Table 1: The input data to the TF from the HB. The format of the data structure is defined in reference [2]. In this table, "layer" is the SVX-II layer ID, "layer(XFT)" [:= 5] is the XFT layer ID in the SVT, "z" is the z barrel ID of the hit, "lc" is the bit that identifies a long cluster from the HF, and "PA" is the parity of the data [3].

<table>
<tr><td>bit</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>use</td><td>HD</td><td>DS</td><td>EE</td><td>EP</td><td colspan="21">data</td></tr>
<tr><td>wd1.1</td><td></td><td></td><td></td><td></td><td colspan="3">layer</td><td colspan="3">z</td><td>lc</td><td colspan="14">x_0</td></tr>
<tr><td>wd1.2</td><td></td><td></td><td></td><td></td><td colspan="3">layer</td><td colspan="3">z</td><td>lc</td><td colspan="14">x_1</td></tr>
<tr><td>wd1.3</td><td></td><td></td><td></td><td></td><td colspan="3">layer</td><td colspan="3">z</td><td>lc</td><td colspan="14">x_1'</td></tr>
<tr><td>wd1.x</td><td colspan="25">:</td></tr>
<tr><td>wd1.n</td><td></td><td></td><td></td><td></td><td colspan="3">layer(XFT)</td><td colspan="18">XFT information for the AM</td></tr>
<tr><td>wd1.(n+1)</td><td></td><td></td><td></td><td></td><td></td><td></td><td>sign</td><td colspan="6">c from the XFT</td><td colspan="12">ϕ from the XFT</td></tr>
<tr><td>wd1.(n+2)</td><td></td><td></td><td></td><td>1</td><td colspan="4">sector</td><td colspan="17">AM road ID</td></tr>
<tr><td>wd1.x</td><td colspan="25">:</td></tr>
<tr><td>end</td><td></td><td></td><td>1</td><td>1</td><td colspan="2">L2B</td><td colspan="10">error flags</td><td>PA</td><td colspan="8">Event Tag</td></tr>
</table>

there are more than one hit in a layer, the TF receives more than seven words per road, for example, the x_1' hit in Table 1. The TF receives several roads per event when the AM system finds multiple track candidates. For an event in which no road is found, the TF receives only the end of event (EOE) word.

2.1.2 Output

The output of the TF consists of three track parameters, ϕ, d, and c. In addition, the TF sends the other information listed in Table 2. Some variables listed in Table 2 might not be important for the trigger decision, but are important for monitoring SVT performance both online and offline since only the TF output data are recorded in the CDF data stream. The output data from the TF are sent to the L2 interface board via an SVT Merger board. If no road passes the track quality cut or the event has no road, the TF only sends the EOE

Table 2: The SVT data sent to the L2 Interface board. The format of the data structure is defined in reference [2]. Each variable is defined in Table 3.

<table>
<tr><td>bit</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>use</td><td>HD</td><td>DS</td><td>EE</td><td>EP</td><td colspan="21">data</td></tr>
<tr><td>wd1.1</td><td></td><td></td><td></td><td></td><td>1</td><td>ERR</td><td colspan="6">z</td><td colspan="13">ϕ</td></tr>
<tr><td>wd1.2</td><td></td><td></td><td></td><td></td><td>0</td><td></td><td>sign</td><td colspan="8">c</td><td>sign</td><td colspan="9">d</td></tr>
<tr><td>wd1.3</td><td></td><td></td><td></td><td></td><td colspan="4">sector</td><td></td><td></td><td colspan="15">AM road ID</td></tr>
<tr><td>wd1.4</td><td></td><td></td><td></td><td></td><td></td><td colspan="10">x_1</td><td colspan="10">x_0</td></tr>
<tr><td>wd1.5</td><td></td><td></td><td></td><td></td><td></td><td colspan="10">x_3</td><td colspan="10">x_2</td></tr>
<tr><td>wd1.6</td><td></td><td></td><td></td><td></td><td colspan="11">χ^2</td><td colspan="10">x_4</td></tr>
<tr><td>wd1.7</td><td></td><td></td><td></td><td>1</td><td colspan="12">Track Fitter status</td><td colspan="9">Track Number</td></tr>
<tr><td>wd2.x</td><td colspan="25">:</td></tr>
<tr><td>end</td><td></td><td></td><td>1</td><td>1</td><td colspan="2">L2B</td><td colspan="10">error flags</td><td>PA</td><td colspan="8">Event Tag</td></tr>
</table>

word.

The details of each output parameter are listed in Table 3. The definitions of the error flags and the TF status word are found in Section 8. Although we send only the 8 LSB of

Table 3: The definition of the track parameters in the TF. The range and the least count of the track parameters depend on the fitting parameters, and they are adjustable.

Parameter	# bits	least count	range	Comments
ϕ	13	0.76 mrad	$< 2\pi(6.28)$	
z	6			three MS bits: z ID of the most outer hit, three LS bits: z ID of the most inner hit.
ERR	1			OR of all errors for BP_FIFO.
d	10	10 μm	$< 5,120$ μm	The MSB is the sign (1: negative).
c	9	$1.17 \times 10^{-3}\text{m}^{-1}$	< 0.3 m^{-1}	The MSB is the sign (1: negative).
road ID	15		$\leq$32k	AM road ID
sector	4		$\leq$12	Sector ID
x_i	10	3.75 μm for x_0, x_2, x_3 3.875 μm for x_2 4.0625 μm for x_4	$\leq 1,024$ μm	8 LS bits of the hit position at the layer i; the second MSB is the long cluster bit; the MSB is the hit existence bit.
χ^2	11	1	$< 1,024$	The MSB is the overflow bit.
Track Number	9	22 mrad	$< 2\pi(6.28)$	The 9 MS bits of the XFT ϕ.
Track Fitter status	11			The MSB is OR of all errors. (see Section 8).
Event Tag	8			The bunch cross counter.
PA	1			the parity (see Section 6).
error flags	10			see Section 8.
L2B	2			L2 Buffer ID.

each SVX hit position, we can reconstruct the full hit position (14 bits) using the AM road ID as shown in Equation 2.

2.2 Conceptual Design

The main function of the TF is to execute the vector calculation of Equation 1. The $\vec{x}$ in Equation 1 is a seven dimensional vector with 14 bits of data for each SVX hit, 12 bits of XFT ϕ and 7 bits of XFT c. In order to obtain full resolution for the track parameters $\vec{f_i}$, we would have to perform 14-bit times 14-bit multiplication for seven products, and sum them to construct each track parameter. Such large calculations cannot be carried out with current technology for FPGAs (Field-Programmable Gate Array). Therefore, we use the following algorithm to reduce the load of the calculation in the FPGA. The range of $\vec{x}$ must be the size of the Super Strip (SS) in the AM road for that track candidate. If we define the lower edge of the SS in the AM road as $\vec{x}_0$, the relative coordinate of the hit in the SS is expressed as $\vec{d} = \vec{x} - \vec{x}_0$ (Note: x_0 is independent of curvature because track curvature is not used in the SS definition.). The range of $\vec{d}$ is the SS size, which is typically 500 μm or less. Thus $\vec{d}$ can be expressed with 8 bits with a least count of ~ 4 μm. With a linear approximation, we can express Equation 1 with the vectors $\vec{x_0}$ and $\vec{d}$ instead of $\vec{x}$:

$$p_i = \vec{f_i} \cdot (\vec{x}_0 + \vec{d}) + q_i,$$