A.1: Timing Control achieves designed bunch filling patterns in the Indus-2 ring

A Timing Control system was designed for controlled filling of bunches in the ring of Indus-2 in three selective modes, viz. 'Single Bunch', 'Three Symmetric Bunches' and 'Multiple Bunches' mode. Trials were conducted to fill Indus-2 with above selective filling patterns. The design and development of the system was carried by the Accelerator Controls Team in RF Systems & Controls Division of RRCAT.

1. Single bunch: In this mode, only one bucket, out of 291 total available buckets, is filled. The bucket number is selectable. This assumes that single bunch is available from booster every second. At present, however, two bunches are extracted from booster and hence, two buckets are filled in the single bunch mode. Selected bucket and the seventeenth from selected bucket are filled. Two buckets in Indus-2 are separated in time by 1.99 ns. Figures A.1.1 to A.1.4 show signals from wall current monitor of Indus-2, for different modes.
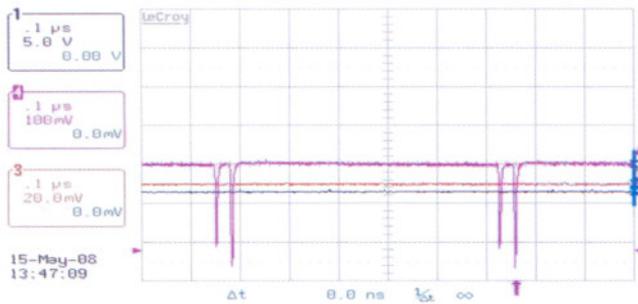

Fig.A.1.1: Single bunch filling.

In Fig.A.1.1, single bunch filling can be seen. Two bunches coming from booster, placed 31 ns apart are seen. The second set of bunches show signal of second turn and both sets are separated by the revolution time of Indus-2 ring.
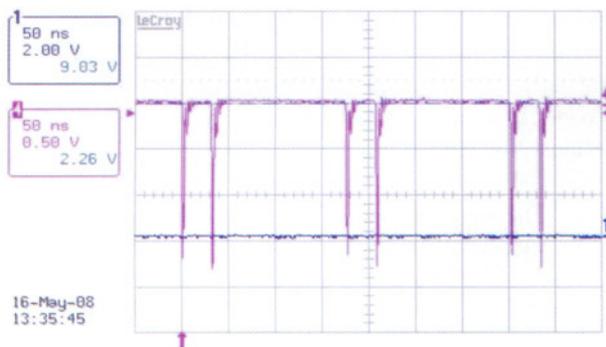
2. Three symmetric bunches:

Fig.A.1.2: Three symmetric bunch filling.

In Fig.A.1.2, the ring is filled with 3 symmetric bunches. Since two bunches are extracted from the booster, total 6 buckets are filled in three bunch mode. Bucket number 1, 98 and 195 were selected for filling.

3. Multi bunch: This mode allows defining start and end bucket over the whole available range and fills all the buckets between these. This mode is aimed at filling 2/3rd of the ring rather than full to take care of the space charge effects. Figs.A.1.3 and A.1.4 show wall current monitor signals when multi bunch filling mode is selected.
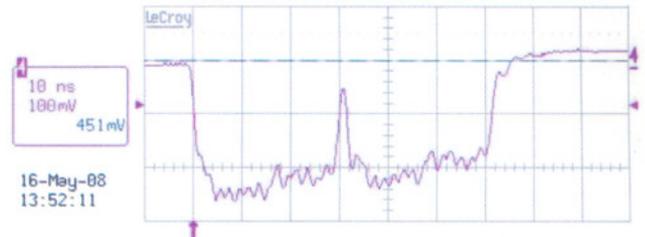

Fig.A.1.3: Multi bunch filling (start bucket-1, end bucket-15).

In Fig.A.1.3, starting bucket no. is 1 and end bucket no. is 15. Since two bunches are extracted, bucket no. 1 to 15 are filled, followed by bucket no. 17 to 31. Bucket no. 16 carries no current.
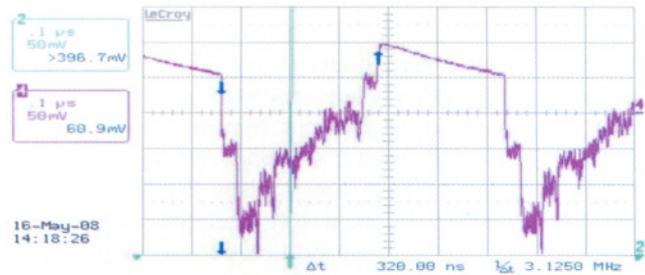

Fig.A.1.4: Multi bunch filling (start bucket-1, end bucket-165).

Fig.A.1.4 shows filling with starting bucket no. 1 and end bucket no. 165. Corresponding width of 320 ns can be seen. Remaining part of ring, corresponding to 126 buckets is empty. In this case, the filling sequence is - first fill bucket no. 1 and 17, then 2 and 18, then 3 and 19 and so on. Bucket number filled is advanced every second. Buckets no. 1 to 15 will have half current as compared to the rest as they are filled once in every cycle while others are filled twice. Ideally the waveform should be rectangular, but probably because of response limitations of wall current monitor, slope is observed. With these three filling modes, any part of the ring can be selectively filled, as per the requirements of experimental users. When only one bucket is to be filled, only one bunch can be extracted from booster by suitably adjusting the extraction kicker delay. Timing system generates delays synchronised to Indus-2 RF clock (505.8 M Hz). The delay generator card is designed using ECLinPS series ICs and uses 24 bit counters counting at Indus-2 RF frequency. The coarse delay resolution is 2 ns and fine delay resolution is 100 ps. The delay range is from 100 ps to 33 ms. Jitter observed in the trigger signals is less than 100 ps.

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