode fiber. TCLK and MIBS are broadcast over copper repeaters and are available through IRMs in each building.

Downstream buildings also receive copies of a delayed BES and a gated BNB RWM. These signals have been manipulated to suit a specific experiment's need before being broadcast through AD-supported hardware, which is a problem AD is trying to solve with these new signal pathways. The unprocessed NuMI RWM is broadcast to LArTF, but it will need to be interrupted in MI-12 to incorporate it into AD-supported hardware.

Once all AD-supported signal pathways are installed, the BNB RWM and NuMI RWM will also be broadcast from the same hardware as the BES and BRF in MI-12. AD will not support the delayed BES or the gated BNB RWM the experiments have built and rely upon now. When the experiments' NuMI RWM signal is patched into the transmitter, it will arrive at all downstream locations an estimated few tens of nanoseconds later than it does now.

The BNB RWM signal presently passes through two stages of discrimination before being input to the transmitter. This will change following the 2019 shutdown, and the BNB RWM will be input directly to the transmitter. Experiments have built and relied on a delayed version of BES, but the hardware will be removed following the 2019 shutdown as soon as experiments can verify that the AD-supported BES is suitable.

## AD-Supported Hardware

BES and BRF are split once they arrive in MI-12 and one copy of each is collected into the Copper to Fiber Transmitter. The copper BES and BRF inputs to the transmitter each have six copies leaving MI-12 on multimode fiber.

One of these fiber copies of both signals is delivered to SciBooNE, SBN Near Detector Building, MiniBooNE, LArTF, MINOS Service Building, and SBN Far Detector Building. Although it is not necessary, a compatible Fiber to Copper Receiver is available for purchase through the AD External Beams Department. Experiments are free to use any other compatible signal converter they choose.

A Multi-Function Timing Unit (MFTU) can generate delays based on different signal and clock inputs, which are settable on ACNET once appropriate parameters are created to interface with the hardware. These are available as an option for building data acquisition gates and can also be purchased through the External Beams Department.

TCLK and MIBS are patched into a repeater at each service building and require an IRM or VME crate with appropriate decoders to use these signals. TCLK decoders offer eight channels which can be configured to output eight different TCLK event triggers, each with a settable pulse width and delay in milliseconds. MIBS decoders offer four channels which are hard coded to output the Main Injector 120 GeV to NuMI extraction event (MIBS $74) and have settable pulse widths and delays.

## Signal Generation

TCLK is generated by a front end called the timeline generator (TLG) and is broadcast at 10 MHz to each accelerator service building. The TCLK signal carries individual encoded events, which have hexadecimal values $00 to $FF. The control devices which are decoding these events are programmed to treat each accordingly.

As an example, a $1D is known systematically as a Booster event for BNB beam. Most devices are waiting to decode the $1D and are programmed to output a command signal following a delay of so many RF cycles (RFC), nanoseconds, microseconds, milliseconds, or some combination of these, which is often settable via ACNET.

MIBS is like TCLK in that the signal carries encoded events that machine hardware is decoding, but the clock frequency of MIBS is locked to the Main Injector RF. Main Injector RF sweeps from 52.8 MHz to 53.1 MHz every full acceleration cycle, Main Injector has circumferential room for seven batches of Booster beam (one of these is kept empty), so the MIBS is broadcast at a rate of 7.5 MHz, which is the MI RF divided by the number of Booster batches held in Main Injector. When the MIBS $74 extraction event is broadcast, the TCLK $A9 is broadcast over the TCLK link a short time later to signal that beam was extracted.

As stated earlier, BRF and BES originate in the Booster LLRF Room and are converted from RF to TTL at the MI-12 service building with a Copper to Fiber Transmitter. BRF sweeps from 37.7 MHz to 52.8 MHz at a rate of 15 Hz. The BES signal indicates that 8 GeV protons have been extracted from Booster, regardless of what their downstream destination is. It is possible to see a BES broadcast with no beam permitted to BNB.

BNB beam travels through an RWM which picks up the 1.6 µs long, 52.8 MHz signal of the 81 individual 18.9 ns wide bunches that come with each batch sent to the BNB target. The NuMI RWM picks up the 11.1 µs long, 53.1 MHz signal of the 486 individual 18.8 ns wide bunches that come with each batch sent to the NuMI target and is digitized at MI-60.