Kicker systems are just that. Design both magnet and power supply in harmony.

Kicker systems typically have concerns from every discipline, electrical engineering for power supplies and some magnet issues, mechanical engineering (structural, thermal and vacuum) for magnet and some power supply issues, accelerator physicist for specifications of many other aspects (beam impedance, kick direction, vacuum requirements) and all have a impact on the whole system.

Every now and then take a step back and think about what you really want to accomplish as a system.

Make sure requirements are known before final design.

Try and test all components in a realistic environment (radiation, temperature, vacuum, voltage, current, etc.)

Design should be maintainable in some minimum downtime way (hot spare, swappable components). Typically the loss of a single kicker stops operation (not always true of ring bend supplies or RF stations)

Two styles of kicker magnets, Traveling Wave and Inductive

Fermilab - All kicker power supplies are in unlimited (non-radiation) occupancy space for ease of troubleshooting and reduced downtime. This imposes several performance constraints. Done not only for radiation concerns but because beamline access has additional downtime penalties (search and secure, LOTO of ring buses, limiting operation scenarios)

Other National Labs - Brookhaven has many kicker power supplies in beam enclosure. Argonne APS has some kicker power supplies in beam enclosure, but has long scheduled maintenance periods. SLAC complex has power supplies outside of beam enclosure. CERN LHC complex has power supplies outside of beam enclosure. DESY HERA complex (I think) has power supplies outside of beam enclosure.

Fermilab - All kicker systems have a spare magnet, but not a spare power supply (downtime vs dollars vs beamline access). Magnet fixes typically require breaking vacuum and best to swap and fix later in a controlled environment. Power supply can be fixed by swapping parts, so it’s design has to be more maintainable.

Traveling Wave (Single ended and Balanced)

- Terminating impedance (usually Z0, but can be good short)
- Generally limited to ~60 kV due to component issues for magnet (capacitors)
- Fast Rise Time and Fall Time
- Flattop of much more than rise or fall time
- Single turn to get good impedance match
- Balanced gives either half rise time or half voltage of Single Ended (L. Reginato)

Traveling Wave Magnet Examples

• TeV Proton Injection Kicker, 150 GeV/c protons (installed 2001)
- Aperture is 4.6 cm V x 7.4 cm H x 1 m (5 Modules, magnetic gap is 4.6 cm) with Bgap ~ .04 T
- Each module has field rise time of < 130 ns using 12.5 Ohm, 45 kV Source, Balanced
- Flattop of ±1% for 1.6 us, fall time to 1% ~ 500 ns due to dispersion in pulse forming cable
- Thyratron based for long lifetime/reliability (10^5 shots per year)

• Main Injector Extraction Kicker, 150 GeV/c protons (installed 1999)
- Aperture is 5 cm V x 11 cm H x 2 m L
- Each module has rise time of 780 ns (2 Modules) using 10 Ohm, 60 kV Source, Single Ended
- Flattop of ±1% for 1.6 us, fall time to 1% of 1 us due to dispersion in pulse forming cable
- Thyratron based for long lifetime (10^7 shots per year)

Inductive

- Sine wave rise time
- Sine wave fall with "Flattop" much less than rise or fall
- Long exponential tail with droop of 10% or more.
- Most cost effective if flattop is not required.
- All Fermilab inductive kickers are single turn, but no compelling reason.
- Can use series resistance to get more flat top

Inductive Magnet Examples

• Tevatron Abort Kickers, 1 TeV/c protons (installed 1990)
- Aperture is 7 cm x 6 cm x 1.9 m (5 Modules, magnetic gap is 6 cm) with Bgap ~ 0.56 T
- Each module has a field rise time of 5 us, 35 kV magnet voltage, 25 kA magnet current
- Droop is approximately 10% over 21 us length
- Thyratron based because of dynamic range required (abort from 150 GeV/c to 1 TeV/c)
- 10^4 shots per year

• Main Injector Antiproton Extraction, 150 GeV/c antiprotons (installed 1999)
- Aperture is 5 cm x 11 cm x 2 m(2 Modules, magnetic gap is 5 cm) with Bgap ~ 0.07 T
- Each Module has a base width of 18 us, 8 kV magnet voltage, 3 kA magnet current
- Flattop is middle 1.2 us which has flattop of approximately ± 1%
- Thyratron based. dI/dt to big for thyristor. 10^4 shots per year

• Main Injector Proton Abort Kicker, 150 GeV/c protons (installed 1999)
- Aperture is 5 cm x 11 cm x 2 m(2 Modules, magnetic gap is 5 cm) with Bgap ~ 0.06 T
- Same magnet as used for antiproton extraction except with 12.5 ohm series termination
- Each module has a field rise time of 800 ns, 33 kV magnet voltage, 2.6 kA magnet current
- Flattop is 10 us long and approximately ± 3%
- Thyratron based, long lifetime (10^7 shots per year), 33 kV on PFN with step up transformer

• Pbar target Sweeping Kicker (not operational, but built)
- Pulse Compression system, 3 stages, Output is oscillatory (full reversal).
- This type of circuit can not be directly done with a thyratron or semiconductors
- 1.6 us period, 8 kA peak.
- Thyristor based, 1 kA/us and step up transformer
- Adaptive computer control of timing due to non-linear behavior
- Computer control also corrects for voltage and temperature sensitivities