Consider the block diagram below.

1. Describe its function or purpose, and give an application where it might be used.

   This is a complex baseband bandshifter. It creates a decimated complex envelope representation of \( x[n] \) at baseband. It is used for signal processing of bandpass signals, such as digital wireless communications, sonar, radar, etc.

2. If \( x[n] = \cos \omega_0 n \), what is \( x_a[n] \)?

   \[
   x_a[n] = e^{j\omega_0 n}
   \]

3. What are some problems with this system that would arise in a real-world implementation of it as diagrammed?

   a) A causal version of the Hilbert transform is required, so the real channel must also have a delay inserted (length \( M/2 \)) to phase align the two channels.
   b) Since decimation is performed, this is not a computationally efficient architecture.

4. Draw a block diagram of another system that accomplishes the same thing, but resolves the problems of question 3.
\[ x[n] \rightarrow \times \rightarrow x_i[n] \rightarrow \text{LPF} \downarrow M \rightarrow x_o[n] \]

\[ x_0[n] \rightarrow \times \rightarrow \text{LPF} \downarrow M \rightarrow \{x_o[n]\} \]

\[ \cos \omega_c n - \sin \omega_c n \]

\[ e^{-j\omega_c n} \]